PROCEEDINGS OF WEED SCIENCE CONFERENCE

1977

INDIAN SOCIETY OF WEED SCIENCE

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE, A. P. AGRICULTURAL UNIVERSITY

RAJENDRANAGAR, HYDERABAD-(A.P.) INDIA

CONTENTS

Foreword

Indian Agriculture has made several advances in recent past due to multi-disciplinary approach to the problems leading to stabilisation in production. It is a great tribute to the Indian Agricultural Scientists to achieve this measure of success in a comparatively short period. The increased emphasis on agriculture on National planning given by the Government well augers the future scope for rapid strides in this direction. In this endeavour all facets of crop production needs to be strengthened to achieve the higher goal. Weed science naturally is an important aspect in the long chain of scientific endeavours. This being a relatively new and sophisticated science, concentrated efforts in teaching and research have to be made to take full advantage of this science in the national efforts for higher productivity. The revival of the Indian society of Weed Science with the national convention early this year at Hyderabad was a step in this direction. The proceedings of this convention that are being published in this volume will be of immense use to the research workers and Educational Institutions and I am confident that Indian Society of Weed Science will continue its efforts to promote the various aspects of weed science and help the cause of increased agricultural production in India.

C. KRISHNA RAO
Vice-Chancellor,
A.P. Agricultural University.

Hyderabad
18th November 1977.

Preface

This Volume I of the PROCEEDINGS OF THE WEED SCIENCE CONFERENCE AND WORKSHOP IN INDIA contains the Inaugural and Valedictory adresses, Invitational Papers, Workshop Papers and Recommendations, Session Reports on the Conference Papers, Minutes of Business Meetings of the Society, and Financial Statements of the Organizing Committee. Volume II (and possibly Volume III) will have the technical papers presented during the Conference. Papers that may not be accommodated in these volumes will be published in the Indian Journal of Weed Science, the official publication of the Indian Society of Weed Science.

This publication is a modest effort in putting together the views of various scientists on the progress and future direction of weed research, and the need for more interest in upgrading curricular developments and the teaching of weed science in the agricultural universities and colleges in the country. It is hoped that the ideas presented here will encourage scientists, educators, and administrators to understand the proper role of weed science in the over-all scheme of plant protection and, therefore, to give appropriate recognition to this discipline in the agricultural curriculm and institutional research activities. Future conference should discuss the developments and problems resulting from the ideas and recommendations contained in this Proceedings, to determine what appropriate actions may be necessary to strengthen Weed science.

Very little editing was done but an attempt was made to have all the papers conform to a uniform format. The main objective was to have the papers printed in a readable form so that the ideas can be communicated with minimum delay to interested workers.

The authors have done a commendable job in putting forward their ideas and suggestions as well as in presenting the results of their experimental work. They all deserve the sincere gratitude of the members of the Local Organising Committee and of the Indian Society of Weed Science.

Inaugural Function

WELCOME ADDRESS

DR. C. KRISHNA RAO[1]

Our honourable guest Vice-Chancellor Gopalakrishna, Distinguished Delegates, and Friends :

It is my great pleasure and privilege to welcome you all to this All India Weed Science Conference and Workshop in the Rajendranagar campus of the Andhra Pradesh Agricultural University. I welcome you to this historic city of Hyderabad where the North meets South and the East meets West. Hyderabad symbolises the cultural synthesis of India.

We offer you not only a well organized Scientific Conference but also a very pleasant weather. You will feel very comfortable as you visit our many beautiful landmarks and historical spots, our shopping centers and the January All-India Industrial Exhibition that is now in progress in the city. I hope you will enjoy all these as well as the natural friendliness and unsurpassed hospitality of our people.

The Conference we are about to start was conceived in early June of last year by our weed scientists, agronomists, and plant protection specialists. Hyderabad is the Center of many research institutions and they all cooperated with us. The following deserve special mention : the ICAR, All India Coordinated Improvement Projects for Rice, Sorghum, and Dryland Agriculture; the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the Central Plant Protection Training Institute. Indeed, it is time that Hyderabad hosts such a gathering of scientists, we are grateful for this signal honour of sponsoring this Conference, for which we are thankful to the officers of the Indian Society of Weed Science for voting in favour of us. For, it may be recalled that the last Conference of the Society was held in 1973 and since then tremendous progress has been achieved in weed science. This conclusion is borne out by the number of papers submitted for discussion in this Conference. But more than this research output, there is also a need to discuss among ourselves the task of rationalising the future activities in weed science- its goals and directions, in order that this discipline becomes a permanent asset for a more productive agriculture and a healthier environment for all of us. For, while it is a new discipline, perhaps the

1. Vice-Chancellor, Andhra Pradesh Agricultural University, Hyderabad.

youngest among the branches of agriculture, weed science promises to be an important and an indispensable part of modern plant protection technology.

The idea that it is enough to have good seeds, fertilizers, water, and sufficient control of insects and diseases is *not* and will never be the answer to our objective of high crop production. Experience has shown that it is entirely useless to use good seeds, fertilizers, and protective measures against insects and diseases unless weeds are likewise controlled or managed effectively. In fact, no attempt should be made to use any modern crop production technology unless weeds are controlled *first*, for removal of weeds is the one most important single factor which permits the means by which the effects of other production inputs could *best* be manifested and realised. Unfortunately, farmers and scientists have often overlooked this basic factor in agricultural production technology, which might explain to a large extent the many failures we have had in introducing new techniques of modern farming.

We have an extensive agenda for this Conference 6 invitational papers, and 200 technical papers. Also, we have a workshop in which we will try to identify the weed research needs in India and to develop a suitable curriculum in weed science for *adaption* in all agricultural universities in the country. In order to make it easier for delegates to understand the problems requiring immediate attention, background papers were solicited from various authorities and these were printed for your analysis and criticism. I hope that you will have a productive and constructive discussions on the workshop topics.

We have tried our best to prepare everything for your convenience-hostel accommodation, transportation, food, and abstracts of papers for the Conference. While we do not anticipate major problems, we will be very happy to assist you in any way we can, so that you can participate actively in the Conference and also enjoy the pleasant atmosphere of Hyderabad.

Once again, on behalf of the Organizing Committee, the Andhra Pradesh Agricultural University, all the cooperating Institutes in Hyderabad, and the State Government of Andhra Pradesh, I extend our most cordial WELCOME to all delegates from various parts of India and to those from foreign countries who have come to participate in this scientific forum.

Inaugural Address

HOT SPOTS IN WEED SCIENCE TECHNOLOGY

DR. N. GOPALAKRISHNA[1]

President of the Weed Science Society ; Director of ICRISAT, Dr. Cummings ; Vice-Chancellor of Andhra Pradesh Agricultural University, Dr. C. Krishna Rao ; Prof. Mani ; Dr. Venkatachari, distinguished scientists, ladies and gentlemen :-

"A year's seeding is seven years weeding," thus goes an ancient Indian proverb. Indeed, agriculture has been defined as a "confrontation with weeds". Weeds are the worst enemies of crops and vegetation. Millions of rupees go down the drain on account of the tremendous losses caused by weeds. The welfare of mankind is highly dependent on the farmers' ability to control the growth of weeds. Much of, the joy of the farmers and gardeners gets subdued due to weed infestations. Thus more energy is spent in weeding out the undesirables than for any other activity related to increasing agricultural production.

Weeds are strangers and parasites claiming share of soil fertility and productivity of crops. The problem of weeds is particularly severe in tropical and semi-tropical countries including India. Depression in potential yields due to varying levels of weeds infestation have been recorded by various research workers : 9 to 57 percent in paddy, 14 to 71 percent in sugarcane, 20 to 61 percent in cotton, 6 to 40 percent in sorghum, 6 to 35 percent in wheat, and 13 to 15 percent in pearlmillet. It is clearly evident, therefore, that weeds are a major hindrance to agricultural production. Weeds are innumerable, extending over many families of the plant kingdom.

Holm (1971) listed some of the worst weeds of the world. These are: nutsedge *(Cyperus rotundus L.)* bermudagrass *(Cynodon dactylon L. Pers)*, barnyardgrass *(Echinochloa crusgalli* L. Beauv*)*, jungle rice *(Echinochloa colonum* L. Link.*)*, goose-grass *(Eleusine indica* L. Gaerth*)*, Johnsongrass *(Sorghum halepense* L. Pers.*)*, guinea-grass *(Panicum maximum* Jacq*)*, water-hyacinth *(Eichhornia crassipes* Mart. Solms.*)* cogongrass *(Imperata cylindrica* L. Beauv*)*, and *Lantana camara* L.

1. Vice-Chancellor, Punjabrao Krishi Vidyapeeth (Punjabrao Agricultural University), Akola.

In our country, there are some weeds which are pernicious or obnoxious, such as *Cypereus rotundus*, *Cynodon dactylon*, *Lantana camara*, *Saccharum spontanium* (in M.P. and U.P.), *Xanthium strumarium* (in Rajasthan and M.S.) *Plucha lanceolata* (in U.P.), *Striga* sp. (in M.S., Rajasthan, Karnataka, and A.P.), *Imperata cylindrica* (in Assam), *Pennisetum clandestinum* and *Oxalis latifolia* (in Nilgiris.)

Witchweeds (*Striga* sp.), a root parasite, is the real worry of many growers because it causes enormous damage to crops like sorghum, maize, pearlmillet and sugarcane in most States of our country, particularly Maharashtra, Rajasthan, Karnataka, Madhya Pradesh, Bihar and Uttar Pradesh.

The damage caused by broom rape (*Orobanche* sp.) on tobaccoo is also considerable and it causes losses to the extent of 5 to 10 percent in West Bengal, 15 to 20 percent in Maharashtra and Gujarat, and 30 to 35 percent in Tamilnadu.

Apart from the weeds of arable lands, aquatic weeds like waterhyacinth is a serious menace, causing tremendous damage to fishery tanks and canals as well as low lying rice area in Assam, Bihar, Punjab, Haryana, West Bengal, Orissa, Andhra Pradesh and Uttar Pradesh.

In West Bengal, the algal weeds like *Chara* sp. and *Nitella* sp. are a great menace to the growth and yield of paddy in low lying areas. Waterfern (*Salvinia molesta*) in Kerala & two species of pond weeds (*Potamogeton pectingtus* and *P. perfoliatus*) in irrigation canals in Rajasthan, Kerala, Andhra Pradesh, and Uttar Pradesh are posing acute problems.

In recent years, due to unregulated import of foodgrains, seeds, nursery materials and similar other commodities, the introduction of exotic weeds have challenged the scientists of this nation. *Parthenium hysterophorus* has entered our land along with imported foodgrains and has spread very rapidly throughout the length and breadth of the country. It has infested farms, cities, mountains and banks of rivers. Similarly, *Avena fatua* (wild oat) and *Phalaris minor* are also rapidly spreading in the Punjab, Haryana, Uttar Pradesh and other wheat growing areas and have become a real menace to the wheat growers. Some of the weeds are not only harmful to the crops but they are a health hazard to men and animals.

It is of paramount importance to tackle this nation-wide problem of weeds with a consortium approach of scientists drawn from Agricultural Universities, National Institutes and International Organisation. I hope that this conference will discuss the issue in all its perspectives and enunciate an action plan.

Weed control is an age old practice followed by the farmers in ancient lands ever since the inception of agriculture. *Weed control must assume top priority in crop production technology*. Chemical weed control is considered as a miracle of the present era. Though the science of weed control is in its infancy, a spectacular progress has been achieved through scientific research as evidenced by the availability

of a wide spectrum of herbicides. Today nearly two hundred herbicides are marketed the world over under various labels. Farmers in technologically advanced countries like U.S.A., Japan, U.K., and Europe are using chemicals in addition to mechanical weed management practices. The cultural and mechanical methods are laborious and time consuming.

In countries where manpower is proportionately high, total switch to chemical control of weeds may not be ethically or morally correct. Sprayers and granular applicators for herbicides require calibration to deliver the exact amount of chemical over a given area. By and large the majority of our farming community are yet to be exposed to this sophistictaed technology. Hence, the control of weeds through the use of herbicides has not gained popularity. Majority of the farm holdings being small and the cost of the input being high, it precludes wider acceptance of herbicides by this time.

In the developed countries the consumption trends of herbicides is very high assuming top rank amongst insecticides, fungicides, and other pesticides all put together which are 42, 34, 18 and 6 percent, respectively. Contrary are the trends in the developing countries like India. The weed control specialists and the extension workers should make enough efforts to extend the already available technology to the fields of the farmers.

Total reliance on herbicides is not a sound proposition since its applicability under all situations is not advisable. In some situations, measures such as biological control may have to be resorted to. The present available knowledge of research under Indian conditions is limited in respect of weed science. Indian scientists have yet to go a long way in working out various parameters in this field. It is of paramount importance to conduct in-depth studies on the harmful effects of herbicides to marine life, soil microflora, and environmental pollution.

One of the vital aspects of weed science research is to make herbicides least harmful to biological life without polluting the biosphere. Of late there has been a serious apprehension in the minds of the scientific and general community all over the world regarding the possible misuse of herbicides as a weapon of war for destruction of vegetation. It may not be out of place if I were to suggest here that dn international law may have to be enacted for this purpose in the interest of humanity and this planet.

Lastly, I thank very much the Andhra Pradesh Agricultural University and the Indian Society of Weed Science for giving me an opportunity to share my views with you in this Conference.

It gives me immense pleasure in declaring this Conference open and wishing it every success.

PRESIDENTIAL ADDRESS

RALPH W. CUMMINGS[1]

I am sure you recognize that the presiding officer does not have for his principal function the delivery of anything quite so formal as a presidential address, but his function is to preside and to introduce the distinguished participants in the inaugural function. So I will not attempt really to give an inaugural address. I would like to say a few words on topics which I think are self-evident to all of us. First of all, what are weeds? Weeds are plants but they are weeds simply when they are growing where they are not wanted. In nature, it is normal for various plants to grow in mixed culture and in association with one another. It is only when one wants to selectively grow one plant to the partial or total exclusion of other plants that the other plants become weeds and compete therewith. The crop which we are growing may itself constitute a weed and we normally or frequently sow a larger number of seeds then we expect which may grow up and reach a harvest. We do this as a safety measure, and once they come up the excess plants, which could be counted as weeds, in that they suppress the average growth of the plants and might suppress the harvest, are weeded out as our crops are thinned.

The problem of weed control is as old as crop culture itself. I remember one of my earlier readings in the Bible, the parable of the sower, in which a portion of the seeds fell on improperly prepared ground and the weeds grow up and choked them out so that they did not produce a harvest. From the time when crops began to be cultured selectively for their harvest, the competition with other crops came into the picture. What we want to do in weed control is to selectively eliminate the competition from other species with the one we want to favour so that all the components of the environment, such as soil fertility, water and sunlight, can be optimized in directing their effects towards producing the maximum amount of harvestable yield of the crop we are favouring.

Weeds are worthy of respect. They do not become weeds unless they have strong survival and competitive ability. So they are pretty good plants themselves and worthy

1. Director, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 1-11-256 Begumpet, Hyderabad.

of respect. If they are not strong and competitive then they don't become much of a problem. They are not always undesirable. It is only when they compete with the desired crop species that they become undesirable. When we expose land to the weather, any kind of vegetation on that surface will protect it from the destructive effects of erosion and we can be thankful that on much of the land which we are not attempting to crop, weeds do grow up and protect the soil surface from destruction until such time as we might need it for producing the crops we want. They also produce very useful fodder during those periods when the land is idle. One of the problems created thereby though, is the fact these plants keep on producing more seeds and when we want to reclaim the land for crop production, we often find it very heavily loaded with seeds and during the early stages we may have a problem to overcome these weeds.

Weed science, as a science, is relatively new. Prior to World War II, every farmer was concerned with controlling weeds by cultivation or hand weeding. There was a good deal of attention given to identification, to the cultural methods, and the threat of spread of the undesirable or objectionable weeds to new areas. Seed cleaning, quarantine methods, and various other measures were adopted to reduce or to prevent this spread. Dr. Gopalakrishna and others have made reference this morning to *Parthenium*, the weed which come into this country by accidental introduction. One can find other very important instances in which weeds have been accidentally introduced into new areas around the world. I remember one which came to my attention several years ago, on the border of North Carolina. This was the iintroduction of *Striga*, or witchweed, which was making it practically impossible on many of the fields to grow maize in that area and attempts were made to find means of control or eradication of that particular species. Another example is *Lantana* which was introduced as an ornamental plant. It was quite attractive when controlled, but has caused real broblems when it escaped the gardening and was found to be quite highly competitive.

The growth of weed science as a science, really dates from World War II, with the discovery and beginning of commercial production of some of the chemicals which served as selective herbicides. It was with the introduction of this and the rapid development of the chemical industry that attention was focussed on weed control in a new and different manner. I understand that the Indian Society of Weed Science is now 9 years old. It appears to be a very vigorous *weed* itself because it is growing at a tremendously rapid rate and I wish to congratulate you on this. I was really taken by surprise to realize that with only about 6 months of time for organizing this conference, we have a group such as this assembled here this morning. In addition to the inaugural praticipants this morning, I note on the programme 6 invitational papers and abstracts of 190 others that have been presented for consideration of this conference. This is a very formidable agenda and does represent a great and remarkable attention to this problem which extends beyond anything that I had realized and developed in India in that short period of time. I do want to wish you well in your efforts.

When I first came to India, I was surprised to see large areas without crop during the monsoon season. I had anticipated that the monsoon season would be the

season in which all of your land would be utilized and every attempt made to utilize the moisture at the time when it was abundant. But I found that in many situations that was not true. With frequent showers early in the monsoon season, one of the problems is to be able to get into the field and control the weeds adequately by cultural methods alone. This is particularly true in the deep vertisols. That is the problem which I am sure looms large in preventing, under present technology, the planting of vast areas of vertisols during the monsoon. If we can develop management systems to adequately and satisfactorily control the weeds, I am sure thrt it would contribute substantially to enabling us to utilize the moisture supplies when they are abundant, as well as utilizing residual moisture after the rains cease.

The farmer is going to need reliable information on every possible means of controlling his weeds. His decision on which method he uses for weed control will be based on what will give him the best results in terms of his net return. Where the differences are small, he probably will be based in favour of the methods which require low investment and in favour of methods which he can employ without or with a minimum cash outlay. This is going to vary a great deal from situation to situation and as some of the other speakers have already mentioned this morning, the choice may differ in India quantitatively it certainly will where Iabour is relatively abundant from what it may be in situations in which labour is less abundant and more costly. Whatever the method, however, the farmer is going to need to have reliable information as to what are the options available to him and what are the results he can expect. It is out of the results of good careful experimentation, testing and demonstration, that these practices are going to be worked out and you are the people who are going to be in the fore front leading that investigation and that demonstration.

Again, I want to extend my warmest best wishes and congratulations on the progress you have made today and to wish for you the greatest of success in this conference and in your efforts in your work in the years ahead.

I would now like to call on Dr. N. C. Joshi, Director of the Central plant protection Training Institute to give some concluding remarks and to release the magazine "Take it Easy". Now that is a humorous magazine. I don't belive that weed scientists can afford to and are likely to take it easy very long. I do commend to you the vaule in having a good sense of humour- Now I'd like to call on Dr- Joshi for his concluding remarks.

Valedictory Function

WELCOME ADDRESS

N. C. Joshi[1]

Most Distinguished Guests, Dr. Arakeri and Mr. Lal; Respected Vice-Chancellor, Dr. Krishna Rao; Conference Delegates and Friends:

This Valedictory Function is convened to assess the progress of our 3-day Conference and to make a clear statement of our future plans and activities in weed Science.

We are really fortunate to have with us this afternoon Dr. H. R. Arakeri, Vice-Chancellor of the University of Agricultural Sciences at Bangalore, who from the very beginning took active interest in weed control. He worked and contributed a good number of articles from 1949 onwards, which had led to the early development of weed science in this country. Likewise, we are highly honoured to have with us Mr K. B. Lal, Second Secretary of the Government of Andhra Pradesh and Agricultural Production Commissioner, and who comes from the ranks of the I. A. S. professionals. Mr. Lal is an efficient administrator who has taken a lead in pushing agricultural programmes, resulting in increased production for which Andhra Pradesh is now famous in our part of the country. It is certainly a pleasure also to have Dr. Krishna Rao who,in spite of his busy schedule, found it convenient to come to this Valedictory Function. Dr. Krishna rao had earlier welcomed the delegates during the Inaugural Function both on behalf of the University and the Local Organizing Committee of which he is the Chairman.

There is no doubt in my mind, and I hope the delegates will agree with me, that with this Conference we have set a milestone in the history of Weed Science in this country.... and in this part of Asia.

We had a wide ranging discussions that are vital in the future of Weed Science and of agriculture. We went beyond the usual discussion of research papers. We have dealt in the Invitational papers and in the workshop two major items, namely: (i) the development of a weed science curriculum in the agricultural universities and (ii) the weed research needs in India.

Our discussions on weed science curriculum is a *unique* aspect of our Conference in that to my knowledge no other Weed Science Conference anywhere in the world had

1. Project Director, Central Plant Protection Training Institute, Rajendranagar, Hyderabad.

attempted to examine the need to institutionalize this discipline as part of the educational requirements of students of agriculture. If the recommendations of this Conference will be implemented, therefore, we can claim that we have set a new phase in agricultural education - bringing in to full recognition the fundamental requirements of a higher standard of plant protectiom.

The inventory of the goals and research needs in weed science as part of plant protection scheme were also dealt with in some detail. The recommendations will therefore *Supplement* those already developed by our universities and research institutions. The input of the various sectors of the scientific community and of the industry must always be recognized and this Conference has done a valuable service to the nation as a whole charting the priorities in weed research.

The number of scientific papers submitted & discussed-more than 200 of them-has no parallel in this region. This was achieved in spite of the short time by which the Organizing Committee could make the announcement about the Conference. The response, therefore, is a clear manifestation of the genuine interest and dedication of our scientists and industry personnel. It also certifies to the maturity of those who have taken the task of advancing the frontiers of weed science in this country,

Surely it cannot be said that there were no problems during the Conference. But each time we get together in a Conference, we will definitely improve our preparations and accommodations. We must therefore plan ahead and strive hard to perfect our preparations. we have today a new set of officers whom we shall call the WORKING GROUP and we shall expect no less than anything we have seen here in Rajendranagar. Well .. more than what Vice - Chancellor Krishna Rao, Dr. Venkatachari, Dr. Krantz, Dr. Shetty, Dr. Obien, our Colleagues and myself could offer you.

In the "FOREWORD" of the PROGRAM AND ABSTRACTS OF PAPERS you will note the following paragraph which I wish to quote as it may give us some guide in the future. "A lot of obstacles were surmounted to have this Conference scheduled and this publication prepared. The united efforts of the member Local Organizing Committee-under the leadership of Dr. C. Krishna Rao, APAU Vice-Choncellor-point clearly that much could be done if the programme objective is right and individuals are willing to work together". On this basis, the Organizing Committee looks forward to more successful Conferences under the sponsorship of the Indian Society of Weed Science.

Our struggle against weeds does not end with this Valedictory or with the success of this Conference or of the next Conference. Rather, we must accept the fact that we have *fairly* just begun. If it is true that "one year of seeding" is equal to "seven years of weeding," then we must forever be vigilant to the problems of weeds. This is the basic need of our discipline;it is also a fundamental requirement in being able to feed our people. This is our task and this is our responsibility.

With these views in mind, I have therefore the utmost pleasure and privilege of welcoming you all to this Valedictory Function of the Weed Science Conference and Workshop in India.

Valedictory address

WEED SCIENCE TECHNOLOGY : RETROSPECT & PROSPECT

DR. H. R. ARAKERI[1]

At the outset, I would like to express my grateful thanks to the organizers of the Conference for giving me this opportunity to be with you and know the progress achieved in the field of weed science in India. I am glad to note that the Indian Society of weed Science is being revitalised and I wish you all success in your endeavours to build it up to the level required, so that it would serve the purpose for which it is established. I also hope that you have been able to achieve the objectives with which you organized this Weed Conference. I must say that it was probably overdue and I hope it was possible for you to review the work done so far and decide about the directions in which the country should proceed further in the future, taking into account the situations prevailing in the country. On this occasion' I would like to place before you certain of my views on the subject for your consideration.

Battle with weeds is as old as agriculture. It started during prehistoric period when man decided to raise certain plants in preference to others for his substenance. The battle is an endless one. In fact, agricultural practices provide favourable conditions for the maximum growth of useful plants. In doing so,growth of weeds has to be controlled effectively so that all the facilities provided become available to useful plants only. The success of a farmer in harvesting maximum return per unit area, time and various inputs depends to a very great extent on his ability to ensure the supply of what is needed by crop plants at the right time for their full growth by manipulating soil conditions in which plants grow and by controlling weeds which are always ready to share the facilities provided and hamper the growth of wanted vegetation.

Any plant that is out of place can be termed as weed. Unwanted vegetation comes up in cropped land, on the banks of rivers, canals and drains, rivulets, roadsides, grazing areas, forests and other uncultivated areas. The domain of weed science encompasses work in various areas of agricultural sciences aiming at the study of weed plants wherever they appear with an ultimale aim of keeping them under check,

The most ancient method adopted for keeping weeds under check is by hand weeding. It is a common method in India even today. In the earliest period,

1. Vice Chancellor, University of Agricultural Sciences, Bangalore.

unwanted plants were pulled out by hand and destroyed. Later on hand tools were developed to derive some mechanical advantage in carrying out this operation. With the harnessing of animal power for farming, a number of implements were designed and used forcarring out weeding operations. One of the main objectives of all tillage operations carried on with the help of animal power or machine power is to control weeds directly or indirectly.

Although salts, ashes, and industrial wastes have been used to control weeds since long time the use of chemicals in the real sense can be said to have started in the 1930's. The landmark in the history of chemical control of weeeds, however, occurred only in 1944 when synthetic growth regulating substcanes were found to be effective as selective herbicides. With the introduction of these chemicals having potentialities, weed science crossed into a new era. The new chemicals possessed the following four decided advantages over orher chemicals in use:

1. They are relatively inexpensive as very small amounts are required.
2. They are very selective.
3. They do not leave toxic/residues for extended periods in soil.
4. They are nonpoisonus and nonflamable.

A large number of compounds were put in the market then. The one that became very popular was 2,4-D, It is popular even now and it is probably the cheapest. Very large number of chemscals are available today in the world market.

In India, chemical weed control can be said to have begun in 1937 in Punjab when attempts were made to control *Carthamus oxyacantha* with sodium arsenite, a nonselective herbicide, In 1948, 2,4—D was introduced in India. Since then a number of chemicals have been imported and tried. Some of them were quite effective in controlling certain weeds. In India, only few herbicides like 2,4—D, 2,4,5-T and ammonium sulphamate are being mtnufactured indigenously. The installed capacity is about 2,000 tonnes as against the licensed capacity of 2,300 tonnes. Lettersof intent have been granted to produce about 7,000 tonnes of chemicals like dalapon, propanil,nitrofen, butachlor, alachlor, and triallate.

The total area covered under chemical weed control was 1.4million hectares in 1969-70 and 1.7 million hectares in 1971-72. The area covered now would be about 3 millioh hectares, With the shortage of fertilizers in the country, interest in chemical weed control is increasing. Dr. N. C. joshi has reviewed the work done so far in India and has given tne present position ih the publicatioh entitled, "Manual of Weed Control" published by Research Co. Publications, Delhi in India, In the preface of this publication, he has stated, "One of the serious hindrances in the progress and widespread use of weedicides in the country has been the non-development of proper application schedules, Another reason for the slow progress is that the agronomists and weed control specialists have not done enough to propagate the weed control work in farmers' fields". It is very true that the work on chemical weed

control has been sporadic and not very systematic and sustained. With the worldwide enthusiasm generated with the introduction of new herbicidies in 1944, few trained agronomists and physiologists initiated the work and developed few recommendations. The results reported at the conclusion of the Coordinated Projects on weed control with chemicals financed by ICAR somewhere by the beginning of 1960's cannot be said to have been very spectacular. The work has been continned by few research workers in some Universities, Institutes and Coordinated Projects in the country. Very recently, the Indian society of Weed Science has been organised in the country. Weed science is being tanght as a part of Agronomy and/or Botany courses, but not as an independent course in many of the Universities, While this is the state of affairs as far as the research and teaching is concerned, extension and development work is entrusted to workers in the field of plant protection not because they have specialissed gnowledge in weed science but becanse they are incharge of plant protection equipment like sprayers, etc. As a result of the work done so far in the conntry, few specific recommendations have been developed and are being a popularised although a lot more is still to be done.

As stated earlier, the battle against weeds is as old as agricultnre itself. Farmer has been struggling to suppress the growth of unwanted vegetation, so that the desirable plants will grow and yield better. In his attempts to control the unwanted vegetation, he has been using various methods. One of the methods which is being adopted all over the country is hand weeding combined with cultural operations. In a country which is thickly populated the question of providing employment takes precedence over any other objective. As a result, whenever attempts are made to control weeds by using chemicals, a point is raised by many as to whether it is advisable to use chemical method of weed control which is likely to displace human labour. This question will always have to be borne in mind by weed scientists. Weed scientists will, therefore, have to develop methods which will not result in large scale unemployment in the country. It is true that there is inescapable human drudgery in carrying out weeding operations. But at the same time we have to see to what extent it would affect the earning capacity of the labour force that is vast in the country.

The question of energy consumption aiso should be taken into consideration in developing the chemical methods of weed control. With the problem of energy crisis, looming large all over the country weed scientists should always endeavour to develop methods which will consume the least amount of energy. It is therefore very necessary to continue the studies on cultural and other methods of keeping the unwanted vegetation under check rather than going all out for chemical methods of weed control.

It is necessary to point out at this juncture that weed control should not be taken as synonymous with chemical weed control. There are many other methods which could be adopted to ensure the growth of wanted vegetations without much hindrance from unwanted vegetations. Some crops can stand competition better than others. We should try to include such crops in rotatien, so that the unwanted vegetations could be kept under check by competitions. The chemical method should

be adopted to supplement the other methods, but not to supplant them without any advantage. This is a very important and crucial aspect that is required to be kept in mind by the weed scientists. Wherever it is not posible to control the weeds by adopting cultural, rotational and hand weeding methods, the chemical method should be adopted. Weeds provide forage material for animals. This aspect also should be borne in mind as also mixed cropping practices prevalent in the country.

The area where much work is required to be done and where the danger of replacing human labour does not exist, is the control of weed in uncultivated areas, grazing land, roadsides, waste lands, canal sides, transmission lines, etc. At present, very little attention is being paid to keep the unwanted vegetations under check in these areas. These areas do not yield anything at present. On the contrary, weeds grow unchecked and produce large quantity of seeds which are transferred to cultivated areas. Care therefore is required to be taken to control weeds in such areas. Chemical method could be very appropriately adopted for controlling unwanted vegetations in such areas. But weed scientists are not paying sufficient attention to the problems of controlling weeds growing in such areas. More work is required to be done to develop appropriate technology for controlling weeds in such miscellaneous areas. By doing so the utility of these areas could be enhanced to a considerable extent. It is posslbie to use these areas for the production of forage material and tree products on extensive scale.

Attention paid to develop technology for controlling perennial and noxious weeds also is not sufficient. These weeds cannot be controlled easily by cuitural or mechanical methods. It would, therefore, be very appropriate if more attention paid to tackling such weeds rather than the annual weeds which could be controiled to a certain degree by using other methods of weed control.

You have considered at length the aspects connected with educational and training programmes required for preparing scientists and technologists for work in the field of weed science. You have probably suggested an increase in the number of courses to be offered at the B.Sc. level. If every specialists would suggest increase in the time allowed for his subject, probably the period required for graduation will have to be increased to 5 or 6 years. You should, therefore, keep in mind the limitation that is existing as far as period required for graduation. You must consider as to whether it is necessary to provide for specialisation at undergraduate level itself or it will be sufficient if specialisation is provided at post-graduate level. You might have probably examined what is required to be done with regard to extension and what kind of support is required at district and State levels. At present, attempt is made to include weed control in plant protection. I doubt very much whether the background trainiug that the protection specialists are having would be appropriate foı weed specialists. Agronomy and physiology are the important background subjects for weed specialists. I would, therefore, suggest that it may be examined in detail as to whether weed science could be a part of crop production rather than crop protection. The crop production specialists would be in a position

to master weed science aspects better than the plant protection specialists. If it is to be part of plant protection care will have to be taken to provide necessary background.

It has been observed that certain varieties of crop plants are more resistant to chemicals than others. It would be, therfore, necessary to breed varieties that would be resistant to the chemicals that are likely to be used for weed control in the crop concerned. Just as varieties are tested for resistance to insect pests and diseases, similarly testing programme will have to be devised and adopted for identifying the varietiss which are resistant to appropriate chemicals. It is necessary to ponder over this question and make suggestion to the plant scientists to include this as one of the items of research in the future,

I thank you again and wish you all success in your efforts to contribute your bit in increasing agricultural production in the country.

—:o:—

PRESIDENTIAL ADDRESS

K. B. LAL[1]

Prof. Mani, President of the Indian Society of Weed Science; Dr, Arakeri, Dr. Krishna Rao, Dr. Joshi, Dr. Krishna Murthy, distinguished delegates of the Weed Science Conference, Ladies and Gentlemen :

I deem it a privilege to be invited to chair this valedictory session of the Weed Science Conference today and express my deep appreciation to the organisers of this conference. I am particulary happy to be able to meet the distinguished delegates assembled at the conference to discuss about the problems of Weeds and their control.

Weeds are a serious menace to farmers and every one concerned with farming, due to the enormous losses they cause. In India, during 1973 the crop losses due to pests were estimated to be about Rs. 5000 crores (18% of National production) of which 33% (Rs. 1650 crores) were due to weeds. I am aware that such estimates are very rough and vary with every person who does the estimation, but I don't think we need to say it in figures to bring home the importance of weeds in crop production. Every one of us who tries to grow plants either in the farms or even in our homes is aware of the menace.

The introduction of high yielding varieties, intensive multiple cropping, harnessing of new water resources to increase the area under irrigation have all made a favourable ground for the infestation and multiplication of weeds. The awareness of the farmers for the plant protection practices in high value commercial crops such as sugarcane, cotton, banana, etc. has made it possible to introduce herbicides for weed control. The dissemination of knowledge for the usage of herbicides in crops is not so easy as in the case of insecticides and fungicides. The use of proper herbicide at the correct dose and correct time is critical in the chemical control of weeds. Since the number of well trained weed scientists is limited, the dissemination of knowledge has also received a set-back, indicating the need for encouraging the present group of weed scientists to develop the subject and also train more personnel in this important branch of Agricultural Science.

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1. Second Secretary and Agricultural Production Commissioner, Government of Andhra Pradesh, Hyderabad.

At this Conference during the last two days several papers were presented and many aspects of weed science dealing with control of weeds were discussed. Attention was also paid to the development of weed science curriculum in Agricultural, Education, intensification of weed science research in Agricultural Universities and Institutes and Extension of this knowledge to farmers. A peruses of papers received and presented at the Conference indicates that chemical control is receiving the maximum attention, although work is being done on other aspects of weed science. The development of weed science specifically during the past quarter century has been spectacular and the discovery and manufacture of herbicides in the last two decades have developed in such an explosive way that scientists as well as the extension workers found it difficult to keep pace with the development. I am, therefore, particularly happy to find that your society, although young in age, has been active in fostering and developing weed science in this country.

Inspite of the fact a that good amount of research has been done in Weed Science in this country, we still do not apper to have succeeded in finding economic and effective methods to get rid of persistent weeds like nut grass, parasitic weeds like Striga and Orobanche which are a serious menace on jowar and tobacco, respectively, in this state and aquatic weeds like water hyacinth etc. The list of pernicious weeds is growing with each passing year, *Parthenium* is the latest addition to this list. Also, as one who is incharge of Agricultural Production in this state, I am always intrigued as to how far the weed control technolcgy now available, which is predominantly based on chemicals, although shown to be feasible and economical in high value crops grown under irrigation, is relevant to the needs of the average Indian farmer. The two distinctive features of Indian Agriculture are: (1) the dependence of major part of cultivated area on precarious rainfall, and (2) the preponderance of farmers with small holdings. These two conditions impose certain technological as well as socio-economic constraints on Indian Agriculture. Any research designed to serve the Indian farmer must take these constraints into consideration. Economic feasibility coupled with low investments and operational ease to suit his managerial and manipulative abilities must be borne in mind while developing a technology for the dryland farmer and small farmer. Otherwise, the technology ceases to be relevant except for the few elite farmers and commercial planters.

The average Indian farmer has some family and hired labour to work on his fields. He also has bullock power available for frequent cultivation and inter-cultivation. He can afford only small investment in pesticides if they are paying. Can't sound weed control practices be built around these factors? I am aware that the Weed Scientists are trying to develop integrated control practices. May I venture to suggest that much more attention be paid towards such control measures which would enable the use of manual labour for hand weeding, bullock power for clean cultivation and a limited use of herbicides? I am sure this task is not beyond the capacities of the Indian Agricultural Scientists who have proved their abilities in no uncertain terms during the last decade.

Andhra Pradesh has about one-third of its area under irrigation. Thanks to some gigantic river valley projects like the Nagarjunasagar and Pochampad, the irrigated area in the State is on the increase. Situated on the coast, the State is subjected to cyclonic storms and heavy rains especially during the North-East monsoon season. The state has, therefore, large irrigation canal as well as drainage systems. In both the systems weeds figure prominently impeding the flow of water. One has only to go to the command area of the Nagarjunasagar canal systems to see *Typha* choking up small irrigation channels and the numerous small and even large sized drains. In the coastal Krishna and Godavari deltas we have the problem of *Ipomea* and waterhyacinth in our water courses. Perhaps some other states too have similar problems. Should this not be a challenge to the Weed Scientists? I would like the Weed Scientists to step into this area and help the Irrigation Department to minimize if not totally eliminate the enormous national loss caused by these aquatic weeds. I am aware such a programme requires the use of more than one method of control and also a close cooperation between the scientist, the irrigation engineer and the farming community. The task is formidable but must be tackled on a priority basis. I hope the Weed Scientists would take the lead in the matter.

As I have indicated earlier, the present day emphasis appears to be more on chemical control of weeds. Until composite or integrate methods of control are developed, chemicals continue to dominate in weed control at least in situations where it is economical to do so. This brings us to the problems of chemical residues and pollution. Fortunately, unlike in insecticides, these problems appear to be less serious in the case of herbicides. But with the increasing use of these chemicals on crops and especially to soils the problem is bound to snow-ball into a bigger one than it appears now. Application of herbicides also being recommended to control weeds in water courses and reservoirs, which are used as a source of drinkinf water in villages by humans as weel as cattle. I am sure you are aware of these probiems and would be paying the necessary attention they deserve.

Research is not an end in itseif. It is a means to generate technology to help the farmer to grow better crops and increase production with better economic returns for his own benefit as well as the Nation. The purpose of research is served only when the results reach the end user, the farmer, and are utilized by him. The Departments of Agriculture in the various states of India, which perform this function have extension personnel some of whom specialize in various aspects of crop production like agronomy, crop protection etc. I am afraid weed control does not appear to be figuring in any noticeable degree in the extension programmes of these Departments. Is it because of lack of adequate personnel trained in weed control techniques or due to inadequacies of the technology itself? Perhaps, it is due to both. I therefore, urge on this group, which represents the cream of the weed scientists, to bestow their attention to these aspects in the coming years to bring this science closer to the farmer.

Ladies and Gentlemen, as a layman I have put some of my thoughts before you. May be I might have made some critical references to your work. If I have done so, it is not due to lack of appreciation of the excellent work being done by you

and others in your chosen fields, but it is in my anxiety to see that your labours bear fruit, which is possible only when a technology relevant to the needs of the farmer- especially the average farmer is generated and taken to his fields to enable him to adopt the same.

Before I close I would like to once again express my deep appreciation for the opportunity given to me to share some of my thoughts with you. I wish the Indian Weed Science Society godspeed in its endeavours.

STATUS OF WEED SCIENCE EDUCATION IN INDIA AND THE NEED FOR WEED SCIENCE CURRICULUM IN THE AGRICULTURAL UNIVERSITIES

K. KRISHNAMURTHY[1]

I am thankful for the opportunity provided to me to present a paper on the weed science curriculum in the Agricultural Universities.

At the outset, I must say that weeds are the pioneers on land from which crops originated. From the beginning of agriculture, emphasis has been laid mostly on crop production and that work on weed destruction is yet to be fully appreciated. The competitive role of weeds along with the crops is fully known. According to the report of the working group on Fourth Five Year Plan proposal on plant protection, it has been indicated that through a rough estimate insects, rodents and other animal pests cause about 10 percent loss and diseases, weeds and parasitic flowering plants an other 10 percent. At the prevailing price of 1962, total annual monetary value of the damage caused by these agencies is about Rs. 1,000 crores in the country. Inspite of this weed menace, the weed science research and education in India is yet to receive the required status which is equal to the science of insect pests or diseases. It should be noted that in recent years, many weeds (for example, *Parthenium, Salvinia, Eupatorium Eichhornia*, and *Presopis* are posing a threat not only to agricultural production but also to human and animal health. Besides, with the need for increased agricultural production, there is a corresponding need for a greater insight and discourse into weed science. It needs no emphasis that the reduced yields due to weeds bring instability in production in the country. Therefore, weed science education and research should receive equal attention as that of crop production. There is need for a breakthrough in the traditional education of crop production where crops alone are being emphasised and ignoring a discourse into agents like weeds which limit production. Specially, during these years when crop protection is becoming infinitely more complex, there is an urgent need to have a stronger insight into the science of weeds and their control. The teaching and research in crop production and crop protection has to be suitably reoriented.

1. Professor and Head, Dept. of Agronomy, Agricultural College, University of Agricultural Sciences, Bangalore.

I shall not be wrong if I say that in India, weed science has not been taught adequately as a full course at the undergraduate level in the agricultural Universities. At least plant pathology and entomology are being adequately taught at undergraduate level, each constituting about 12 credits of the total 192 credits at the undergraduate level, whereas, weed science forms only a very small fraction of a single course in agronomy covering crop production or soil management (25 credits of Agronomy is taught at undergraduate level). As such, the status of weed science education in the agricultural universities is far from satisfactory. In some universities as at Tamilnadu and Hissar, there is one course of three trimester credits on weed science exposing the undergraduates to the elements of the subject matter. After their degree in Agriculture, when they go for extension, research or teaching job, they do not have sufficient background to handle weed science problems.

It is a point to consider whether, in the final year, students majoring in a given discipline in agriculture could major in weed science by taking major courses. But at this stage if they take weed science as major, this wili be at the cost of already needed courses. Otherwise, could it be possible to add some more credits? Well, even at this stage, the present load is too much of a burden on the part of students. Perhaps, it may be necessary to reschedule the total credits at the undergraduate level and provide for one or two courses in weed science. This would help when the undergraduates proceed for postgraduate education. The credits allotted to agronomy courses need to be reappropriated to provide for at least 3 credits of weed science at undergraduate level. A model 3 credit course is appended.

The weed science education for the present at postgraduate level is slightly better than what it is at undergraduate level. At least there are one or two courses on weeds and their control listed in Agronomy department. Besides, there are other departments like botany teaching taxonomy of weeds, while herbicides physiology by Crop Physiology Department, and herbicide chemistry forming a part of the course in Agricultural chemicals taught by Department of Soil Science and Agricultural Chemistry. Here again, there is no organised approach in most of the Universities for an M.Sc., or a Ph.D. student to specialise adequately in weed science. Mostly, the students in Agronomy Department take up the research problem on weed control in addition to crop productiou and related courses. Besides, they take courses like weed taxonomy, herbicide, physiology, agricultural chemicals, etc., from other Departments. Further, ecological, physiological, pollution, residues, hazards and biochemical aspects of weeds and herbicides are not adequately covered. Evidently, the weed science education at the postgraduate level has not been taught in its completeness and there is lot of scops for improving our weed science education and research in the country.

The National Commission on Agriculture has recommended for the appointment of subject matter specialists even at Taluk levels and at some levels these specialists must have postgraduate qualification. For the weed science specialist to understand the problems of the farmers, there is need for educating and training of the subject matter specialists in weed science in its totality. Besides, it is time that we strengheen and expand weed science education to meet our teaching and research requirements at

the University level. There is an urgent need to formulate weed science curriculum in its completeness for undergraduate and postgraduate levels. Is it not possible to have a separate Departmental set up on weed science bringing together all the related branches of weed science? If not, at least a weed science section within the Agronomy Department is highly desired.

With this need for intensified weed science education, a set of courses are prepared and appended here for discussion. These may be listed under agronomy to commence with and offered by teachers competent to handle each course. Though 11 courses with 32 credits are listed one can take few or all courses depending on his level of Postgraduate education, i.e. M.Sc. or Ph.D. Besides, he has to take minor courses in crops and soils and supporting courses such as taxonomy (appended as an example), agricultural chemistry, biochemistry, crop physiology, and plant protection in other Departments. A model break up for M.Sc. in weed science is given below:

Items	Credits
1. Main courses on weed and herbicides	24
2. Minor courses on crops and soils	12
3. Supporting courses on taxonomy, agricutural chemistry, biochemistry, crop physiology, plant protection	13
4. Research (Thesis)	12
5. Seminar	3
Total.	64

A range of minor and supporting courses as envisaged here are already listed in the respective departments. It would not be difficult for the advisory committee of the student to suggest the courses to be taken.

This Conference will be discussing weed science education (during our work-shop) and the one I have presented here is to stimulate discussions. I have only attempted to place before the esteemed delegates some of my views and the views of my other colleagues with whom I have had the opportunity to correspond. I only appeal to the respected delegates to come out with unified recommendation to strengthen weed science education in agricultural universities. I am sure that the wisdom and experience of the distinguished delegates assembled here will help us in developing a good curriculum.

A. Weed Science Course for undergraduates (300 series)

1. Introductory Weed Science (2+1)

Ecological concept of weed-crop associations. Common weeds and their identification. Scope of weed control, Principles of weed control, cultural, biological and chemical methods of weed control. Herbicides, classification, mode of action, their use and relative choice. Pre-emergence and post-emergence application in field crops.

Herbicide schedule for crops. Special weed problems in cropped and noncropped fields, Different equipments for herbicidal application. Effect of herbicides on soil and crops.

B. Weed Science Courses for Postgraduates (500 series)

1. Weed control in field crops and pastures (2+1)

Common weeds of the farm. Losses caused by weeds. Important herbicides used in different field crops. Selectivity of herbicides. Dose, time and method of application, control ratings and crop injury. Degradation of herbicides in soil and crop. Residual toxicity of herbicides in the soil. Economics of weed control by herbicides in field crops.

2. Weed Control in plantation and vegetable crops (2+1)

Study of weeds and their control in relation to plantation and vegetable crops as indicated for field crops.

3. Parasitic, problematic and aquatic weeds and their control (2+1)

Important parasitic weeds of the world, India and the tract. Detailed studies on Striga, Orobanche, Cuscuta, Loranthus, problematic weeds like Cynodon, Parthenium, nutgrass, Eupatorium, Presopis, Lantana, etc. Eichhornia, Typha, Pistia, Salvinia, Biology, crop and parasite relations. Weed control methods; cultural-dredging and drying, tillage, crop rotation, varietal tolerance. Chemical method (herbicides) dose, method and time of application. Biological method-important insect pests and diseases occurring on the parasites.

4. Cultural methods of weed control (2+1)

Deep tillage, blind tillage, zero tillage, fallowing, inter-culturing, hand weeding in relation to weed control. Rabbing and use of flame in weed control. Water management in relation to weed control. Crop rotation, green manuring and row spacing in relation to weed control. Varietal tolerance to weeds.

5. Herbicides (2+1)

Introduction and development of herbicides, their classification, physical and chemical properties, synthesis, chemical reactions, and structure. Mode of action, uptake and translocation of herbicides by crops and weeds, biochemical processes affected, mechanism of translocation, metabolic pathways, biochemical basis of activity and selectivity. Behaviour in soil, plant, animals and environment. Toxicological properties. Formulations of herbicides. Registered and approved herbicides.

Use of adjuvants, oils and surfactants.

6. Selectivity and degradation of herbicides(2+1)

Selectivity of herbicides, physiological, biochemical basis of selectivity, factors affecting selectivity, varietal differences in selectivity, degradation of each group of

herbicides in soils, plants, and animals, degradation pathways, reactions, and mode of action. Degradation by microorganisms and elimination by animals. Metabolism and selective phytotoxicity. Herbicide photodecomposition. Volatilization of herbicides, environment implication, movement, dessipation and persistence in plant, soil and water.

7. Residual toxicity of herbicides in soil and environment (2+1)

Residual toxicity of herbicides in soil. Break-down of herbicides by micro-organism, anti-dote techniques. Dose and time of application in relation to residual toxicity. Effect of residual toxicity on succeeding crops, crops in relation to herbicide metabolism. Soil-herbicides interactions, residual analysis and bioassay, Spray application, drifts. Environment implications of herbicides.

8. Biological methods of weed control(2+1)

Importance of biological control of weeds, important insect pests, disease causing organisms and animals occurring on weeds. Biological methods of control of weed- *Cactus, Lantana camara, Eichhornia,* and others.

9. Advances in weed management (2+1)

Regulatory concepts and goals in weed management, integrated weed control, crop sanitation. Weed ecology, weed shifts. Surveillance and forecasting crop weed problems. Zero tillage, minimum tillage. Weed research needs of small farmers. Predicting possible future weed problems and control methods. Identification of weed control problems and developing action plan. Weed control acts, regulatory laws.

10. Weed control equipments (2+1)

Types and selection of equipments. Efficacy and utility of different equipments, nozzles, etc. Application and its techniques. Precautions and hazards. Theory and operation of internal combustion engines. Repair and maintenance. Developing equipments for different purpose and for different set of conditions.

11. Weed science study tour and extension (0+2)

Organised study tour of problematic areas of weeds and assessment of situations. Visit to Research Stations and institutes involved in weed science activities. Study of specific research problems. Visit to herbicide formulation/manufacturing plants. Visit to villages. Preparation of educative materials to farmers. Training and education to farmers, laying out demonstrations on weed control.

C. Suppor ing Courses In Weed Science At 500 Series

1. Taxonomy of wee ls (2+2)

Taxonomy and its significance, General principles of classifications. Current systems of classification. Bentham and Hooker Engler and prantl and Hutchinson, Plant nomenclature-beginning of organised nomenclature, codes of nomenclature international rules of botanical nomenclature, concepts of taxonomy. Plant

identification, field and herbarium techniques, collection procedures, preparation of specimens. General survey of the families with special reference to their important characters persistance, hazzards and economic importance. Chemical and numerical taxonomy.

To be offered by Botany Department.

WEED RESEARCH IN INDIA : STATUS, PROBLEMS AND STRATEGIES

V. S. MANI[1]

I. Multiplicity of Weed Problems :

Weeds through their harmful effects in growing crops rank among the most important enemies to agricultural production. The combined effects of weeds, pests and diseases set serious limitations in the efficient utilization of the indispensable precious and costly inputs such as the high yielding short duration cultivators of crop plants and use of fertiliser, irrigation and pesticides.

Estimates have been made in our country of appreciable losses in grain production and substantial depletion of nutrients, both native in and added to the soil, by unwanted weed growth in arable land. India is losing annually Rs. 5000/- crores worth of agricultural production due to weeds, pests and diseases. It is estimated that the maximum damage is caused by weeds 33% of the potential production followed by diseases 26% and insects 20%. The remaining loss to food production is due to rodents (6%) and storage losses (6-8%). Weeds take away as much as 30-40% of nutrients from the soil.

In addition to yield and nutrient losses, weeds also harbour insect pests and diseases. There are a number of insects and diseases for which weeds serve as alternate hosts. The unholy triple alliance among weeds, pests and diseases create ideal ecological conditions for crop losses in more than one way. From all these counts, particularly for avoiding grain losses and halting further deterioration in soil fertility and productivity and for effecting a more rationale and judicious exploitation of the natural resources such as sunlight, water and land, it is imperative that measures should be taken to be curb weed growth in situations where allowing weed growth run amuck will prove counter productive to man's efforts to reap bumper harvests.

II. National Weed Culprits :

Some weed species which have gained notoriety in our country are listed below :

1. Terrestrial annual weeds : Annual grass weeds, wild oats *(Avena fatua)* and *Phalaris* sp. in wheat ; water grass *(Echinochloa* spp.*)* in rice and annual dicot species

1. Senior Agronomist (Weed Research) Division of Agronomy Indian Agricultural Research Institute, New Delhi.

as *Trianthema monogyna (=T. Portulacastrum)* in diverse crops as maize, cotton, sugarcane, sorghum, millets and pulses.

Parthenium hysterophorus has invaded all waste lands and this species has been reported to cause skin ailments. *Xanthium strumarium* is another plant species that has spread all over the country and dense infestations of this weed are a common sight along the rail tracks throughout the country. Another equally ubiquitous species both in cropped and non-cropped land all over the country is puncture vine *(Strebulus terrestris)*.

2. Perennial weeds : Nutsedge *(Cyperus rotundus)*, Johnson-grass *(Sorghum halepense)*, Bermuda-grass *(Cynodon dactylon)*, wild sugarcane *(Sachharum spontaneums)* Lalang-grass *(Imperata cylindrica)*, *Eupatorium*, *Mikania* are found in diverse situations and in many crops including plantation and horticultural crops. *Lantana camara*, a woody shrub, has firmly established in forest areas and in pasture land.

3. Parasitic weeds : The three important sinister weeds in this group are witch-weed *(Striga)*, broomrape *(Orobanche)* and dodder *(Cuscuta)*.

4. Aquatic weeds: Water hyacinth *(Eichhornia crassipes)*, waterfern *(Salvinia sp.)*, water lettuce *(Pistia stratoites)* algae such as *Chara* and *Nitella* and many submerged species such as pond weeds and emerged ones as sedges, cattails, tules, rushes etc., are the most troublesome water weeds.

III. Problems of Applied Nature in Weed Research :

The per cent losses in yield due to unchecked weed growth in different crops have been found to be substantial. In some crops the yield is reduced by more than 50 per cent due to weed infestation. The losses are on the high side in crops with poor competing ability as linseed and ground-nut, in vegetable crops as potato, peas, carrot and onion ; and in summer and rainy season crops as cotton, maize, millets and pulses. The increased yield secured by adoption of weed control measures leaves no room for doubting the magnitude of yield losses due to unchecked weed growth. As the crop yield from a single application of an herbicide is at par, if not more, with the produce secured from repeated application of physical methods of weed control, a strong case has been made by research investigators in this country for utilisation of weed killing chemicals in crop fields. This dual advantage of keeping weed growth under check maximising crop yield through utilisation of herbicides can be successfully and profitably applied in many diverse situation.

The new agricultural strategy involves growing of high yielding varieties of crop plant under conditions of heavy fertiliser application, frequent irrigations and repeated measures against insect, fungal, virus, bacterial and nematode maladies. These very conditions which stimulate crop growth are also salubrious for weeds to put up rank growth. Unless the latter are controlled, the very purpose behind adoption of improved technology for realising the maximum yield potential of these precious varieties evolved by the breeder gets defeated.

Modern farming aims at maximum production of food, vegetable, pulse, commercial and fodder crops, and this is possible by growing a series of crops per year in quick succession on the same piece of land. In this intensive and diversified multiple cropping patterns, weed growth prior to sowing of the crops can be destroyed by non-residual and quick acting herbicides. Weed growth during the crop growing season can be kept under check by adopting the pre-emergence and post-emergence techniques of herbicides application. This system of multiple cropping which includes crop rotations, relay and mixed cropping is a unique characteristic of Indian agriculture and chemical methods of dealing with weed problems have to be devised.

An important function of preparatory tillage or cultivations during crop growth is to control weed growth. The minimal cultivatiou concept in crop production has been the outcome of utilisation of herbicides to deal with weed growth in diverse situations where cultivations can be reduced to the minimum or where cultivations may not be desirable as these may accentuate the problems of soil erosion or compaction.

Another important area where problem-oriented research is of great relevance to this country pertains to dryland or rainfed agriculture. In the vast areas where water is a very scarce commodity and where it has to be harvested by suitable techniques, perennial weeds and seasonal annual weeds with the ushering of some rain have to be controlled through herbicides. The exploitation of the minimal cultivation concept through herbicide use offiers immense scope to stabilise production in these vast tracts subject to the vagaries of nature. This concept also offiers great promise in controlling weed growth in direct seeded rice; in addition this concept can be employed to the best advantage in situations where transplanting of rice could be done without puddling the soil for which large quantities of water are required.

Another problem-oriented research is concerned with aquatic weeds. Controlling weeds in rivers, canals, irrigation channels, drains and water reservoirs is a problem of national importance. Aquatic weeds interfere with the carrying capacity and delivery rates of water. Weed growth collects mud and other debris resulting in gradual silting up of the channel and loss of efficiency. Weeds in the channels of water transport, if allowed to flower and set seeds cause great damage to crop fields in that the weed seeds are transported along with irrigation water. Effective, safe and economical methods of control have to be devised for controlling weeds in water systems.

Another problem of applied nature is connected with control of weeds in grasslands and pastures. In grassland, weeds take up the space that would be better utilised by grass and legume. They depress the yield of the more desirable species or interfere with proper grazing of the sward. The full value of the applied fertiliser to improved species cannot be realised unless weed growth is checked. Some weeds which are poisonous can cause reduction in milk yield, unthriftiness and even death. Animals normally avoid poisonous plants, but when food is scarce they may turn to them. Another possibility also exists, that if such weeds cut along with fodder are

fed to cattle, there may ensue serious consequences. Weed control is thus an important problem in grasslands, pastures and ranges. Here two aspects are involved viz. (i) in areas where improved varieties of forage crops are under cultivation, weed growth has to be kept under check; otherwise the yield as well as the quality of the fodder will be affected as a consequence of which the health of the livestock is in jeopardy and (ii) in areas which have to be reseeded with superior varieties, the inferior native grass and shrub have to be got rid of before reseeding to improved species. This is possible through ploughless farming which involves employment of chemicals as paraquat-diquat, MSMA, DSMA, dalapon, ATA etc. in destroying the existing inferior vegeta, tion followed by reseeding or planting the improved varieties. Methods have to be worked out for enhancing the quantity and improving the quality of fodder grasses and legumes through herbicidal control of weeds. Sublethal doses of herbicides are reported elsewhere to effect improvement in the nutritional quality of food and forage crops.

Another problem of applied nature in arable land concerns perennial weeds such as nutsedge *(Cyperus rotundus)*, Johnsongrass *(Sorghum halepens)*, bindweed *(Convolvulus arvensis)* camelthorn *(Alhagi camelorum)*, *Pluchea lanceolate*, *zizyphus spp.* etc. A combination of mechanical methods and herbicide may, it is felt, will be effective and economical, Timing of these operations have to be worked out.

Still another problem of applied value concerns the control of parasitic weeds such as dodder *(Cuscuta)* witchweed *(Striga)* and broomrape *(Orobanche)*. Using trap crops, rotating crops, breeding of crop varieties resistant to parasitic weeds and employment of chemical methods may provide the necessary solution for dealing with the phanerogamic flowering parasitic weeds.

An additional useful area of applied research is concerned with engineering ingenuity in developing suitable equipment for the large scale timely application of herbicides in large and small area under different crops/cropping systems as well as for control of perennial weeds and also for non-cropped areas.

IV. Problems of fundamental nature in weed research.

An understanding of weed species is of great importance in devising appropriate methods to protect the crop plants from the aggressiveness of weeds. Some of these aspects are related to the dormancy, viability and periodicity and peak period of germ-ination of weed seeds in soil, the dispersal mechanisms and modes of reproduction of perennial weeds species etc. An understanding of the biology and ecology of weeds, including aquatic species, particularly the characteristic features of weed seed dormancy and viability, the processes of accumulation and depletion of food reserves in the subterranean parts of perennial weeds and the host specitivity and modus operandi of parasitic weeds is necessary for devising simple, effective and economical methods of control.

Some of the fundamental problems in herbicide research are concerned with mechanisms of lethal and selective action of herbicides; inherent and residual toxicity,

lechability, persistency and biodegradation of herbicides in soils, plants and water. These aspects of study are of great relevanee in that an understanding of all these processes in perspective will obviate or minimise pollution problems connected with continued use of herbicides in cropped as well as non-cropped land. Fundamental investigations probing into the mechanisms that determine the lethality and selectivity of herbicides are valuable in that it is possible to 'tailor' varieties of crep plants that may resist the toxic action of herbicides or to design herbicides that may be harmless to crop plants and the products harvested from herbicide treated material is safe to man and animal. Careful and critical experiments would have to be initiated to study soil-plant-water-biosphere-herbicide interactions as such type of study alone can provide the necessary scientific guidelines for the effective and safe use of herbicides in intensive and diversified agriculture and in non-crop situations.

V. Current Status of Weed Research in India

Ever since the genesis of agriculture, man has been devising methods of weed control both preventive and curative comprising preparatory tillage, intercultivation, physical methods involving mechanical and manual weeding, crop rotations. These traditional methods have been built up over the ages for securing maximum relief to crop plants, from unwanted weed growth in many diverse situations where agriculture is being practised.

The first attempt in our country to control weeds by means of chemicals was made in Punjab in 1937 with the use of sodium arsenite, a non-selective herbicide for controlling *Carthamus oxyacantha*. With the discovery of auxin herbicides like MCPA and 2, 4-D in U.K. and U.S.A. respectively in the early 1940s and their commercial availability in 1944, chemical weed control research gained momentum. In 1952 the Indian Council of Agricultural Research sanctioned a total of 13 schemes for testing the field performance of weed killers in crops like rice, wheat and sugarcane in the first instance. The States operating these schemes were Tamil Nadu, Bose Research Institute, Calcutta, Punjab, Maharashtra, Andhra Pradesh, Rajasthan, Kerala, Assam, Madhya Pradesh, U.P. and J & K.

The different State Departments of Agriculture and Agricultural Universities and the Central Institutes under ICAR have carried out some commendable work relating to a survey of weed flora and specific chemical weed control recommendations for individual crops such as wheat, rice, sugarcane, oilseed and pulse crops. However, there has been not much of a sustained follow up action and as the state of affairs currently indicate not much of an impact of chemical weed control research has been felt on agricultural production in our country. As far as the fundamental aspects are concerned, nothing much worthy of mention has been done with the exception of some work relating to the effect of 2, 4-D on physiological processes as transpiration, photosynthesis, respiration, chlorophyll synthesis and destruction at the Bose Research Institute, Calcutta during the late 50s.

VI. Strategies

A. Applied Research

The main objective in any weed control research programme should be to evolve effective, easy, economical and safe methods of weed control in diverse farming and weed situations involving minimal tillage and control of aquatic and phenerogamic parasitic weeds. Besides this, the programme should work out suitable weed control practices or schedules in multiple cropping and horticultural crops. Further a relevant chemical weed control technology needs to be developed to cater to the needs of the marginal, sub-marginal farmers scattered all over the country particularly in situations prone to drought, flood and other natural hazards. In addition there are some special problem weeds both annuals and perennials which merit the attention of weed scientists to work out a programme for their control

Weed control through chemicals is a science involving many discipline such as biology, ecology, agronomy, physiology, microbiology, soil science, toxicology, biochemistry, residue chemistry and engineering. All these varied aspects connected with herbicide use have to be carried out. All these research efforts should be coordinated effectively so as to make a dent on our agricultural prosperity without polluting the environment and avoiding disturbances or upheavals in ecological balance.

An inter-disciplinary approach made for tackling the unwanted weed growth in cropped and non-cropped land should pay heavy dividends. Based upon the information that would be made available from the multidisciplinary approach integrated control or alternate methods of fighting the weed menace could be worked out. The immediate items of research that could be pursued are concerned primarily with herbicide use in multiple cropping patterns inclusive of crop rotations/relay and mixed cropping systems; minimal tillage, parasitic, aquatic and special weed . All these problems will have to be studied through an interdisciplinary approach from various disciplines such as agronomy, physiology, toxicology, ecology etc. An integrated approach combining the cultural, mechanical, chemical and biological methods, would it is felt, solve the challenging weed problems of our country.

Some of the weed problems that have not been received any attention so far are listed below. Suggestions have also been given for undertaking research in these areas.

Control of weeds in non-cropped areas has not received any attention so far in our country. Some of the situations where chemical weed control can be practised with advantage are wastelands, industrial sites, air-ports, rail tracks, road-ways, play grounds parks, cemetries etc. In these situations one can secure any degree of control right from total eradication to controlled growth of vegetation for varying periods of time. The various types of organic herbicides as the quick-acting non-residual bipyridyls and arsenicals, the slow-acting but longer lasting auxin herbicides and the powerful soil sterilants as the triazines, ureas and uracils can be employed to secure any contemplated degree of freedom from weed growth. The investigations on chemical control of weeds in noncropped areas have to be directed towards (1) finding out the best period at which the application has to be made (2) determining

the optimum dosage (3) exploring the possibility of increasing the efficiency of herbicides by making use of a combination of herbicides at low doses along with addition of adjuvants, wetters, nutrients etc. (4) assessing the possible damage to adjacent crops, useful insects as bees etc. (5) studying the possible pollution effects from continued use of herbicides over a long period of time.

An additional useful line of applied research is concerned with engineering ingenuity in developing suitable equipment for the large scale application of herbicidss in large and small areas under different crops as well as for control of perennial weeds and also for noncropped areas. The great strides that the industrialised countries have made in the field of chemical weed control are in a large measure due to the efforts of engineers. In our country also, we have to develop suitable equipment for the pre-planting soil-incorporation, pre-emergence and post-emergence techniques of herbicide application. The engineer can play a notable role in the development of mechanical appliances to deal with aquatic vegetation, devise sprayers that will reduce the drift hazards, fabricate particular types of spray equipment as to suit the varied patterns of agriculture so characteristic of our country to design experimental plot sprayers like the logarithmic sprayer for field use, design sprayers that can manipulate the droplet size, pressure, gallonage, discharge rate etc. for use in the glass house for the study of selectivity and toxicity of herbicides on different plant species.

B. Fundamental Research

An understanding of the biology and ecology of weeds, particularly the characteristics of weed seed dormancy and viability, the processes of accumulation and depletion of food reserves in the sub- terranean parts of perennial weeds and the host specificity and modus operandi of parasitic weeds is necessary for devising effective methods of weed control.

In the use of herbicides for weed control in crops the main emphasis has to be on the selectivity or safety of the weed-killing chemicals on crop plants as any chemical which exerts a toxic action on crop plants will not have any chance for its utilization during the crop growing season. If differences are found to exist among varieties of crop plants in regard to their reaction to herbicides it is possible to 'tailor' varieties that may resist the toxic action of herbicides or to design herbicides that may be harmless to crop plants. One of the ways to test the reaction of different species of crop plants to a number of herbicides consists in employment of screening tests under controlled conditions. This sort of study will elucidate the mechanism of biochemical selectivity. This study under controlled conditions should be supported by field studies. This work will have to be initiated by Weed Scientists in cooperation with plant Breeders, Geneticist, and Cytogeneticist. Different varieties of crop plants in their progeny stages should be screened for their tolerance or otherwise to different herbicides. Such investigations probing into the mechanisms that determine the selectivity and lethality of herbicides are valuable in that it is possible to give fool-proof herbicide recommendations and further the seed harvested from herbicide-treated material is safe for sowing purpose or for consumption by man and animal.

In the earlier section a reference was made to improvement in the nutritional quality of food treated with sub-lethal doses of herbicides. In this connection the employment of simazine for improving the nutritional quality of grain and forage is notworthy. Experiments in progress concerning utilisation of sub-lethal doses of simazine have given encouraging results in maize and berseem. Elucidation of the biochemical mechanisms that lead to improvement in quality from sub-toxic doses of herbicides wlll be of inestimable value in fighting malnutrition on a national scale.

Experiments in progress at IARI, New Delhi, employing very low doses of foliar applied herbicides such as 2, 4-D and MCPB combined with 3% urea indicated that urea inclusion to low doses of herbicides improved the weed-killing potency of the latter, further this combination treatment led to substantial improvement in dry matter production and mineral nutrition resulting in enhanced grain production of crop plants. The biochemical mechanisms responsible for these observed results needs critical experimentation through radio-tracer techniques.

Soil application of herbicides may affect microflora whose activities are of paramount importance in building and maintaining fertility and productivity of arable soils. Microbial activity is largely responsible for the decomposition of herbicides in soils there by preventing a build up of toxic residues. In the utilization of herbicides for weed control in crops it is of vital concern that the effect of these on soil microflora should be carefully assessed. Further, the effect of herbicides on the nodulation and nitrogen fixing ability in the case of legumes needs to be studied in depth. The modern techniques of microbiology should be employed for identification of the breakdown products or metabolities from herbicides. Chromatography GLC and other modern-methods have also to be made use of in these studies. Experiments will have also to be initiated for understanding the interactions among herbicides, insecticides, fungicides and nematicides.

The inherent toxicity and persistence of herbicides in different soils and under different conditions of fertility and moisture can be studied through bioassay methods. The dissipation of herbicides can be directly assessed through chemical methods. Extensive studies have to be made to correlate the toxicity and persistence of herbicides with various soil, climatic and other factors.

Careful and critical experiments should be initiated to study herbicide-soil-plant relations as such type of study alone can provide the necessary guidelines for the safe and effective use of herbicides. Methods should be standardised for determination of herbicide residues in soils and plants.

Pollution aspects assume importance in situations when herbicides are employed in high doses to destroy weed growth in non-cropped areas and also in water systems because there may occur biological magnification that may lead to catastrophic results. Methods have to be worked out for determining the degree of pollution that herbicide use in these areas has created. Side by side steps should be taken to minimise pollution due to herbicide use.

There are some useful broad spectrum herbicides like methabenzthiazuron, fluorodifen, prometryne and glyphosate. These are not available in the country. Manufacture of the chemicals should be entrusted to National Chemical Lab at Poona and to some renowned organic chemists working in different organisations.

VII. Broad Outlines of Work That May Be Taken up at an All India level.

I. Herbiciae Use in Arable Land :

1. *Individual crops* (Food, fodder, pulse, vegetable, commercial crops, orchard crops and ornamentals.)
2. Dryland agricultue.
3. Minimal tillage.
4. Multiple cropping patterns including relay and mixed crops.
5. Parasitic weeds.
6. Grassland and pastures,
7. Residues-Soil-Water-Plant-Biosphere,
8. Regulation of nutritional quality.

II. Herbicide use in non-cropped land :

1. Aquatic weed control.
2. Wasteland weeds.
3. Special weeds.
4. Soil sterilisation.
5. Brush control.
6. Forestry, Landscape Planning, Soil Conservation Programme.
7. Biological Control.
8. Pollution Aspects.

A mechanism should be evolved at the national level for devising suitable and appropriate measures for developing and propagating pest management schedules involving agronomic, biological, genetic and chemical methods of weed control.

VIII. Suggestions for Strengthening Weed Science Discipline :

Weed Science is a distinct discipline and it has its own individuality as any other discipline such as Agronomy, Plant physiology, Soil Science etc. At present in in this country there is hardly half a dozen full time weed Scientists. This situation has to be corrected if we have to harvest the full benefits of Weed Science in terms of increased food and fibre production besides providing healthier living and restoring the recretional value of the environment we live in and to allevate the misery from manual weeding operations.

Steps should be taken to create independent departments of Weed Science in the different Agricultural Universities and State Departments of Agriculture. The apex crop production and plant protection bodies as ICAR and Plant Protection Directorate should have cells devoted to weed research and these should be manned by competent weed scientists. A Central Weed Research Institute together with four regional substations under the Central Institute should be established. An important function of the Central Institute will be to coordinate the research work carried out all over the country. The other important functions of the Central Institute will be in the direction of education and extension and help the Government and other apex organisations in national policy decisions regarding all matters related to weeds including their control through herbicides and the attendant pollution problems.

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WEED RESEARCH IN THE TROPICS[1]

C. PARKER[2]

ABSTRACT

This paper surveys the types of weed problem facing the small-scale tropical farmer and discusses the need for both research and extension in their solution. Herbicides are seen as potentially valuable tools in improved control of weeds but reliance on chemicals alone must be discouraged at all costs so that the danger of shifts to more difficult weed species are avoided. Many other approaches can be explored to help reduce the population and influence of weeds but where herbicides are used the simplest and most important of these is a late hand-weeding to prevent seeding of surviving weeds.

My treatment of this extremely broad topic must inevitably be a personal view, based on a fragmentary knowledge of the problems over a wide range of contrasting situations, and picking on a few aspects that I feel need particular emphasis.

Basically the job of the weed research worker in the tropics is to improve the efficiency of weed control methods. "Efficiency" may be judged in two distinct ways. It may be a matter of increasing crop production-or it may just be a matter of achieving the same productivity at lower cost. Although both effects commonly occur together and interact, it is important to bear the distinction in mind and I believe that *increased crop production should be the primary aim rather than reduced costs.*

There are several reasons for this choice of emphasis which I will explain in the course of the paper, but the overwhelming reason is, of course, the prospect of food shortage in the future and the almost desperate need to increase world food production. Lester Brown (1975) paints a gloomy picture of the way ahead and points out how the early effects of the " green revolution " have tended to wear off and global cereal production is now tending to level off or even decline, rather than go on increasing. Many countries previously exporting cereals or on the point of self-sufficiency as was India herself in 1972 are becoming increasingly dependant on exports from North America. Perhaps 1976 has been more encouraging but will the improvement last.

Estimates of food lost to weeds can only be very approximate, but we have guessed at a current figure of nearly 300,000,000 metric tons per year or 11.5% of present

1. Contribution of ARC Weed Research Organization, Yarnton, Oxford, UK
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food production (Parker and Fryer 1975). It could be argued that to eliminate all losses due to weeds would only compensate for 5 or 6 year's increase in world population at 2% per year, so is it worth even trying ? In the developed countries where herbicides are already being widely used the answer is yes, not because there is great scope for increasing productivity by weed control alone (only 5 to 10%) but because the weed problems are not static and we have to work hard to find new solutions to changing problems otherwise losses due to weeds will rapidly increase. In the tropics and sub-tropics there is much more scope for increased food production. In Africa, for instance, weeds tend to limit the area of land farmed rather than simply interfering directly with yields on the planted area, and more land could almost certainly be cropped in India during the monsoon season if it were not for difficulty with weeds ; while primitive weeding methods in many countries allow substantial losses, often unrecognized.

The losses we are talking about are not those due to uncontrolled weed growth-the weed science literature is weighed down with statistics of this sort which are of very little but academic interest-but those that occur in spite of the normal weeding practices, which are very often too little and too late.

In the tropics where herbicides are so far being less used than in temperate regions there is not the same immediate threat of reduced yields due to changing weed flora but there is, in spite of widespread under-employment, a tendency to reduced availability of labour for weeding at critical times and therefore, the same need for weed science to run fairly fast to stay in the same place in respect of maintaining crop yields.

Weed research, therefore, has a contribution to make throughout the world, both in helping to maintain current levels of food production and also hopefully to do better than that and help world agriculture to " buy a few more years " of time while the increase in world population is brought under control- By our own perhaps rather optimistic calculations we believe that over the next decade losses might be reduced to about two thirds of their present levels-enough to compensate for about two year's population growth !

Before considering what weed research priorities should be in a developing country, we should ask the question-is it research that is required to bring about improved weed control methods ? Have suitable methods not already been developed and proved in more advanced agricultural systems, and is it not a problem of extension, education and economics rather than lack of research which is holding back progress ?

Although I am a researcher at heart I am positive those three E's should receive the greatest priority, and that much of our research effort will be wasted if the procedures and infra-structure for further development are not attended to urgently. In the richer countries the economics of herbicides use are favourable and the chemical companies have found it profitable to invest enormously in field development of products and education of the farmers in their use. In developing countries the economics of herbi-

cide use are not only less attractive to the farmer ; they are also less attractive to the agro-chemical company, facing enormous problems in building up a profitable marketing and distributive system. There is, therefore, much less commercially supported development, extension and education. All of which adds up to a vastly greater responsibility upon official bodies to look after these developmental aspects by appointing weed specialists within the extension service on a local basis. That is, assuming that chemical herbicides are the answer.

We shall return to the question of whether herbicides should be the main component of improved control methods but can assume for the moment that they do offer the most dramatic possibilities. Technically there are herbicides to suit a great many of the crop and weed situations in the tropics and they are being used on the larger farms. The reasons they are not being used on the smaller farms is generally that they are not safe enough to crops. not simple enough to apply and not cheap enough. Each of these hurdles could theoretically, eventually be overcome by massive extension, education, subsidies and credit, without further research, but the whole process could be greatly accelerated by suitable contributions from research effort, leading to safer, simpler, cheaper treatments which make chemicals easier to introduce to the farmer. Hence the need for research - but always geared to the needs and capabilities of the smaller farmer and in close collaboration with the official and commercial bodies responsible for guiding the farmer.

We should now go back a step to consider the nature of the problems causing the greatest losses and so most urgently requiring solution, the possible approaches to their solution and the need to strike the right balance between these approaches.

In my experience problems tend to begin with P and the three with embrace most agronomic weed situations are *peaks*, *perennials* and *parasites*. If none of these apply, then the small-scale farmer with a modest amount of family and other labour available should be able to maintain weed populations at an acceptable level and should not be encouraged to depend on chemicals, though he could of course be helped in various other ways to make his weeding easier and cheaper.

Peaks : The farmers who have least problem from peaks and are best able to manage their weeds without chemicals are almost certainly the rice farmers who have reliable irrigation water or very prolonged wet season. They can grow transplanted rice, and use water as a cultural weed control practice, spreading their planting over a relatively prolonged period. Rice growers depending on seasonal rainfall or relatively uncontrolled flooding on the other hand may have much greater problems due to the peak demand for labour at the beginning of the rain or flood season, with cultivations, irrigation and planting all conflicting with the needs for early weeding. Such seasonal peaks of labour demand are common to a large proportion of tropical farming and in West Africa, careful economic studies have shown how this early season labour bottleneck, mainly for weeding, seriously restricts the area that can be formed (Norman, 1970). Further more the rainfall is often particularly heavy and continuous in the early stages of a monsoon season and mechanical weed control whether by hand-hoe or inter-row cultivation may be impossible or ineffective.

Hence the enormous potential for herbicides, particularly those that can be applied at or before planting, to prevent weed competition in the vital first 3 to 6 weeks of crop growth. This has of course been recognised for a long time and there has been ample activity in many tropical countries not least India, to determine the suitability of the available herbicides under local crop, weed, soil and climatic conditions. This activity has not resulted in any very conspicuous progress on any but the larger farms for a variety of reasons - mainly the three E's mentioned above. And in a way it is perhaps just as well, because there is a danger inherent in the repeated use of most of the less expensive herbicides which has been gradually revealed in Europe, North America, and Japan - namely the everchanging weed flora, leading to the need for still newer and more expensive compounds, often several per crop per season to deal with the more tolerant weeds. Gradually we have shifted the weed flora to those species more closely related to the crop such as wild oats (*Avena* spp) in cereals, *Cassia* spp aad other leguminous species in leguminous crops and eventually the ultimate problem of wild rice (*Oryza* spp) in rice (*O. sativa* L.) or wild beet (*Beta vulgaris* L. spp. *maritima*) in sugar beet (*Beta vulgaris* L.) completely defying soulution by conventional chemical approaches and requiring the use of antidotes or crop protectants (which may be unavailable or expensive) or cultural procedures (which are often inconvenient or unproductive). So, rather than eliminating weed problems by chemicals we have sometimes created even worse ones (Parker 1977).

These changes in weed flora are encouraged particularly by monocropping and the repeated annual use of the same or closely related herbicides. In the tropics cropping may be more varied and there is the theoritical possibility for the rotation of different classes of herbicide now that a wider range is available. But there is still the same danger particularly as only a narrow range of herbicides is likely to fulfil the criteria of safety, simplicity and cheapness in the tropics and the full range will not be immediately available for "rotation." There is the further problem of mixed cropping restricting the range of suitable herbicides still further.

These dangers need not discourage us from maintaining or increasing our efforts to find herbicides suitable for use in a wide range of situations, but we must bear these dangers in mind and aim at making use of the one resource in which the tropics are relatively rich, human labour. Hand-weeding we all know is a tedious and unrewarding activity and Dr. Holm (1971) was right to point out the social evils of the use of child labour for weeding and the need to relieve man of this degrading, back-breaking task, but it is dangerous folly to encourage farmers to think that chemicals will completely *replace* hand labour. Chemicals should certainly replace a large proportion of the labour required but so for as it is possible at all, at least one hand-weeding should always be retained even if in the short term it may appear uneconomic. There is no weed control agent so selective as the human and only he can ensure that the plants going through to fruition in his field are crop and not weed. The one weeding need not be early, provided the herbicide has worked reasonably well. A 10% weed population should have little effect on yield upto six weeks and they can then be weeded out at relative leisure. There may be little effect on yield even if they are *not* removed, so in the short term it appears uneconomic to use both

herbicide and hand-werding but if those 10% of tolerate weeds are allowed to seed they may from 50% or more of the population within a year or two. In our weed research, therefore, we should generally allow for such a follow-up hand - weeding not early in screening trials, but as soon as yields are being measured. I am sure many of you already do this but the published literature suggests that a great many institutions, who should know better, do not follow or promote this important principle.

In rice, especially where it is grown as a monocrop, there are particular dangers, an example being the build-up of *Scirpus maritimus* L. on small farms in the Philippines. Many workers are conscious of the possibility of this type of shift but they are spending too much time measuring it or trying to overcome it by expensive changes or mixtures of herbicide rather than preventing it by the much simpler, cheaper expedient of a later hand-weeding.

Earlier I emphasized the preference to concentrate on increased production rather than reduced cost of weeding. If one thinks purely of short-term economic returns, one would leave surviving weeds following an imperfect herdicide treatment because there would be no immediate benefit, but in the longer term that small investment of labour could prevent considerable losses later and at the same time there is less risk of causing social hardship where there is labour requiring such work. The time taken to perform this late weeding can also be used as an extra assessment of the success of the herbicide treatment.

There are certain implications of this simple principle for our weed research. In particular, it means that our herbicide need not have very prolonged persistence provided that the weeds emerging later are either easily removed by hand (and perhaps useful as fodder) or are effectively suppressed by shading from the crop. The numbers and spectrum of weed species controlled by herbicide should, therefore, be looked at in this light. Prostrate, competitive weeds difficult to hoe out need chemical control more than erect species. The germination biology of the weeds will be of interest in terms of their seasonality of germination and in their response to shading by the crop.

The agronomy of the crop has also to be studied in order to achieve the most rapid and complete shading which is compatible with crop production and other insect pest and disease factors. This approach is receiving close attention at several of the international agricultural research institutes, including ICRISAT here in Hyderabad and at IRRI in the Philippines. Work at IRRI has confirmed the much smaller incidence of and effect from weeds at high densities of transplanted rice but there are interfering problems of insect pest and disease at these high planting densiteis.

Also at IRRI, there are indications that different varieties of mung bean, soya-bean. etc., differ in the degree to which they suppress weeds and these differences are not necessarily related to leaf area or shading (K. Moody, personal communication). There are possibilities of crops suppressing weeds chemically, as shown by Putnam and Duke (1974) and such effects deserve further exploration. All such factors can contri-

bute to a general lowering of weed populations so that the number of weeds to be removed by the final hand-weeding is reduced to a minimum.

Ideally, combinations of such methods with standard hygienic procedures of sowing clean seed, preventing weeds from seeding after harvest, use of inter-row cultivations, etc., could preclude the need for herbicide or will at least usefully reduce the losses from weed competition where chemicals are out of the question.

One very neglected area is that of the efficiency of hoe-weeding. It could be that with standard heavy hoes it takes very nearly as much time and effort to remove a light weed population as it does a dense one but there are real possibilities for modification of traditional tools to suit different types of weed stand whether it is the removal of thin stands of larger weeds, or the early removal of small dense weed populations when chemicals have not been used. Druijff in 1972 described the advantages of lighter hoe-designs which have proved very popular in parts of Africa, but most of us have continued to be dazzled by the prospect of chemicals providing all the answers and have neglected this important approach.

Returning to the herbicides themselves-where crop safety is the problem we can look for varieties, soil types, depths of planting, formulation, timing and placement of the application with the aim of finding treatments sufficiently safe to put in the hands of farmers with limited education and understanding. In all this work we need to use doses higher than normal to be sure there is a safety margin to allow for inaccurate application and accidental overdosing.

We can perhaps hope for still safer and more selective herbicides for the tropical situation but we cannot depend on their development. The rate of introduction of new pesticides is slowing down for various reasons and we will be reliant on the currently available compounds for most crops for some time to come.

We can also perhaps hope for the development of herbicide antidotes which will increase the usefulness of certain herbicides and/or make them safer to use. The antidotes available so far are rather too specific both in terms of the crops protected and the herbicides protected against and are only likely to be of value in maize (*Zea mais L.*) and perhaps a few other cereals such as rice and sorghum (*Sorghum bicolor Moench*). The development of an antidote specific to a herbicide group such as the photosynthetic inhibitors but non-specific in terms of crops protected would have a great potential but we have to await the ingenuity of the chemists in industry for this.

Herbicides have to be extra safe in the small farm context because we have to allow for less accurate and uniform application. How can research help to simplify application methods and so help the farmer to use chemicals more accurately and safely? The processes involved in knapsack spraying for instance include (a) calculating and measuring the correct amount of chemical per tankful and (b) uniformly spraying that tankful over the correct area of ground. He may be able to see where he has sprayed and where he has not but soil wetted with 200 L/ha may not look very

different from soil wetted with 1000 L/ha and the difference could be lethal to his crop. With granular herbicides on the other hand, step (a) is normally eliminated (ie no dilution process unless we consider the farmer making his own home-made granules, as described by Zahran *et al* 1976, using superphosphate as a carrier) and step (b) is easier in that the granules are visible on the ground and the farmer can judge how much and how uniformly he is putting them on. Granules have proved very successful and popular in small-scale rice growing, but in upland crops they have not generally proved sufficiently reliable. More research is needed to see if there are not certain compounds which could be adequately reliable under upland conditions. Even if slightly higher doses were needed, the extra cost could be outweighed by the advantages.

A technique receiving a great deal of attention at present is "controlled droplet application" or CDA. This involves battery-driven spinning disc sprayers such as the "Herbi" (Bals, 1975) with which herbicides can be applied at only 20 l/ha. This technique could eliminate the dilution step (a) but still presents problems of uniform distribution especially as the spray droplets may be quite invisible. The technique requires more research and development but offers particular advantages in semi-arid areas, greatly reducing the volume of water which has to be carried, at a time when water may be extremely scarce.

Where dry-planting is practiced towards the end of the dry season, there is a need for herbicides which will persist on the soil surface under hot dry conditions until the rains begin. There is a lack of systematic information on the behaviour of herbicides under these conditions. These are just some examples of the fields of research and the approaches that I believe are needed in relation to general annual weed control. *Perennials*: The second major class of weed problems is that of the perennials, perhaps not as widespread as the problem of "peaks", especially in regions with a very prolonged dry season, but it is a class of problem which tends to increase with the introduction of herbicides. The cheapest and most widely-used herbicides in annual crops have little action on perennials such as *Cyperus rotundus* L. and *Cynodon dactylon* L. and these two can build-up and cause the farmer much greater and more expensive weed problems than he had before he started using chemicals.

It is, therefore, vital that in all research with herbicides, even when perennial weeds are not the main target, the perennials are not ignored. There are of course herbicides which control perennials, the thiocarbamates for *Cyperus* spp for instance, but they often involve higher cost and more complicated application tha then "standard" herbicides, and still do not provide eradication or kill, only temporary suppression. Hoping and searching for the super perennial killer is almost futile. Glyphosate (N-phosphono methyl glycine) comes nearer than any before but even this excellent compound does not give 100% kill and is not generally suitable for annual crop situations, quite apart from its cost. If there were a compound even better than glyphosate, then it would, at least for its patentable life, be even more expensive and utterly out of the reach of the farmers we are here to help. The moral of this is that we have to make use of all the less-than-adequate treatments that we can afford, putting them all together in a sequence or package which gradually, perhaps over several years, brings and keeps these weeds under control.

Before we resort to herbicides, can we not perhaps do more with dry season cultivations ? If the soil is too hard and dry for the traditional bullock-drawn implements, then can those implements not be re-designed ? Again our hopes have all been on chemicals and we may have overlooked ways in which the engineer can contribute. If dry season cultivations are possible, do we know how deep we need to go ? There is a surprising lack of good information on the depth of rhizome systems of our perennials, and just because some are recorded at vast, incredible depths, it could still be enormously useful to destroy the 90% of rhizomes that we can reach and then use some other method to prevent the other 10% from flourishing by shading in particular.

Parasites : The two most important groups of parasitic weeds, the *Striga* sppt and the *Orobanche* spp both flourish in semi-arid areas and cause farmers almos. completely unavoidable losses. Once they have become established, normal crop rotations are not enough for their eradication and the growing of susceptible crops may have to be given up for up to 6-10 years. But the choice of crops in areas of low, unreliable rainfall is very limited and there is no *Striga*-resistant substitute for sorghum and millet. So these crops continue to be sown and the farmer can do nothing to attack these weeds until after they have emerged and already done most of their damage.

Vast areas are affected by *Striga* species in Africa as well as India and the losses caused by this genus of weeds almost certainly exceed the losses due to *Cyperus* species (wrongly regarded, I believe, as the "worst weed in the world") and rival those caused by *Avena* species in wheat and *Echinochloa* species in rice.

Fortunately there are big variations in the susceptibility of sorghum and millet varieties to *Striga*. There have been attempts in India in the past to select sorghum varieties with good resistance. These efforts have often been successful but of rather restricted local value. Now the efforts are being resumed on a larger and more systematic scale, with intensive work here in Hyderabad, at ICRISAT and with the prospect that usefully resistant material will be disseminated to many other region to be incorporated into more local breeding programmes.

At WRO we hope to be collaborating in this work soon, helping to clarify the nature of the resistance mechanisms and to get a clearer understanding of host specificity and the possible dangers of certain strains or species of *Striga* overcoming resistance.

This work is completely non-chemical in approach and offers the possibility of the simplest, safest and cheapest possible solution for the smaller farmer. Meanwhile other approaches may still be relevant in certain situations and there is potential for further work on the *Striga*-suppressing effects of nitrogenous fertilizers and the germination-stimulant effects of ethylene (Eplee and Langston, 1976) and the latest "strigol" - analogues (Johnson *et al* 1976).

For *Orobanche* spp the possibilities of resistant varieties are not as well defined as for *Striga* but this is likely to be a very fruitful approach. Ethylene does not

stimulate *Orobanche* germination. but the strigol-analogues do and will certainly deserve further study.

There are many other types of weed problem and weed research that I have not touched upon. There are urgent needs in aquatic weed control, in bush control, in forestry and in road-sides. All of these and many more demand equally careful, balanced approaches with no one method of control likely to do the whole job unaided, though in several of these situations it is likely that biological control methods may be important, as this approach is particularly suitable where there is a single dominant species and almost any shift in the flora will be beneficial. I have in mind examples such as *Mikania micrantha* H. B. K. in tea and in forestry and water-hyacinth (*Eichhornia crassipes* Mart. Solms) and *Salvinia molesta* D S Mitchell in water, as well as the dreaded "congress gress" (*Parthenium hysterophorus* L.) on road-sides. But biological control can have the same problem as chemicals because of its selectivity, and the grass carp *Ctenopharyngodon idellaval*. will almost certainly lead to the build-up of the less palatable species such as *Myriophyllum* and *Vallisneria*.

Where herbicides have been used for some years there are already the "second generation" problems of *Avena fatua* L. and *Phalaris minor* Rets. in wheat, *Ischaemum rugosum* Salisb., *Scirpus maritimus* L. and wild or red rice in rice, *Rottboellia exaltata* L. and *Cyperus* species in maize, *Cynodon dactylon* L. Pers. in cotton. There are promising chemical treatments for most of these problems but you can be sure that there are "third generation" problems waiting to take their place and they could be worse still-so let us proceed with the greatest care and wisdom :

I believe I may have disappointed you by dwelling on such old-fashioned things as hand-weeding, hoes and cultivations rather than holding out hopes of fascinating new technological advances, but we should perhaps lower our sights a little and aim at a package of simple approaches for the tropical farmer, with or without chemicals, but at the same time ensuring that we do not get him on to the same slippery slop that we have seen in Europe and North America- The last thing we must do is to encourage him to think that he can manage with chemicals alone. We must, of course, keep our eyes and minds open for the dramatic break through but mean while work with the simple tools that we have, to devise combinations and systems of weed control that, if you wish to be fashionable you may call " integrated control ", but which I prefer to think of as common sense.

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WEED RESEARCH NEEDS OF THE SMALL FARMERS

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Agriculture has some times been defined as a "Controversy with weeds". Weeds are the most universal of all pests, proliferating in varying number each year on every farm. Because of their universal presence, there is a tendency to regard weeds as unavoidable problems in farming. The FAO has recently estimated that world agriculture is losing up to 75 billion dollars per year due to pests, including weeds, insects, & diseases. One third of this loss ($25 billion) was accounted as due to weeds, an estimate which, percentage-wise, is similar to losses due to weeds, in India. In fact, as agriculture's worst enemy, weeds have recently come under world-wide attack as man has realised the problems and implications weed have upon food production. Consequently, Weed Science has emerged from its low status to one of the rapidly growing agricultural tehnologies in recent times.

Early weed scientists were primarily botanists who identified "weeds" from 'crops" and defined their habitat and origin and in some instances described their life cycle and ecology. Recommendations for control generally included plowing, cultivation, hand pulling and crop rotation. Then the discovery of 2,4-D and MCPA and their subsequent release for farmer ues in the 1940's led to the beginning of a new era in weed control. Since then, the developmen1 of herbicides that kill weeds without being toxic to crops has burgeoned. The history of weed control is, therefore, characterised by a shift from the maximum use of human energy, to petroleum-powered energy and then more recently, to chemical energy. However, many believe that the satisfactory control methods will be based on the continued employment of each form of these energies rather than of chemical energy alone.

There is no doubt that the discovery of herbicides led to what must surely be regarded as one of the greatest contributions to world agriculture. But, unfortunately, the developments in the field of chemical herbicides have been so rapid and the number of componds showing herbicidal activity so great that it has almost reached a stage where herbicides are being taken for granted for weed control. In the last two decades, the greatest expansion in chemical weed control has taken place in those countries where agriculture is at a high level of technical efficiency and where labour costs are high and agriculture is capital intensive. Moreover, the results gained from the

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world-wide "conventional" weed research benefit the farmers of the developed countries far more than those of the developing world. For this reason, there exists a dire need for a different, "non-conventional" weed research especially designed and suited for the small farmers, who are rural dwellers on small scale subsistence farms.

In this paper we try to analyse the weed control problems of the peasant farmers and to consider some of the weed research approaches which may be adopted in planning future weed research programmes.

THE SETTING

The weed problems of "small farmer" as referred to in this paper are characterized by many distinct factors distinguishable from those of the farmers of more developed countries. These include :

1. Tropical weed problems are more complex than those of the temperate zones.
2. The farm sizes are small ; in addition, almost all fields are surrounded by uncultivated areas or bunds which are serving as sources of weed infestation.
3. The heterogenous nature of soils makes them difficult to handle.
4. Rainfall is erratic in terms of the total quantities of precipitation and distribution, making tillage difficult and crop growth extremely unpredictable.
5. The technology required, especially for upland crops under rainfed conditions, is complex and, if available, has not yet fully reached the farmer.
6. The farmer owns limited resources and operates with scarce and expensive capital. The average holding in most cases is less than 3 ha.
7. Most farmers are illiterate and, therefore, much of the available agricultura research is not being understood and adopted by them.
8. Agricultural production is unstable and yields are low.
9. The supply of labour is abundant at the present time.
10. There is a lack of understanding by the researcher of the farmer and his production system.
11. Due to the possibilities of intensive cropping the production potential of the small farmer per unit land area is greater than that of larger farmers of the developed world.

The agricultural environment of the peasant farmer is therefore very complex. Consequently, the weed problems and the impact of weeds on peasant farmers and their dependents in the developing countries are also very severe (Holm, 1971 ; Parker, 1972). The peasant farmers are often unaware of or are fatalistic about the yield losses caused by weeds. They do recognise the problems of insect and disease pests ; some may even apply insecticides or fungicides. However, one of the recent surveys conducted by the International Plant Protection Centre (IPPC, OSU, 1975) showed

that small farmers are beginning to realise weeds as major problems, but only second to insects.

Farmers depend predominantly for weed control on hand pulling, the "guntaka", or the hoes, and the machete. Weeding is left until weeds are well established. Many farmers wait for the weeds to become fodder or in some cases weeding is not done at all. Kasasian and Seeyave (1969) and many others have shown that a delay in weeding can reduce yields substantially even though subsequent weedings are carried out effectively. Late weedings with hand or implemen.s may also damage crops (Druijff and Kerkhoven, 1970).

HERBICIDES AND PEASANT FARMER

Worldwide weed research has been focussed mainly on the use of herbicides. The results gained from these efforts, in general, have not reached the small scale subsistance farmers because of many difficulties in persuading them to use herbicides. They are :

1. Ignorance of the losses caused by weeds and a fatalistic acceptance of weeds, ironically, because of their almost universal presence.

2. The limited cash turn over preventing the adoption of herbicides and other new practices. The income of the farmers is low with little or nothing left to invest in the farm. Most Indian farmers are primarily subsistance farmers, marketing little of what they raise.

3. The present day ample supply of labour-both family and hired. The increasing wage rates coupled with the rapid expansion of industry may later result in scarce farm labour, but this is not expected to happen very soon.

4. The farmer usually hesitates to accept risks by adopting new practices. He does not change long existing, well tried, farming practices suddenly. Furthermore, his inability to read and understand the label of herbicides could prove disastrous.

5. The farmer does not need a "clean" crop and in some instances wants the weeds to become fodder to feed his cattle. Some weeds are deliberately left because they serve as vegetables. Clean culture with total dependence on herbicides may add to the problem of soil erosion on steep and shallow soils.

6. Since the small farmers grow several crops several herbicides may be needed. The problem of growing more than one crop (multiple cropping) in a year becomes more complex when more than one crop is grown simultaneously (intercropping) in one season on the same farm. Obviously, there exists an opportunity for mistaken usage of herbicides with serious crop damage. Also very little is known regarding herbicides safe for multicropping and at the same time effective against several weed species.

7. The lack of trained personnel and weed scientists who have undergone training in Weed Science. At present, agricultural universities, research centres, governmental extension departments, and pesticide industries do not have sufficient technical know-how in the field of herbicide science. Only very few universities have included weed science in their teaching curriculum.

The use of herbicides alone may be uneconomical unless the entire farming system is improved (Binswanger and Shetty 1976). Improved education on weed science, extension services, and provision of credit may solve some of these problems (Hammerton, 1974). A herbicide suitable for all the crops grown in an area would be the "ideal" for the farmer to have but it is difficult to invent one at least in the near future (Ogborn, 1969).

THE NEED FOR CONTINUING HERBICIDE RELATED RESEARCH

Although at present it is relatively hard to convince the small farmer to use herbicides, to obtain significant increases in crop yield it is necessary to use herbicides. In India, herbicide related research has been initiated in almost all agricultural universities and research stations. Still more emphasis should be given to this branch of agricultural science. In the long run, herbicides can surely help small farmers in many ways :

1. As the critical period of crop weed competition in most of the annual crops falls during the early part of the crop cycle, pre-emergence herbicides would be of immense help. Hand weeding, by its very nature, necessiates waiting till the weeds can be handled. Lange *et al* (1973) showed the improvements in yield, ranging from 13% in cotton to 24% in rice, by the use of herbicides in comparison with normal local weeding practices. The overall improvement in yields for seven different annual crops was 19.3%. Parker and Fryer (1975) estimated that the potential for yield improvement was probably more than 20% and it is not necessary for the herbicides to provide completely weed-free conditions. Therefore, when a herbicide brings about the early weed control over that normally achieved by careful hoeing, yields may be increased.

2. As Hammerton(1974) and Ogborn (1969) pointed out, selective pre-emergence herbicides can increase the total acreage handled by single family, or hand work will be greatly eased so that fields not treated with herbicide can be weeded effectively.

3. Herbicides may be the only solution for controlling some perennial weeds like *Cyperus* and *Cynodon*. Consequently, large proportion of abandoned areas can again be brought into cultivation.

4. As the tropical sub-subsistence farmer practices muliiple cropping an indirect yield may be achieved by releasing labour from one crop in which herbicides have been used for the more timely planting or improved care of another crop in

which herbicides have not been used. During the peak labour demand like the period when harvesting of the previous crop and planting of the next crop occur simultaneously herbicide use may be of help.

5. In some of the semi-arid lands where soils are heavy and rains fall frequently, hand-weeding in time is not possible and herbicides may be the possible answer.

6. In the areas where soil moisture is critical, the practice of minimum or zero tillage is being considered and many herbicides play an important role in making this practice effectively productive. A minimum tillage system based on herbicides may be one answer to the soil conservation problem.

7. Herbicides could also assist in land clearing and for shifting cultivation.

8. Herbicides could be useful tools in checking intense weed problems during fallow seasons.

9. To carry out many agricultural operations at an optimum time like optimum planting, particularly when they are related to rainfall occurrence, herbicides can improve yield by permitting a larger area to be planted.

10. Herbicides are in many cases an integral part of improved farming systems involving new crop cultivars, fertilizer, irrigation, and other agronomic practices. These and many other factors necessitate the need for herbicide use even by small scale subsistence farmers.

The trend in the present weed research is towards the "conventional" herbicide research approach involving the routine herbicide screening for individual crops. For the less developed countries like India "simple" herbicides should be developed if only for short term control of weeds in the early stages of crop growth. It should not be forgotten that hand-weeding will stay for years to come and therefore it should be regarded as an integral part of the weeding program (Parker and Fryer, 1975). Some areas of herbicide research which need to be looked into are :

1. Possibility of improvements of herbicides which can lead to a reduction in costs and hence enhance the utility and readiness to be accepted and used by the farmers.
2. Can herbicide dose be minimised ? Example : band application of herbicides ?
3. Simplification of equipment : How about the use of herbicide granules, low volume sprayers, etc, ?
4. Can herbicides be formulated with fertilizers or insecticides ?
5. Can present day cropping systems be simplified to enable the use of herbicides ?
6. Possibility of the development of an "ideal" herbicide with low mammalian toxicity, tolerance by many or most of crops, high selectivity index, compatible with insecticides and fertilizers, minimum soil or plant persistence, no drift, etc.

Research is urgently needed to develop cheap herbicides which are well suited to local soils, climates and cropping patterns of the small farmers. One of the most important "improvements" required is in the price of herbicides (Parker and Fryer, 1975). The weed scientists of the developing world have not yet found the solution to this problem.

The Integrated weed Management Approach

The setting and the agricultural environment of the average small farmer led to the conclusion that in the *near future* the farmer will not be able to rely heavily on herbicides to solve his weed problems. Therefore, the research approaches should be to combine the principles of the existing cropping systems with available new technology to develop effective systems of weed management. We should depart from the conventional "chemical only" approach to an integrated management approach (Bantilan and Harwood, 1974),

The objective of the integrated approach to weed management in a crop-weed community is to shift the balance in favour of crops to the point where weeds are no longer economically important. Thus, weed management can be designed to minimise losses due to weeds by means of (i) a system of cropping methods, (ii) cultural practice techniques, and (iii) the supplemental use of herbicides. A combination of these may make weed control effective and economically feasible to the small farmer.

Indeed, the concept of "management" is more feasible under the peasant farmer's conditions of limited mechanization, farm size and capital. The proper combination of agronomical methods, mechanical tillage, and supplemental use of herbicides also give maximum stability to any integrated weed management (Bantilan and Harwood 1974). This approach is more significant when the farming systems as a whole area taken into account rather than just the problems of individual crops.

There has been a tremendous interest in cropping systems over the past few years because intensifying crop production on existing lands is one of the major approaches to increasing world food production. Consequently, many international as well as national programs have initiated research in this area. Overall management approach is being given primary importance and, to deal with this objective effectively, research on the farming systems as a whole is necessary. Thus, the overall management of pests within the agricultural environment will then become necessary. The development and recommendation of integrated weed management systems which can easily fit into the farmer's existing farming system is the need of the hour. Weed management is therefore, one of the focal areas of cropping systems research and should receive much attention.

Much research is therefore needed in looking into various alternate agronomical and mechanical tillage methods in combination with herbicides and then to choose from these combinations the most viable, economically feasible system. Since the major objective of an integrated weed management in a farming system is to shift

the crop weed balance more favourable towards crops, a number of new questions arise. Weed scientists should try to find solutions for some of these questions :

1. What are the factors affecting crop-weed balance ?

   Quantification is required on the effect of shade, fertility (NPK), crop density (plant population), crop combination and the interactions of these various factors. Bantilian *et al* (1974) have demonstrated that crop weed balance is dependent upon plant type, density, crop fertility level and weed control method. Many other factors like soil moisture level temperature, light intensity, rainfall, insect and disease problems, allelopathy, tillage, and cropping pattern are yet to be investigated in respect to their effect on crop-weed balance.

2. What are the impact of changes in the physical, biological and cultural factors on succeeding weed communities ?
   Are there any shifts in weed communities ?

3. Are there any scope for further research on cultural control, weed surveys, weed biology, and for minimising environmental hazards from continued use of herbicides ? Continuous research on weed control for the various individual component crops suitable for adoption into multiple cropping programmes are a must to study weed control in multiple cropping.

4. Does each cropping system provide a different ecological niche for the weed community ?

5. If there are any shifts in weed species, what factors in the cropping system are responsible for these shifts, especially in the case of difficult - to - control weeds - like perennials ? What manipulations in the system are necessary to control them ?

6. Can we predict these shifts and decide prior warnings ?

   While approaching the concept of habitat management of weeds or weed ecology management, studies on life cycle, ecological requirements and basic biology of some of the troublesome and potentially troublesome weeds are absolutely necessary.

Recently Plucknett *et al* (1976) described weed research needs of a cropping systems program as follows :

1. Inventory of the local weed flora of existing farming systems and the losses caused by them.
2. Behaviour of the existing noxious weeds as influenced by a change in component/components of the farming system.
3. What are the existing management systems of the farmer that appear suited to control most weeds ?
4. Should we attempt clean cultivation ? If not what levels of weed infestation are reasonable ?

5. How can the present management system be shifted to manage noxious weeds ?

The basic principle of weed control is to prevent the weeds from multiplication and to deplete the weed seeds/propagules from the crop fields. Therefore, the following problems need to be investigated :

1. What are the mechanisms by which the major weeds of the region establish and spread ? How long does the dormancy period exist ?
2. Are the present management factors favouring multiplication and spreading ? How can this be avoided ?
3. Are there any new varieties of weeds which are resistant to herbicides and other cultural factors ?
4. What factors can be manipulated to prevent the multiplication and spread of weed seeds/propagules ?

The biology and ecology of perennial and difficult-to-control weeds should be studied in more detail. Perennial weeds like *Cyperus rotundus*, *Cynodon dactylon*, *Imperata cylindica*, *Paspalum conjugatum* and annuals like *Setaria*, *Eleusine*, *Digitaria*, and *Echinochloa* are still the major weed problems in most parts of the country. Studies on their biology and ecology with respect to agricultural environment should be carried out, possibly on a regional basis. Parasitic weeds like *Striga* and *Orabanche* cause serious losses and yet knowledge on these weeds is not sufficient to enable the development of adequate control methods. Too little is known about the physiology of weed seeds and vegetative propagules of major weeds. Moody (1976) has recently made an exhaustive review of weed control in multiple cropping systems. Additional emphasis should be given to developing weed control technology for the farming systems of the peasant farmer as a whole even includiug the field bunds. We must learn more about the ecology of the weeds, their association with surrounding environments, their life cycle, morphology and physiology.

On The Farm Weed Research

Plucknett *et al* (1976) have stressed the need for on the farm weed research. With our ultimate objective being to improve the farming system as a whole, more information could be made available if the research were carried out in the farmer's fields with the farmers as an integral part of the technology development. Hitherto very little research has been carried out in the farmer's field. However, considerable emphasis is now being given to these "Operational research programs". Some of the benefits of on the farm research are :

1. The involvement of farmer in planning and executing Weed Research Programs helps the scientists to know more abont the philosophy behind existing traditional practices.
2. When experiments are on the farmer's fields we deal with natural existing weed flora and not with the weed flora of an experimental station which may be different.

3. It is much easier to compare modern methods with the traditional ones. Traditional methods simulated in the experimental station often differ from the true traditional methods.

4. Experiments in the farmer's fields help to serve as an extension-demonstration method for the neighbouring farmers.

5. It is easier to test concepts under several environments in the farmer's fields than in the experimental stations.

To decide on the permanent production systems with built-in flexibility many basic assumptions and principles involved have to be studied in detail :

1. Plant Competition : Research should be initiated/continued with careful selection of adapted and desirable species or varieties and maintenance of optimum soil fertility and cultural condition to maintain the crop in more advantegeous position over the weeds. Can we grow some "smother" crops ? Can we grow some weed competitive varieties ? Can Plant breeders and weed scientists work together in an effort to evolve competitive and more herbicide tolerant cultivars ?

Breeding crops for greater competitive ability against weeds usually has been attacked only in a casual way. Tall leafy cultivars may suppress weed growth by shading. Recent reports on allelopathy also suggest that studies should be conducted on determining whether allelopathy is heritable and can be incorporated into plant cultivars.

2. Tillage : A basic principle of weed control is that control measures should be directed at survival mechanisms in the soil. For annual weeds the objective is to prevent seed production and to deplete seed reserves. With hardy perennials, destruction of underground vegetative organs is sought. Tillage is the initial phase of the weed control program. Dryden and Krishnamurthy (Personal communication) recommend a "Year Round Tillage Program" for farmers working under rainfed conditions. Some questions regarding tillage are yet to be answered :

1. What are the merits or demerits of deep or shallow tillage ?

2. What are the advantages and disadvantages of tillage immediately after kharif/ rabi harvest ?

3. What is the optimum tillage necessary ? Can minimum or zero tillage be adopted ?

4. In which crops do weeds pose serious problems (e. g., castor, sorghum, pearl-millet, groundnut) in respect to tillage operation ?

5. When should we prepare the seed bed for kharif planting ? When should we plant ?

6. What is the best time for intercultivation and hand-weeding ?

7. What is the optimum tillage during the fallowing ?
8. What is the efficacy of shallow tillage for the control of the germinated weeds ?
9. What method of planting (square planting for castor, sunflower, etc. ?) would facilitate tillage to permit inter-row tillage in two directions ?
10. Can we improve tillage equipment such as plow, blade harrow, etc.?

We should keep in mind that weed control techniques which are incorporated with sound crop husbandry and soil management practices are very successful and effective, particularly under semi-arid tropical conditions. Until the dreams of having an "ideal herbicide" and "weed resistant varieties" become true, it will be necessary to continue the battle against weeds as agriculture's worst enemy. It must be realized that "no weed control method has ever been abandoned, only new ones have been added". Therefore, integrated management techniques by combining the improved older methods with the modern herbicides seem to be the most feasible and to be economically within the reach of the small farmers of our concern.

An experimental concept

At the International Crops Research Institute for the Semi Arid Tropics, the recently initiated weed research is aimed at the development of effective weed management systems for the semi-arid tropical farmers. In addition to "conventional" weed research on ICRISAT's five major crops considerable emphasis is being given on cropping systems of the Semi-Arid Tropics. All possible weed management techniques are being investigated in an effort to minimise losses due to weeds by means of a "systems approach". We visualise that the proper combination of agronomic methods, mechanical tillage, and supplemental use of herbicides (if necessary) can give maximum stability to any integrated weed management program in a productive farming system.

As described briefly in the earlier part of this paper we recognise that "prevention is better than cure". The best way to reduce the number of weeds in an area is to never allow weeds to mature and go to seed and to employ methods to exhaust the weed seeds reservoir from the soil. Two of the major sources of weed seeds are :

1. The weedy field bunds (or contour bunds) which serve mainly as boundaries between farmers' fields. In the rainfed areas these bunds may occupy as much as 10% of the land area.
2. Weeds left in the fields after crop harvest. These produce copious quantities of weed seeds since the land is usually not tilled until the rains soften the soils sufficiently to facilitate tillage.

The recently developed broad ridge and furrow system (Krantz *et al* 1976) has a potential for eliminating both of these weed seed sources as well as providing other resource - conserving and production - increasing features. The chief features of this farming system are as follows :

1. Broad (150 cm) ridges and furrows are established on a graded contour with an average slope of 0.6 to 0.8% in black soils and 0.4 to 0.6% in red soils. These ridges and furrows lead to a natural drainage way which should be grassed to prevent gulley erosion. Thus once these land features are established they can become permanent just like graded contour terraces and no additional surveying or "laying out" is needed. All future cultural operations follow and maintain the broad ridges and furrows. The plowing, ridging and planting is all being done with an animal - drawn two - wheelled tool carrier. In all operations the wheels and bullocks always follow the furrows ; thus there is no soil compaction in the broad ridge crop production area. Since the broad ridge and furrow system can be permanent land features, the land area of each farmer can be designated by the number of broad ridges he owns and can be marked with a granite block or stone. Thus, the need for field bunds is eliminated and the system would enable each farmer to gain up to 10% of land area previously occupied by bunds, and would reduce the weed seed problem.

2. By maintaining a continum of crops from the onset of the monsoon through the rainy period and as far into the post-monsoon period as possible by various means of double cropping, weed growth can be greatly reduced by effective crop competition after early weed control.

In the black soil it is possible to plough immediately after the timely harvest of the second crop ; thus any immature weed will be killed and not allowed to go to seed after the crop harvest. In the red soil it will sometimes be necessary to delay the plowing until the first monsoon shower. If so, the weeds could be heavily pastured, cut or sprayed to prevent them from going to seed. Since the major portion of weed seeds sprout in the first or second year it should be possible to greatly reduce the weed seed source and thus reduce weed competition and cost of weed management.

Some of the other possible advantages of the broad ridge and furrow system and early plowing are :

1. The soil moisture remaining in the profile after the second crop is saved.
2. Land preparation can be completed well ahead of planting time.
3. By the use of a left and right hand plow on the tool carrier it is possible to plow one broad ridge at a time, moving the soil towards the centre and thus covering 150 cm of land surface with one trip with animal-drawn plows. This system provides a manifold increase in efficiency of animal power.
4. The broad ridge and furrow system avoids large concentrations of water since each small furrow carries its own water, thus facilitating more uniform distribution of water over the field and reducing soil erosion. The furrows provide for drainage and reduction of water-logging during wet periods and also facilitate recycling of supplemental water to break a drought during the monsoon and to extend the post-monsoon crop season.

It is recognised that some of these concepts are still in the experimental stage, but they do offer potential for improved weed management, crop production and resource conservation in the semi-arid tropics.

In conclusion, the task ahead of the weed scientists working for tropical small farmer is great. However, with the inter-disciplinary "systems approach" and agronomically and economically appropriate weed research technology, it is possible to develop effective and economically feasible weed management systems for the small farmers.

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ADVANCES IN WEED RESEARCH IN TEA OF NORTH INDIA[1]

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ABSTRACT

Approximately 55% of the area under tea (*Camellia* sp.) in Northeast India is under herbicides and this accounts for about 70% of the herbicides marketed in India. This achievement is mostly due to the poineering research done by Tocklai on chemical weed control in the past 25 years. During this time, a number of new chemicals have been tested, and effective herbicide coubinations selected and recommended for nursery, young tea, and mature tea areas. Efficiency of herbicides, persistence of toxicity, phytotoxicity to tea plant, and effect of herbicides on quality of cup tea were the main criteria used in developing these recommendations. This was made possible by a well organized herbicide testing and certification programme.

Research has also been conducted on: a) biology and control of individual weed species predominant in tea growing areas, b) changes in weed spectrum due to continuous use of herbicides on the same soil, c) enhancement of herbicide activity by wetting agents, surfactants, and fertilizers, and d) prevention of rain-wash of post-emergence spray off weed foliage. Significant amount of work has also been done to standardize spraying techniques and spraying equipment. The possible use of substandard and adulterated herbicides by tea estates is discouraged and prevented with the help of a quality testing programme.

INTRODUCTION

Northeast (NE) Indian tea industry comprising chiefly Assam, West Bengal, and Tripura accounts for 80%of the area under tea in the country, 80% of the tea produced, and 80% of the tea exported (Table 1). Tocklai Experimental Station (named after a small water stream following adjacent to the Institute), the oldest and largest tea research institute in the world and the oldest agricultural research institute (set up in 1900) in India serves 83% of the 290,000 hectare tea industry of NE India through its well-organized research and advisory (extension) activities and a network of branch advisory stations.

Tocklai is ably supported by the Tea Research Association (TRA), a cooperative organization between the NE Indian tea industry and the Council of Scientific and

1. Contribution of Department of Agronomy, Tocklai Experimental Station, Jorhat, Assam.

Industrial Research (C.S.I.R.). The contribution of Tocklai to tea industry has bean enormous in that it helped raise the yield of made tea from 540 kg/ha in 1935 to over 1300 kg/ha in 1975 (1), an increase of 24% in 40 years or 6% per annum. This underscores the fact that the research results of Tocklai have deeply permeated not only to all member estates of T R A but to the non-member estates of the region as well (1). All this has been made possible by a pioneering and intensive research and development programme in such areas as agronomy, plant breeding, soil science, entomology, mycology, plant physiology, biochemistry, engineering, tea testing, and manufacturing.

While research in weed control began long time ago, a more systematic investigation on the use of herbicides for effective weed control was in progress since about 1950. It was only a tribute to this pioneering research that about 55% of the area in the region is presently under chemical weed control and this accounts for over 70% of the herbicides marketed in the country. The important factors that contributed to this quick and wide acceptance of herbicides as a means of weed control in tea as compared to other crops are :

1. non-availability of labour for manual weed control at peak plucking periods,
2. greater labour absenteeism during peak requirement period,
3. low plucking efficiency by labour when the garden is heavily infested with weeds *(Borreria hispida* (L.) K. Schum, *Polygonum chinense* L., *Polygonum perfoliatium* L. etc.*)* and creepers *(Mikania scandens* Willd.*)* which cover the tea bush,
4. inefficient manual weed control practices which allow vigorous regrowth of weeds, and
5. enterprising and well-organized nature of the tea industry.

In a commercial and export-orientated crop like tea where economic efficiency of inputs receives first priority, the use of herbicides became a permanent practice. There are many a garden in the region where herbicides are used over the entire 100% of the area under tea.

Advances made by Tocklai in weed research can be itemized as under ;

A. Herbicide research.

B. Herbicide testing and certification.

C. Herbicide spraying techniques and equipment.

D. Quality testing of herbicides.

E. Training and advisory services in weed control.

DISCUSSION

A. Herbicide Research

Herbicide screening and selection : The main objective of herbicide screening was to select the best herbicides for effective weed control in the nursery, young tea, and mature tea growing areas. The main criteria used in selection of new herbicides were : a) efficacy of herbicides, b) persistence of toxicity, c) herbicide toxicity to tea plant, and d) effect of herbicides on the quality of tea. After an intensive screening over a period of time, new herbicides and herbicide combinations were recommended for use in different situations in tea culture. The various chemical weed control recommendations developed at Tocklai which are now widely followed by the tea estates in NE India are as follows (2).

1. Nursery : In the nursery, seeds or leaf cuttings of clones are planted to raise seedlings which are grown for over a period of 12 to 18 months before being transplanted in the field. It is very essential to keep nursery beds or sleeves from weed competition and allow the cuttings and young seedlings establish and grow vigorously. The predominant weeds are generally of broadleaf species and some annual grasses.

Weed control recommendations : In clonal nursery beds or sleeves, simazine (50 WP) should be applied at least 15 days before planting of cuttings at a rate not exceeding 2 kg/ha* in about 400 to 500 litres of water. In case the cuttings are planted in Polythene sleeves, small amounts of herbicide solutions are made at the above rate and sprayed uniformly. If the soil is dry at spraying time, the soil surface is moistered. Simazine application may be repeated after the cuttings have made two flushes of growth.

For seed nursery beds or sleeves, hand cleaning of beds or sleeves is recommended for about six months after planting to avoid herbicide injury to the germinating seeds and the very young seedlings. Thereafter, simazine (2 kg/ha) should be applied to weed-free soil at pre-emergence to weeds.

2. Young and mature tea : Until the tea plant is five years of age from the time of transplanting, it is called young tea. Bushes which are above five years of age are termed mature tea. Weed situations in young tea and mature tea vary in that the latter has the advantages of having bush canopy and growing under established shade which partially inhibit weed growth infestation. However, weed infested areas in young and mature tea can be broadly classified (2) into three groups.

Predominantly broadleaf weed areas : In areas where *Borrerira hispida*, *Ageratum conyzoieds* L., *Mikanifa micrantha* HBK., *Scoparia dulcis* L. are predominant, the ground should be manually cleaned and depressions around the collar (base) of the bushes filled up before herbicides are applied. Before the weeds begin to emerge following first rains, simazine should be applied at pre-emergence to weeds at 1.5 to 2.0 kg/ha or diuron (80 WP) at 1 kg/ha in tea above three years of age. On the subsequent

* Herbicide rates in this paper are expressed on active ingradient basis, i.e. kg a.i./ha.

regrowth of weeds, paraquat (20 EC) is recommended for post-emergence spraying at 0.3 to 0.4 kg/ha or at a dilution of 0.15 : 200 to 0.2 : 200 for spot spraying wherever necessary. If in case the broadleaf weeds have become a problem or are resistant to paraquat, sodium salt of 2,4-D (80 WP) at 0.75 kg/ha or 2,4-D amine (72 EC) at 0.5 kg/ha will kill these weeds.

Mixed stand of grasses and broadleaf weed areas : The widely used recommendation is application of paraquat (0.3 to 0.4 kg/ha) and 2,4-D sodium salt (0.75 kg/ha in a combination. Paraquat controls grasses and 2,4-D broadleaf weeds. Application of this combination may be repeated whenever regrowth appeared. In lieu of paraquat + 2,4-D, paraquat (0.3 to 0.4 kg/ha) + diuron (0.5 kg/ha may be used in tea of above two years of age.

If the weeds include thatchgrass *Imperata cylindrica* (L.) Beauv. as a predominant species, dalapon (85 WP) (3.0 kg/ha) may be mixed with 2,4-D (0.75 kg/ha) and sprayed in April or May depending on weed growth. This may be followed, if necessary, by paraquat application at a dilution of 0.2 : 200.

Predominantly grassy weed areas : Among the persistant perennial grasses found in tea areas, thatchgrass, *Setaria palmifolia* (Koen.) Stapf., *Paspalum conjugatum* Berg., *Paspalum scrobiculatum* L., and *Digitaria sanguinalis* (L.) Scope. Are the most predominant ones. At present, dalapon (3.0 kg/ha) is recommended to be applied at post:emergence to actively growing and immature thatchgrass infested areas. This may be followed, a week later by paraquat at a dilution of 0.2 : 200. Dalapon or paraquat applications may be repeated when necessary. For toxicity reasons, dalapon is prohibited to be used in tea areas below three years of age. If the grasses are tall and excessively growing, a sickling is advised and the herbicide treatment may be given on active growth of 15 to 25 cm.

Dalapon may be applied three times in a year and at no more than a total of 8 kg/ha.

3. Non-tea areas : These includ sides of the drains and other non-tea growing areas. These areas may be sprayed with 2,4-D (up to 2 to 2.5 kg/ha) to control broadleaf weeds and dalapon (5 to 6 kg/ha) followed a week later by paraquat (0.3 to 0.4 kg/ha) to control grasses. If necessary, repeat applications of 2,4-D or paraquat may be given.

Enhancement of herbicide activity : Polar herbicides like 2,4-D and dalapon do not readily penetrate cuticle of some weed species and hence would require addition of an adjuvant to reduce surface tension, increase spreading and wetting of the leaf surface, and improve retention of spray droplets of herbicide solution. In such situations, addition of Teepol or SNID-PGN is recommended at 1 : 500 dilution.

In a recent study, addition of urea to 2,4-D spray solution markedly enhanced the herbicide activity (Table-2) at the lower rates of application. Such a combination has great economic utility as it can reduce the rate of herbicide application for

effective weed control. Further work is underway to explore this possibility with other herbicides and fertilizer materials.

In another study (5), the effect of Triton AE (resins of synthetic esters 37.5%, and iso-octyl-phenoxypoloxethanol, 12.5%), a new sticker, speader, and wetting agent on the activity of herbicides was tested under simulated rainfall (1.25 cm) conditions. Triton AE was added at 0.06% concentration to the herbicide solution. The commonly predominant broadleaf weed *B. hispida* was used in a study with 2,4-D (sodium salt) and the perennial grass, thatchgrass, in studies with dalapon (Dowpon) and paraquat (Gramoxone).

Addition of Triton AE retained the activity of 2,4-D (Table-3) even when rainfall occured for upto four hours after herbicide application. More herbicide was retained at the higher rate of the application (0.8 kg/ha). At lower rates, most of the 2,4-D was apparently washed off the foliage despite the presence of Triton AE. Similar results were also obtained in case of dalapon. Triton AE, however, had absolutely no effect on the activity of paraquat.

These findings suggested that the addition of Triton AE to a contact herbicide like paraquat will serve little purpose; but it will be very useful to prevent washing of translocated herbicides like 2,4-D and dalapon off weed foliage by rain. The pronounced influence of Triton AE may be attributed to retention of herbicide spray on the foliage and the enhanced rate of herbicide penetration into plant tissue.

Biology of weed species : Oxalis acetocella L., a predominant broadleaf weed in tea has a tap root just below the leaf base around which forms a cluster of 70 to 100 bulbils which serve as the most prolific means of propagation. They can remain dormat in the soil and germinate later, thus posing a sizable problem in tea growing areas. This necessitated a study to determine the rate of multiplication of different types of bulbils (5).

In this potculture experiment, the propogating material, separated into four groups, mature bulbils, semi-mature bulbils, very young bulbils, and young buds which later develop into bulbils were planted and grown in potted soil. The results indicated that 82% of the mature bulbils germinated only five weeks after planting (Table-4). Very little germination (0 to 14%), even after three months of planting was observed in the other types of propagating material. It was thus evident that the pea sized round to oval-shaped mature bulbils which drop off to ground easily when the plant is uprooted provide a good propagating material for this weed.

In another experiment, the plants grown from mature bulbils were allowed to complete their life cycle. New mature bulbils were found forming about 3½ months after planting of mother bulbils, and their most prolific formation was about 4½ months after planting (Table-5). The other types of new bulbils and buds formed early in the growth period matured later to become new mature bulbils. Thus it is evident that using of proper herbicides or control measures is essential no later than three months after germination.

Further work is underway to study the biology of other important weed species like *Polygonum chinese*, thatchgrass, etc.

Control of weed species : Control of persistent and problem weed species individually constitutes a sizable amount of weed research. The important species on which work has been in progress are : thatchgrass, *Paspalum* sp., *Setaria palmifolia B. hispida*, *Polygonum* sp., *Mikania scandens*.

The volume of the data collected from these studies is so much that their presentation and discussion are clearly outside the scope of this paper. A part of these results are, however, discussed in another paper presented at this conference.

Changes in weed spectrum due to herbicide usage : Since chemical weed control has become a permanent practice in tea cultivation, the probable changes in weed species due to continuous use of herbicides were monitered from a permanent herbicide trial. The experiment started in 1972, has different herbicide treatments in the presence and absence of mulch. Changes in the order of the first three most dominant weed species are presented in Table-6. Due to continuous cheeling (using spade with long handle) *Paspalum conjugatum* become the most dominant weed. Paraquat application brought two species, *Polygonum chinese* and *Erecthites valerianaefolia* DC. which were minor weeds in 1972 to the rank of the most dominant weeds in 1976.

Continuous application of 2,4-D and dalapon made the fern, *Pteridium aquilinum* Kuhn. Which was not present in 1972, the second dominant weed in 1975, and the most dominant one in 1976. At present (June 1976) this species accounts for about 70% of the weeds in this treatment. Either this herbicide combination (2,4-D + dalapon) or the competition from this fern or both had completely eliminated *Ageratum conzoides* L.and *B. hispida*, the common broadleaf weeds in 1972. Similarly, paraquat + 2,4-D + dalapon treatment also made *P, aquilinum* as the second dominant weed in 1976.

Mulching in combination with any herbicide treatment also changed the order of weed dominance. For example, *P aquilinum*, *Commelina benghalensis* L. and *E. valerianaefolia* which were minor weeds in 1972 became very dominant in 1976.

These results clearly indicate that changes in weed species and hence the order in the weed spectrum will indeed take place due to continuous application of the same herbicides or a weed control practice on the same soil. This suggests the need a) to follow a well-planned rotational ptogramme for application of herbicide (s) and their combinations over a time period, b) to constantly search for effective new herbicides, and c) to adopt an integrated approach to combat weed problems effectively.

B. Herbicide Testing and Certification

Tocklai was the first agricultural research institition in the country to set up, over 20 years ago, a full-fledged pesticide Testing Unit in an effort to undertake

systematic testing and certification of new pesticide products for eventual use in tea. The main objective of this programme till 1971 and in a different set up since, was to test all new pesticides intended to be markeed in tea by the manufacturers for their efficacy in controlling weeds, insects, diseases, nematodes, and other pests, and their safety on tea before they can be certified for use in tea growing areas of NE India. The approved products only are recommended to the member estates of TRA for use in tea.

Testing of new herbicides. All herbtcides submitted for certification by Tocklai must be registered or registerable with the Central Insecticides Board (CIB). These chemicals are tested under the following broad eategories (3).

1 *Phytotoxiciiy.* To find out whether or not the herbicide will cause any damage like scorching, stunting, and suppression of growth of tea bush.

2. *Tainting.* To check for residual taint or any other undesirable effect on made tea.

3. *Bioassay.* To study the efficacy of the herbicide under field and laboratory conditions in controlling the commonly occurring weed species.

4. To determine the presence of residues in made tea.

Phytotoxicity and bioassay tests are conducted in three stages. During the first stage, the herbicides are tested under laboratory or greenhouse conditions. Products found promising at this stage are further tested in the second stage under field conditions on established weed stand. The chemicals found very good in the second stage are extensively tested in the third and final stages in full-scale replicated commercial field trials in tea under varying soil and climatic conditions for over two or three seasons. Tatnting tests in the quality of made tea (colour, flavour, and strength of liquor) are conducted in the first and second stages. After satisfactory results at the end of the third stage, interim certificates of appoval of their use in tea are given.

Within a period of 3 to 5 years after getting the interim certificate, the manufacturer has to provide analytical data indicating acceptable level of tolerance residues of the herbicide in made ten for issuance of a final certificate- As adequate facilities for residue analysis are not available at Tocklai, the manufacturlrs are required to get this residue data from a residue analytical laboratory in the country or abroad. The interim certificate will, however, not be issued to herbicides based on heavy metals; only the final certificate will be issued after submission of residue data.

Testing of new commercial products of a herbicide. In case of new commercial or proprietory products of a herbicide already certified and being marketed in tea (like 2, 4-D, dalapon, paraquat, simizine, diuron, etc.) check tests will be carried out on herbicide activity. The effect of a new commercial product will be compared with that of the standard product of the same parental herbicide and a certificate will be given, if the performance of the new product was found satisfactory.

Testing charges. In order to defray the expenses involved in testing these products, the manufactures have to pay testing charges at rates fixed by the Station.

C. Herbicide Spraying Techniques and Equipment

Detailed research was conducted to standardize spraying techniques, minimise toxicity to tea, and enhance efficacy of herbicides on weed control. Following are some of the spraying guidelines recommended by Tocklai and adopted by the estates (2).

1. The herbicide must be applied at the right time. Preemergence herbicides should be sprayed to clean gound before the weeds emerge, and postemergence chemicals when weeds are actively growing and immature.

2. To save labour and water required to cover an area and give better distribution of the spray fluid on weed foliage or soil a low volume nozzle delivering 40 litres per hour should be used. The high volume nozzles designed to discharge 60 to 70 litres per hour are less efficient.

3. In order to avoid drift damage to tea bush or plant, the spray should be directed at weed foliage and/or soil.

4. Spray swath can be adjusted by raising or lowering the nozzle height, and the spray delivery should be kept at 25-30 cm above ground level.

5. To obtain effective weed control, there must be a minimum gap of 4 hours between herbicide spraying and rainfall latter.

6. A hand operated sprayer of the Knapsack type fitted with pressure regulator discharging no more than 700 g per sq cm (10 lb per sq inch) should be used.

7, Sprayers fitted with a flood jet of the fan type should be used to obtain a wider sweep of spray resulting in larger area coverage in a single operation.

8. A sticker and spreader should be used (1:500 dilution) particularly with postemergence herbicide like 2,4-D and dalapon to improve spray spread and retention on waxy leaf surfaces in high rainfall areas.

9. All spraying workers are required to use protective vests, masks, and gloves while applying herbicides.

10. To enhance the life of spraying equipments they should be cleaned with Teepol or soap water.

11. Empty herbicide containers should not be misused by storing edible or drinking materials. Instead, they should be destroyed or buried in the soil.

D. Quality Testing of Herbicides

Quality testing programme was undertaken to safeguard the tea industry from using adulterated and substandarad herbicide products. The member estates send suspected substandard herbicide samples either before or after buying a consignment to ensure quality. These samples are tested in the field and/or laboratory along with the standard herbicide samples. Field tests include bioassy on specific weed species. In the laboratory, tests are conducted on colour, odour, specific gravity, solubility (in

water, organic solvents etc.), colorimetry, chromatography, determination of percent active ingredient, etc.

This data will be used to determine the quality of a particular herbicide sample and advise the estate accordingly.

E. Training and Advisory Services in Weed Control

Training programme : Tocklai offered a lecture-cum-demonstration course on the use of agricultural chemicals for the benefit of management personnel of the tea industry between 1968 and 1972. This course was reorganized and enlarged in 1976 into a field management training course. Under these training programmes, organized lectures and demonstrations are given on principles and practices of weed control. In another programme, Vegetative Propagation course, the trainees are given field training on weed control measures in the nurseries.

Degree Programme : Tocklai provideds facilities for weed research by M. Sc. and Ph. D. students of the neighbouring Assam Agricultural University. The institute also offers Junior Research Fellowships of C. S. I. R. to candidates interested in taking up Ph. D. programme in agronomy and weed science.

Advisory service to tea estates : Advisory service in weed control, besides in other areas, is provided by advisory officers located in various parts of NE India through periodical visits to estates. Meetings arranged for planters of a region is attended by scientists and advisory officers to exchange information on various problems. The Weed Scientist also visits estates, when requested, to study weed problems and recommended proper weed control measures. Advisory officers also conduct various advisory trails including those in weed control to determine the suitability of weed control practices in his region.

Current Developments in Weed Research

The cost of weed control in tea in NE India (Rs. 9 to 10 crores) far exceeds that of insect and disease control and ranks next only to the cost of fertilizers and manures (Rs 20 crores). Hence, chemical weed control has become a permanent and essential cultural practice in tea. In the next few years, about 95% of the area under tea in the region is expected to be under chemical weed control. This will naturally be followed by a multiplicity of complex problems particularly with regard to herbicide residues, herbicide toxicity, changes in weed spectrum, interaction of herbicides with other chemicals, etc. This required immediate strengthening of weed research activities by establishing a full-fledged Weed Research Unit in the Department of Agronomy. This Unit came into existence in October 1975 with the appointment of a Weed Agronomist and supporting staff. The primary objective of this Unit is to provide tea industry with adequate, effective, safer, and economical weed control recommendations. Research is now initiated or strengthened in the following areas of work.

1. Weed competition and economics of weed control in tea.
2. Selection of herbicides and herbicide combinations,
3. Increasing the efficacy and safety of herbicides.
4. Biology, chemical control, and allelopathic interaction of weed species,
5. Metabolism and residues of herbicides in tea and soil.
6. Integrated chemical weed control in conjunction with agronomic practices.
7. Interaction of herbicides with other pesticides.
8. Effect of continuous use of herbicides on changes in weed spectrum, and monitoring of herbicide usage by tea industry.

Adequate field facilities are available to conduct research on these projects. A well-equipped weed research loboratory is being established to serve the needs of research on absorption, translocation mode of action, metabolism, and residues of herbicides.

A radiotracer laboratory is also being established and this will amply strengten weed research programme.

Conclusion

The aforesaid discussion clearly illustrates the extent of contribution Tocklai has made to weed research in India in general, and to combat weed problems in tea of northeast India in particular. The past research as had a tremendous impact on the tea industry and its economy to enable chemical weed control become a permanent practice in tea cultivation. The present efforts are directed to make this practice more economical, effective, and safer with an integrated approach. A successful weed control practice will neecssitate changes in the existing agronomic, insect and disease control, and soil management practices. But no task is greater than the one already completed.

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Table 1. Area and production of tea in India and Northeast (NE) India.

Item	1974-75			1975-76[a]		
	India	NE India	%	India	NE India	%
1. Area under tea (thousand ha)	362	288	79.6	364	290	79.7
2. Production made tea (million kg)	490	390	79.6	489	387	79.1
3. Value of made tea produced (million Rupees)	550	440	80.0	575	460	80.0
4. Value of made tea exported (million Rupees)	220	176	80.0	240	192	80.0
5. Area under tea receiving Tocklai's advice (%)	—	80	—	—	83	—
6. Expected annual growth rate in tea production (%)	3	3	—	3	3	—

[a]Values for 1975-76 were based on estimations as the official figures are not available.

Table 2. Effect of urea on 2, 4-D activity on broadleaf weeds.

2, 4-D (kg/ha)	Urea (Kg/ha)	% control of broadleaf weeds at				
		3 days	1 week	3 weeks	4 weeks	6 weeks
0.5	0	5	50	70	70	35
0.5	0.5	5	85	100	100	90
1.0	0	10	85	100	100	90
1.0	0.5	10	90	100	100	95

Table 3. Effect of Triton AE on the activity of herbicides under simulated rainfall conditions.

Herbicide (kg/ha)	Triton AE (0.06%)	% control Rainfall (1.25 cm) after herbicide spraying					
		30 min	1 hr	2 hr	3 hr	4 hr	8 hr
2, 4-D							
0.2	—	5	5	10	10	15	—
0.2	+	15	15	20	20	25	—
0.4	—	5	5	20	20	20	—
0.4	+	15	20	25	30	30	—
0.8	—	40	40	40	45	45	—
0.8	+	45	60	60	70	75	—
Dalapon							
1.5	—	—	10	15	—	20	25
1.5	+	—	15	20	—	25	25
3.0	—	—	25	30	—	35	45
3.0	+	—	30	35	—	50	55
Paraquat							
0.3	—	—	65	65	—	—	—
0.3	+	—	65	65	—	—	—
0.6	—	—	80	80	—	—	—
0.6	+	—	80	80	—	—	—

[a]Weed control was rated four weeks, six weeks, and one week after application of 2, 4-D (sodium salt). dalapon, and paraquat respectively. Test species : *Borreria hispida* was used in case of 2, 4-D and *Imperata cylindrica* in case of dalapon and paraquat.

Table 4. Germination of various types of propagating material of *Oxalis acetocella*.

Propagating material	% Germination Weeks after planting					
	5	7	9	10	12	16
Mature bulbils	4	56	78	82	86	88
Semimature bulbils	2	4	6	6	6	6
Immature bulbils	0	0	2	4	6	8
Buds	0	0	4	8	10	14

Table 5. Rate of formation of bulbils or buds from plants of mature bulbils.

Type of bulbils or buds formed	No. of bulbils or buds formed/plant Weeks afer planting						
	12	14	16	18	20	22	24
Mature bulbils	0	0	20	120	119	115	90
Semimature bulbils	14	23	23	3	2	2	0
Immature bulbils	44	42	44	0	0	0	0
Buds	10	7	8	4	3	4	0

Table 6. Changes in weed spectrum in different weed control Treatments.

Treatment and No. of times applied per year	Dominant weed species 1972 (April)	1975 (February)	1976 (March)	Weed cotrol rating (March, 1976)
Cheeling (control) Four times	*Borreria hispida* *Ageratum conyzoides* *Erecthites valerianaefolia*	*Paspalum conjugatum* *Drymaria cordata* *A. conyzoides*	*P. Conjugatum* (30%)[a] *A. conyzoides* (25%) *D. cordata* (20%)	7.0[b]
Paraquat (0.6 kg/ha) Three applications	*A. conyzoides* *B. hispida* *P. conjugatum*	*A. conyzoides* *P. conjugatum* *B. hispida*	*A. conyzoides* (40%) *Polygonum chinense* (20%) *E. valerianaefolia* (15%)	5.0
2, 4—D+dalapon (0.8+3.0 kg/ha Two applications	*A. conyzoides* *B. hispida* *P. conjugatum*	*A. conyzoides* *Pteridium aquilinum* (Fern) *P. conjugatum*	*P. aquilinum* (45%) *D. cordata* (20%) *P. conjugatum* (15%)	4.0
Paraquat+2,4—D dalapon (0.6+0.8+3.0 kg/ha) One application	*A. conyzoides* *B. hispida* *P. conjugatum*	*A. conyzoides* *B. hispida* *P. conjugatum*	*A. conyzoides* (45%) *P. aquilinum* (15%) *E. valerianaefolia* (10%)	7.0
Mulch+2, 4—D+ dalapon (0.8+3.0 kg/ha) One application	*P. conjugatum* *A. conyzoides* *Saccharum spontaneum*	*A. conyzoides* *Mikaniya scandens* *P. aquilinum*	*P. aquilinum* (30%) *A. conyzoides* (25%) *D. cordata* (15%)	6.0
Mulch+paraquat+ 2,4—D+dalapon (0.6+0.8+3.0 kg/ha One application	*A. conyzoides* *B. hispida* *P. conjugatum*	*Commelina benghalensis* *B. hispida* *M. scandens*	*C. benghalensis* (30%) *A. conyzoides* (25%) *P. aquilinum* (20%)	7.5
Mulch+paraquat (0.6 kg/ha) One application	*B. hispida* *A. conyzoides* *S. spontaneum*	*A. conyzoides* *M. scandens* *P. aquilinum*	*M. scondens* (30%) *A. conyzoides* (25%) *E. valerianafolia* (15%)	7·5

[a]The percent coverage by each weed species. [b]Weed control rating (0-10) in the treatments. In mulching treatments, green *Guatemala tripsacum* Laxum. grass was applied at 30 tons per hectare.

ECONOMIC ASPECTS OF WEED CONTROL IN SEMI-ARID TROPICAL AREAS OF INDIA[1]

HANS P. BINSWANGER & S. V. R. SHETTY[2]

The economical control of weeds is one of the oldest and most frustrating problems of agricultural production. In developed countries it has been made easier by enormous amounts of power available to farmers and by the invention of chemicals for weed control which, at the high wage rates of the developed countries, have almost totally replaced handweeding.

In the developing countries of Asia, capital is much more scarce than in developed countries and wage rates are lower. Farmers frequently do not even have sufficient funds to make effective use of improved seeds and fertilizers. Frequently one observes poor crops on weed-infested fields. As a consequence it is often assumed that farmers in areas like SAT India have either a poor understanding of the damage caused by weeds , or understand the damage but do not possess the draught power and labor resources to effectively take care of weeds by hadweeding and interculture.

In this paper, we firstly use date from ICRISAT's Village Level Studies to document the extent and timeliness of weed-control activities by farmer in three distinct agro-climatic zones of SAT India. We want to see to what extent the assumption about farmers' understanding of the weed problem or of their constraints are correct. Secondly, we present budgets for alternative weed-control plans with and without herbicides to assess the potential for use of herbicides in these areas at the present time and with the existing resource position. We finally explore the implications for weed research.

The analysis in this paper raises a number of questions which require further analysis. It is planned to attempt to answer these using 1976-77 data as soon as they become available. Also, certain questions will require some further field observations.

Current Weed-Control Practices

The results of this paper are based on data from ICRISAT's Village-Level Studies which started in May 1975 in six villages in the Akola, Mahbubnagar, and

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Sholapur dis icts. A stratified random sample of 40 households, of which 30 are cultivators c erating more then ane half acre of land was studied in each village. The data rel · mainly to the cropping yeaa 1975/76, except for the frequency distribution of wee ng and interculture in the Mahbubnagar villages, which are based on 1976/77 dat.. observations. Also in the Sholapur villages tha data are available for bolh 1975/76 and 1976/77. The households in the surveys were interviewed every 3 weeks and the cultivation data gathered plotwise. Each field operation was recorded with its date. This allows the investigation of interval lengths between operations.

Agro-climatologically the three districts are vastly different (Table 1). Akola district in Maharashtra is an asured-rainfall area with medium-deep black soils and kharif cropping. The chosen villages Kanzara and Kinkheda have very little (3%) irrigated land. The main cash crop is cotton (sometimes mixed with sorghum and pigeonpea) and sorghum is the main food crop. Groundnuts are also grown. Some of the farmers have taken to hybrid cotton and hybrid sorghum, and are using fertilizers and insecticides. Herbicides are not used in this area, nor in the other two areas of the investigation

In general, cotton fields in Akola are quite weed-free when cotton is grown as a sole crop. On the better soils, cotton is grown by square planting and this facilitates two-way intercultivation using animals. The farmers consider five to six intercultivations along with hand picking of weeds and stubbles as adequate. In the cese of groundnuts, four intercultivations and one handwceding is the practice regarded as desirable by many farmers (depending upon the bullock and labor resources available). In general, cotton is sown earlier than other crops and first preference is given to cotton during weeding operations. Wherever hybrid H4 cotton is sown, weed management is excellent. However, this is not always so with hybrid sorghums.

The intercultivating equipment is the "blade harrow" or "Guntaka" which seems to be more efficient and does a better job than the "Guntaka" observed in Mahbubnagar district; the blade being sharper and stronger. Handweeding is done squating on the ground and using a small hoe. Hoes with long handles are not seen in the three areas.

In the farms where timely weed-control was not practiced, the major weed species found were *Cynodon*, *Cyperus*, *Digitaria*, *Echinochloa*, *Erograstis*, *Amaranthus*, *Celosia*, *Desmodium*, *Corchorus*, *Crotalaria and Ipomoea*. *Cynodon* and *Cyperus* are the two most serious weeds of this medium black soil region. Even in some cultivated fields, large patches were left uncultivated in the middle due to the *Cynodon* problem. In many of the hybrid sorghum plots, weed infestation was heavier than in cotton and the weedy situation were quite visible due to the short stature of hybrids.

Farmers are aware of the importance of post-harvest operations in managing weeds. However, due to many constraints and nonavailability of resources, only few farmers undertake post-harvest operations within the first month after harvest. This may allow weed to mature seeds.

The Mahbubnagar area receives about 650 mm of rainfall on shallow to medium red soils and soil moisture is much less assured. The two villages Aurepalle and Dokur are about 60 km apart and have quite different cropping patterns Aurepalle has 12 percent of its cropped area irrigated while Dokur has a much larger area of 32 percent. In both villages irrigation is mostly used for paddy. The major rainfed cereal is sorghum and it is generally mixed pearl millet, pigeonpea, and upto four other crops like mungbean, mesta, and cucumber. Sorghum as sole crop is grown mostly with supplementary irrigation. In Aurepalle, the major cash crop is castor. In Dokur groundnuts are grown both in the kharif and rabi season, with irrigation from wells used during the rabi.

A notable feature of intercultivation in the Mahbubnagar area is the different types of equipment farmers use for the purpose. Whereas the farmers of Aurepalle village use a single-bladed "guntaka," in Dokur the common equipment is a primitive type of "danthe," wherein two to three unsharpened iron blades are attached to two to three big wooden hoes branched at the end. Two or three persons are required for the operation to guide the hoes as well as the bullocks. However, two to three rows of crops can be intercultivated simultaneously. This type of equipment does not always perform satisfactorily and patches of weeds may still be left even after passing this equipment a number of times, since the blades are not sharp enough to lift the layer of the soil. With either "guntaka" or "danthe," farmers were not able to remove *Cyperus* and *Cynodon*, the serious weeds of the region.

Handweeding of unirrigated crops is not done in Aurepalle, but is considered desirable in Dokur. In Dokur, farmers have a definite sequence of weeding crops. Groundnuts come first, followed by irrigated sorghum (the food crop mixture) and finally other minor crops sown on very poor lands. Handweeding of unirrigated kharif crops does not conflict with the main thrust of paddy cultivation since the tank irrigated paddy is only transplanted in September or later when the tank is full. Farmers who also have kharif paddy under wells will however give first preference to weeding these paddy plots. This is quite a rational sequence, given the payoffs from handweeding of these crops.

In Aurepalle, where unirrigated crops are not handweeded, preference for interculture is given to castor before the food-crop mixture. Usually intercultivated castor fields look clean without many weeds, whereas in other crops, as well as mixed-cropping systems, weeds within the rows still remain even after intercultivation. To remove as many weeds within the rows as possible, farmers will first "shave" the castor plants from the left and then from the right side, displacing them sideways each time, so that no weeds remain within the row. The deep roots of castor permit this and farmers claim that the plants do not suffer. Generally less weed infestation observed in those fields planted to castor in the previous year. This may be caused by the frequent intercultivation (6 to 7 times in a season) of the castor crop resulting reduced weed-seed production and disperseal at the end of the crop season.

In Dokur village of Mahbubnagar district the paddy crop is only handweeded and not intercultured. Handweeding is done without the use of implements by women in a bending position in standing water.

Sholapur District is a rabi-crop area with deep to medium-deep black soils. Rainfall is lower than in Akola, and rains in the first half of the monsoon are uncertain. 1975/76 was a very wet year and the planting of rabi crops was delayed until mid November. Rabi sorghum suffered from the cool weather and developed sugary leaf disease. The yields were so poor that the area was declared a "scarcity-affected" zone and recovery of loans and land revenue was postponed.

On the other hand 1976/77 was a very low rainfall year, but the rains were sufficiently well distributed to result in fairly good crop yields except for kharif groundnuts and rabi safflower which failed. Due to drought condition at sowing time of the rabi crops most farmers decided not to grow sufflower.

Weeds are a severe problem in the kharif crops of Sholapur. Kharif crops consists mainly of groundnuts and bajra mixtures in the lighter soils[3]. In the rabi season, the weed problem is less severe because most plots are harrowed several times during the kharif season and crop growth as well as weed growth is slower due to lower temparatures. Thus most rabi plots look quite weed free.

Data on the handweedings and interculture operations in the sample villages is presented in Table 2. Panel A gives the percentage of plots handweeded never, once, twice, etc[4]. Panel B groups those plots handweeded at least once into those with delays between sowing and handweeding of less than 15 days, 16 to 25 days, etc., and gives the proportion falling in each class. Panel C shows the proportions of plots intercultured a given number of times, and Panel D analyzes the delays between the sowing and the first interculture.

In the Akola village, between 15 and 30 percent of the fields in all major crops are never handweeded. A little less than half the fields are handweeded once. In cotton, 45 percent of the plots are handweeded two or more times. The delays in handweeding can be substantial. More than 40 percent of the crops are handweeded for the first time later than 36 days after sowing.

Less than 20 percent of the plots in the Akola village are never intercultured and for mixed sorghum and sole sorghum the corresponding percentages are only 8 and 3, respeetively. For both these crops, as well as for cotton (sole and mixed), more than 80 percent of the plots receive two or more interculture operations. In cotton almost 60 percent of the plots are intercultured more than four times. More remarkable is that in the food-crop mixtures and in cotton and groundnuts, more than 90 percent of the crops are intercultured for the first time within the first 25 days after sowing. This is a remarkably good degree of weed-control and implies that the delays in handweeding are of less consequence, especially in many of the cotton fields which are intercultered in a crosswise manner. The overall picture is one of thorough and timely weed control, there were a few exceptions.

3. The difficulty of weed control in the kharif season on the deep black soils may be one reason for widespread practice of kharif fallow in these areas.
4. The analysis is presented here in terms of proportion of plots rather than proportion of total area planted to a given crop or mixture of crops. In Akola the analysis was also done in terms of area, with practically identical results. This implies that there is no strong association between farm size and weed control behaviour, which a perusal of the raw data continued.

In the Mahbubnagar Village of Aurepalle unirrigated crops are practically never handweeded. Six percent of the food-crop mixtures are never intercultured, whereas 27 percent of the castor fields go without interculture. On the other hand, almost 60 pecent of the castor fields receive three or more intercultures, which are very thorough.[5] In both crops delays are longer with most plots receiving their first interculture between 26 to 35 days after sowing. The question arises whether the less intensive weed control in Aurepalle compared to Akola is sufficient for effective weed cantrol. Table shows that it cannot be due to lack of bullock power or family labour, as Aurepalle has substantially higher numbers per 100 ha than the Akola villages. The proportion of landless households is lower in Aurepalle but not by very much. While total availability of labour is not less than in Akola, the labourers may have better opportunities during the weeding season in neighbouring villages which have much more paddy cultivation than Aurepalle itself.[6]

On the other hand, payoffs to handweeding are probably lower in Aurepalle than in Akola. partly because of the special feature of castor interculture and partly because growth of weeds as well as of crops is less vigorous on the light sandy soils of Aurepalle than on the medium-deep black soils of Akola. Growth of weeds is clearly slower in Aurepalle which partly explains the longer delays. Furthermore, visual inspection of the intecultured castor fields showed that weed control by inteculture alone achieved fairly clean fields. It is thus possible that the main reason for the lesser degree of weed control activity in Aurepalle is the smaller payoff from it, rather than unawareness of losses due to weeds.

In Dokur, farmers also rely more heavily on interculture than on handweeding for the unirrigated crops. Of the sorghum and groundnut plots, 33 and9%, respectively do not get any interculture. Of these which are intercultured, most are initiated before the 35th day after sowing. Handweeding is done in more than 6 percent of the plots, but is mostly delayed till after the 35th day. In paddy practically all plots are handweeded once and only 5 percent are handweeded twice. Around 70 percent of the plots are handweeded before 35 days have elapsed, which is a reasonable degree of timeliness. This confirms that weed-control activity is heavily concentrated in paddy-the highest value crop--while unirrigated crops receive only second priority.

In Sholapur, the agricultural resource base is much poorer than in Akola. Furthermore, the 3 years preceding 1975/76 were extreme drought years and the villages had lost up to two thirds of their cattle. During the first year of investigation, the capital stock of the farmers was depleted so that many of them could not even buy groundnut seed to grow this otherwise prevalent cash crop.

Table 2 gives details on handweeding and interculture for three rabi and four kharif crops in Sholapur for 1975/76 and 1976/77. In both years rabi crops were practically never handweeded. In the first year 23 percent of sole jowar plots and 49 percent of the mixed jowar plots were never intercultured as well whereas in the second year the frequency of zero interculture dropped to 4 and 18 percent, respectively. The neglect of interculture in the first year in the jowar fields is probably

5. See the large amount of bullock-pair hours used per interculture in castor (Appendix Table 1)

6. We must be able to show that the female laborers are indeed employed elsewhere and not simply unemployed to show that there is a real labor constraint. Analysis is under way to test this hypothesis.

because of the near crop failure during that year; by the time of interculture sorghum was already severely attacked by sugary leaf disease and stunted in growth which led many farmers to stop investing further in the crop.

Note further that in both years rabi sorghum fields were usually intercultured with a very large delay. Between 60 to 77 percent of the plots intercultured were with delay of more than 46 days from sowing. We will discuss the reasons for this below.

In rabi chickpea the situation is similar to sorghum except that an even higher proportion of the fields were never intercultured at all both years.

On a visit in January 1977 we questioned farmers about the reasons for the delays in interculture of the rabi crops. They generally explained that there are few weed problems in the rabi season because of dry conditions and frequent harrowing of the kharif fallowed fields. Also low temperatures generally delay plant growth. Visual inspection of the fields confirmed the almost total lack of weeds, in the rabi season. Interculture is usually delayed up to the flowering stage and then performed by a small hoe which is pulled by one man aud guided by another one. The main purpose of this operation is not weed-control but closing of the gaps in the deep black soils to prevent moisture losses, and the pushing of the soils towards the plants to give them better support.

In the kharif crops we have data on pearl millet based mixtures, which can also include pigeonpeas as a component. We also have data for pigeonpea as a sole crop or in mixtures which do not include pearl millet. Both of these crop mixtures are grown on the light soils. There is little handweeding in the kharif crops and in 1975/76 half the pearl millet plots did not receive interculture, whereas in 1976/77 the interculture of these crops was much more frequent. Also the delays of inteculture were shorter than for the rabi crops. The increase in frequency of interculture may have several reasons. 1975/76 was wet and up to the weeding stage rainfall was very frequent, which might have made timely interculture difficult. Furthermore in 1976/77 the kharif crops looked remarkably good up to the flowering stage thus prompting farmers to invest more in weed-control. However, the crops were subject to severe drought in the later part of the season and groundnuts failed completely. Finally in groundnuts and chillies weed-control is mainly done by hand-weeding and there seem to be substantial delays in more than half the cases. Overall, farmers in Sholapur seem to allocate their resources to weed-control in a fairly rational manner. They put in more effort in the kharif season crops than rabi crops because weed problems are more; and where crops stands are good, more effort is spent than when crops appear to befailing. Nevertheless visual inspection confirmed that weed-control in the kharif season crops is not sufficient and with exception of the high valued groundnut and chillies crops, handweeding is practically absent. Family labour availability is the same in Sholapur than in Akola. (Table 1). The lack of handweeding is thus not explained by low labor availability. On the other hand, Sholapur had almost 40 percent fewer bullocks than Akola per 100 ha. The insufficient and delayed interculture in the kharif season is therefore possibly explained by bullock power constraints.

Overall, weed-control activity seems to be closely related to (1) the basic fertility of the area, (2) to the value of the crop grown on a field and (3) the crop condition at the weeding and interculture stages. In the assured rainfall area of Akola, weed-control activity can only be described as good, while in the poorer Mahbubnagar and Sholapur areas, much less activity takes place and certain crops may be neglected.

Data on the sex allocation of handweeding and interculture is presented in Table 3. Handweeding is almost exclusively done by females while interculture is done primarily by males (family and permanent 'labor' force). Not presented is the percentage of hours performed by children (of less than 14 years) which was frequently zero or very low and reached a maximum of 5 percent of total hours only in the case of the food mixture in Dokur. Thus, contrary to expectations, primary school age children do not participate substantially in handweeding. They may, however, be called on more heavily during the harvesting season.

Quite impressive is the fact that generally more than two thirds of all handweeding hours were performed by *hired* females and that in Akola it was more than 80 percent expect for chillies where only about 100 hours were involved. The percentage of hired women hours was lower in Sholapur than in the other villages, In table I, we can also see that the percentage of landless households is lower in Sholapur than in Akola, thus forcing households to use more of their own labor. A look at the raw data by farm size also indicated that even small and medium holdings frequently hired female labor for handweeding. It is therefore clear that any reductions in handweeding hours made possible by herbicides would primarily reduce work and income opportunities of the most disadvantaged labor group in the Indian economy, namely female agricultural laborers. We examine this issue more thoroughly in the ensuing section.

Cost Analysis of Alternative Weed-Control Methods

In Table 4 we have drawn up three plans for weed-control for eight crops or crop combinations. Plan 1 is based entirely on herbicides; plan 2 combines herbicides, interculture, and handweeding in a more realistic manner and plan 3 uses no herbicides. We have tried to draw up the plans in such a way that they give an equivalent quality of weed-control within each crop. Any possible yield effect of herbicides is neglected for the moment. We do not endorse the use of the chemicals in the plans, but consider them as indicative. When a choice between equivalent herbicides was possible, we choose the cheaper ones. The prices used in the cost analyses are approximate market prices prevailing in January, 1977.

Human and bullock hours required for handweeding and interculture are based on the hours actually used in the study villages for these operations. The Akola data were used for cotton, groundnuts, and cereals, and it was assumed that chickpea weeding required the same amount of labor as cereals. Aurepalle data were used for castor and Dokur data for paddy. Labour bullock coefficients are given in Appendix Table.I[7]

7. In Akola cereal crops, the per-hectare female handweeding labor requirement is 7.28 8-hour days. On ICRISAT watersheds in 1976, we used 8.6 female days per ha for the first handweeding on ridges and furrows in maize, which is not much different. In cereal crops in Akola 6.84 bullock-pair hours were required for interculture per ha while in ICRISAT we required 7.12 bullock pair hours for the first interculture.

For each plan four alternative costs have been worked out, each with a different valuation of labor costs. *Financial costs* are costs faced by farmers who hire labor and have to commit the full wage rate as costs. The *opportunity cost* is faced by farmers using only family labour for interculture and weeding operations and who value their own effort at only about 70 percent of the current wage rate.[8]

Finally, to study the sensitivity of rankings of the plans, wage rates and opportunity costs were increased by 50 percent and costs calculated again. This is a large rise in real wage rates relative to recent historical experience. Most evidence suggests that in SAT states of India (and in most of tropical Asia) real rural wage rates have failed to rise rapidly and may have fallen in some instances during the past 10 to 20 years.[9] The failure of real rural wage rates to rise is one of the most striking features of India's development experience. For example, in West Bengal and Bihar, real rural wages have not risen in the past 100 years.[10] Given the current demographic projections, rises in real rural wage rates of more than 50 percent are unlikely within the next 10 to 15 years.[11]

The cost data are presented in Table 5. It is immediately clear that in none of the crops considered is it economical to use only herbicides. These plans are at least two and one-half times more expensive than plans without herbicides (Financial Cost) and in the case of chillies the cost ratio rises to 8. Even if wage rates were to rise by 50 percent the pure herbicide plans are still about twice as expensive as the no herbicide plans in the case of pearl millet and cotton. From this we can conclude that, on the basis of cost considerations alone, pure herbicide plans are out of the question for a long time to come.

The mixed plans, involving selective use of herbicides, are also not attractive (at present wage rates) for the rainfed crops under the present system of cultivation. In the case of paddy, the mixed plan, which substitutes for one handweeding a pre-emergence herbicide is Rs. 25 cheaper (Financial cost) than the pure handweeding

8. This is based on the analysis of Subrahmanyam and Ryan [4]. The value of labor on ones own farm is the value of earnings foregone by not working in the hired labor market. The expected wage rate in the hired labor market is the actual wage rate times the probability of finding a job on any given day. In Kanzara this probability was around 70 percent for both males and females during the weeding season of 1975/76. It may be different in the other the areas; therefore the sensitivity analysis on wage rates is quite important.

9. If we take 1956/57 as a base year (=100), then the index of real wage rates for male agricultural field labourers in 1971/72 for states with substantial semi-arid tropical areas where as follows: Andhra Pradesh, 119; Gujarat, 125; Karnataka, 92; Madhya Pradesh, 102; Maharashtra, 99; Tamilnadu, 113. Source: Jose [3].

10. See Bhattacharya and Malakar [1]. Daily male wage rates per day have fluctuated in the range of 2 to 4 kg of rice and have been less than 3 kg since the early 1950s.

11. The most conservative population projections, according to Cassen & Dyson [2], put the all India population in year 2000 at slightly less than 1000 million. Most othet projectiont assvme values higher than 1000 million people. Further more, Census data over the pcss 50 years show that the proportion of female agricultural laborers as percent of female population is rising.

plan. Even a farmer using his own family labor might find the use of one herbicide application to be about Rs. 10 cheaper (opportunity cost) than the use of two hand-weedings. In rainfed crops, however, even a rise of the wage rates by 50 percent would not make a single mixed plan attractive. In pearl millet the selective herbicide plant is still 25 percent more expensive than the no herbicide plan, and in all other plants the cost difference is much larger. With pearl millet where the cost structure is most favourable for herbicides-doubling of wage rates from the initial level would raise the cost of the selective herbicide plants to about Rs. 80 while the cost of the no.herbicide plan rises to Rs. 76. Therefore even a doubling of the real rural wage rates is not sufficient to make a single selective herbicide plan for rainfed crops financially attractive on the basis of cost considerations. For the small family farmer, whose opportunity wage rate is less than market costs, the situation is even less in favor of selective herbicide plans in rainfed crops.

If we consider mixed cropping rather than single cropping of pearl millet and sorghum (where herbicides might become attractive most rapidly), the costs of both herbicide plans rises since we are forced to use more costly and more selective herbicides. Mixed cropping will thus further reduce the comparative advantage of herbicides.

CONCLUSION

We have shown that weed-control activity is clearly related to the quality of the resource base. The better the growth environment for the plants and weeds, the more and better weed control is undertaken by farmers. While, in Sholapur and Mahbubnagar, present weedcontrol practices may be deficient in some crops, they are clearly adequate in the case of Akola. Even in Akola some fields go without weed-control, but they are mostly the fields with poor quality land.

Farmers weed-control activity seem to be guided by quite rational consideration. They will allocate more effort to crops on betterlands and to crops with high values per unit area. They will also reduce the weed-control effort considerably if, at the weed-control stage, crops appear to be failing. We can thus be optimistic that farmers will respond with increased weed-control effort to improvements in their farming system via better varieties and/or improved soil managements techniques.

We have also shown that for dry crops herbicide use cannot at present be advocated on the basis of cost considerations in the semi-arid areas of India. Justification for use of herbicides must come from the possible yield effect of better timeliness in weed-control achievable by herbicides or from the effect of keeping the fields free of weeds during the first 2 or 3 weeks of plant growth when one connot yet go in with handweeding or interculture. Only experiments which compare totally weed-free plots with plots which are kept weed free only from the 15th or 20th day after sowing can tell us whether such yields effects of early weed control exist. Such experiments are now under way at ICRISAT.

Finally it is clear that interculture is done primarily by males while handweeding is primarily be done by *hired* female labor. Labor saving due to herbicides would therefore decrease income opportunities for the most disadvantaged labor groups in India, landless female laborers.

Which then are the agronomic weed-research activities most likely to result in production practices which will increase agricultural productivity in SAT India? We still do not have sufficient knowledge about the real payoff of additional weed-control by farmers under existing farming practices for areas like Mahbubnagar or Sholapur, we still must confirm experimentally that farmers weed-control activity is low because of low payoff to weed-control under existing varieties and fertilizer use levels rather than because of resource constraints such as bullock power, or a desire to use weeds as fodder. If the problem is capital scarcity, herbicides may not provide a solution. We connot expect farmers to buy herbicides in a situation where their capital resources are so severely constrained that they cannot even invest in better seeds or fertilizers. To answer this question will require a limited amount of operational research in farmers' fields and some surveys of attitudes towards the weeding problem.

Within the existing farming system, it will also make sense to explore more thoroughly the use of herbicides for treating patches of weeds which are difficult to control mechanically-such as perennial grasses and sedges.

On the whole, however' agronomic weed control research will be most productive if it is focussed on and associated with research efforts aimed at achieving substantial changes in farming systems via new varieties or improvements in soil and water management. As an example, growing crops on deep black soils during the kharif season may be one way to substantially increase the agricultural productivity of the rabi-growing tracts. There may be areas where a high probability of prolonged wet spells after sowing time may make it impossible to control weeds by handweeding or interculture on medium to deep black soils during the kharif season. In such areas herbicide use may be required for kharif cropping. Further agroclimatic analysis of the probability of wet spells could help in delineating those agro-climatic zones where the probability of wet spells after sowing time is sufficiently high to warrant the use of herbicides. Another example is the problem of weed and stubble control when short-duration and/or short-statured varieties allow double cropping in medium to deep soil areas where single cropping prevailed before. Weed-mangement problems may become more severe and the time between harvesting of the first crop and sowing of the second crop may be so short as to require the use of minimum tillage methods and herbicides. Finding and solving such specific problems will require close association of the weed agronomist with plant breeding, cropping-system research and economics.

Finally we would like to stress the location specificity of these findings. They are not valid for environments where, as in many parts of Africa, substantial scope exists for expanding land area cultivated per worker and where wage rates are much higher. The economics of weed control in such areas may be more favourable for herbicides and the findings of this paper are specific to the economic environments studied.

ACKNOWLEDGMENTS

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Table 1. Charcteristics of the sample households and Study areas

District	Akola	Mahbubnagar		Sholapur
Village	Kanzara/Kinkheda	Aurepalle	Dokur	Kalman/Shirapur
Average Farm size (Net cultivated area in ha)	6.0	4.4	2.6	6.25
Soil type	Medium black kharif crop area	Medium/ shallow red		Deep to medium black rabi crop areas
Average rainfall (mm)	818	636	659	654
Total cropped area irrigable (%)	3	13	38	11
Bullocks per (no) 100 ha/of net cultivated area (sample farms)	26.5	42.2	47.9	17.4
Family workers (no) per 100 ha (sample farms)	70.6	109.4	152.8	71.2
Landless households (%) in population of village	36.2	27.5	13.10	23.9

Source : Village-Level Studies, ICRISAT.

Table-2 Probability distribution of weeding and weeding delays and of interculture and interculture delays.

Crops[a]	No. of plots observed	A Percentage of plots handweeded				B Percentage of delays to first handweeding[b]				C Percentage of plots intercultured						D Percentage of delays to first interculture[c]				
		Never	Once	Twice	Three or more	<15	16-25	26-35	>36 days	Never	Once	Twice	Thrice	Four	Five	<15	16-25	26-35	36-45	>46 days
AKOLA VILLAGES 1975/76																				
Sorghum Mixture (K)	65	31	48	17	4	20	16	22	42	8	2	18	20	29	23	58	37	5		
Sorghum (Sole (K)	29	17	48	28	7	8	33	17	42	3	7	45	28	14	3	36	46	14	4	
Cotton (Sole & mixed) (K)	110	15	40	24	21	8	19	22	51	14	3	8	16	23	36	45	47	8		
Groundnut (K)	16	19	44	12	25	23	8	23	46	19	13	19	25	13	13	61	31	8		
MAHABUBNAGAR (AUREPALLE) 1976/77																				
Sorghum Mixture (K)	34	94	3	3						6	17	35	24	9	9		13	62	9	16
Castor (K)	41	98	2							27	7	10	12	22	22		7	60	20	13
MAHABUBNAGR (DOKUR) 1976/77																				
Sorghum (Sole & mixed) (K)	9	33	67				17		83	33	22	45				33		50		17
Groundnut (sole & mixed) (K)	11	18	73	9			11		89	9	55	36				10		70	10	10
Paddy (K)	45	4	91	5		23	5	40	32	98	2									100

a K refers to kharif (monsoon) crop and R to rabi (Postmonsoon).
b As percent of the number of plots handweeded at least once.
c As percent of the number of plots intercultured at leat once.
Source : Village-Level Studies data from ICRISAT.

Table-2 (a) Probability distribution of weeding and weeding delays and of interculture and interculture delays.

Crops [a]	No. of plots observed	A Percentage of plots handweeded				B Percentage of delays to first handweeding [b]				C Percentage of plots intercultured						D Percentage of delays to first interculture [c]				
		Never	Once	Twice	Three or more	<15	16-25	26-35	>36 days	Never	Once	Twice	Thriec	Four	Five	<15	16-25	26-35	36-45	>46 days
SHOLAPUR VILLAGES 1975/76 & 1976/77																				
Sorghum mixtures (R)																				
1975/76	**39**	87	13					60	40	23	41	23	13				3	3	17	**77**
1976/77	**46**	100								4	74	22					9	14	11	**66**
Sorghum (Sole) (R)																				
1975/76	**160**	81	16	3			3	29	68	49	34	14	3			4	6	12	18	**60**
1976/77	**119**	94	6				43	29	28	18	64	17	1				11	14	11	**64**
Chickpea (R)																				
1975/76	**51**	96	4							63	35	2						16	16	**68**
1976/77	**12**	92	8			100				42	58					14				**86**
Pearl Millet (K) mixture																				
1975/76	**18**	83	17							50	44	6						56	11	**33**
1976/77	**35**	80	14	3	3		29		71	6	37	28	26	3			6	27	49	**18**
Pigeonpea mixtures (K)																				
1975/76	**78**	82	18					7	93	49	37	14					15	40	28	**17**
1976/77	**60**	81	17	2		18		27	55	15	59	18	5	3				16	39	**45**
Groundnut (K)																				
1975/76	**12**	33	50	8	8			37	63	100										
1976/77	**23**	18	65	13	4	5	21	16	58	79	17	4					20	20		**60**
Chillies (K)																				
1975/76	**12**	17		17	67		30	50	20	100										
1976/77	**5**	20	40		40			25	75	40	60								33	**67**

a K refers to Kharif (monsoon) crop and R to rabi crop (Postmonsoon).

b As percent of the number of plots handweeded atleast once.

c As percent of the number of plots intercultured at least once.

Source : Village-Level Studies data from ICRISAT.

Table-3. Distribution of weeding and interculture hours by sex

Crops[a]	Total Hand weeding Hours	%hours by females	%hours by hired females (of total)	Interculture	
				Total hours	%of hours by males
AKOLA (1975/76)					
Food Crop Mixture (K)	5886	98	93	4137	100
Sorghum (K)	5734	96	77	663	95
Cotton (K)	18774	98	91	7710	98
Groundnut (K)	1271	95	83	429	94
Chillies (K)	98	65	35	50	100
MAHABUBNAGAR (Aurepalle) 1976/77)					
Food Crop Mixture (K)	0	—	—	336	100
Castor (K)	72	89	44	1066	100
MAHABUBNAGAR (Dokur) (1976/77)					
Food Crop Mixture (K)	692	95	79	88	100
Jowar (K)	984	100	62	136	100
Groundnut (K)	1078	100	77	133	100
Paddy (K)	2574	99	94	0	—
SHOLAPUR (1975/76)					
Food Crop Mixture (R)	0	—	—	509	100
Sorghum (R)	2698	100	70	1826	94
Groundnut (K)	1128	95	63	0	—
Chillies (K)	1149	100	48	0	—

[a]R=rabi ; K=kharif

Table 4. Alternative weed control methods.

Methods	Cotton	Ground-nuts	Castor	Sorghum	Pearl Millet	Chickpea	Mixture Sorghum P. Millet Pigeonpea	Paddy
1. High Herbicide[a]								
Chemical, Pre	Diuron 1 kg/ha	Alachlor 2.5 kg/ha	—	Atrazine 1 kg/ha	Atrazine 0.5 kg/ha	Nitrofen 2 kg/ha	Prometryn 1 kg/ha	2,4-D Ester 1 kg/ha
Chemical, post	MSMA 2 kg/ha	Not available	Paraquat apply twice 1 kg/ha each time (Directed)	2,4-D Salt 1 kg/ha	2,4-D Salt 0.5 kg/ha	—	Paraquat 0.5 kg/ha (directed)	Propanil 3 kg/ha
2. Selective Herbicide[a]								
Chemical, pre	Diuron 0.5 kg/ha	Alachlor 1 kg/ha	—	Atrazine 0.5 kg/ha	Atrazine 0.4 kg/ha	Nitrofen 1 kg/ha	Prometryn 0.75 kg/ha	2,4-D Ester 0.5 kg/ha
Chemical, post	MSMA 1 kg/ha	—	Paraquat 0.5 kg/ha (Directed)	—	—	—	—	—
Intercultivation[b]	2	1	2	1	—	—	1	—
Handweedings[b]	1	1	—	1	1	1	1	1
3. No Herbicide								
Intercultivations	6	3	4	2	1	—	2	—
Handweedings[b]	4	2	—	2	2	2	2	2

[a] Herbicide rates are in kg of active ingradients/ha. These chemicals are selected only for our economic analysis and the authors do not necessarily endorse the use of these listed herbicides. Many other herbicides are also used on these crops.

[b] Rainfall and soil conditions permitting.

Table 5. Costs of alternative weeding Plans

	Cotton		Groundnut		Castor		Sorghum		Pearl Millet		Chickpea		Sorghum, Pearl Millet Pigeonpea		Paddy	
	Finan-cial Cost	Oppor-tunity Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost	Fin. Cost	Opp. Cost
High Herbicide[a]																
1. Chemical, pre	118		200				128		64		240		120		90	
2. Chemical, post	200		na		630		40		20		—		158		330	
3. Application Charge[b]	20		10		20		20		20		10		20		20	
Total :	338	338	210	210	650	650	188	188	104	104	250	250	298	298	440	440
Selective Herbicide																
1. Chemical, pre	59		80		—		64		51		120		90		45	
2. Chemical, post	100		—		158		—		—		—		—		—	
3. Application Charge	20		10		10		10		10		10		10		10	
4. Interculture[c]	28		12		86		16		—		—		16		—	
5. Hand weeding[c]	6		5		—		7		7		7		7		41	
Total :	213	205	107	103	254	234	97	91	68	66	137	135	123	117	96	86
Wages at 150%	226	216	114	109	269	246	106	49	74	71	143	140	132	125	119	104
No Herbicide																
1. Interculture[c]	82		35		173		31		16		—		31		—	
2. Weeding[c]	50		20		—		27		27		31		27		121	
Total :	132	102	55	42	173	134	58	45	43	33	31	21	58	45	121	94
Wages at 150%	174	134	73	56	197	152	79	61	60	46	40	31	79	61	184	142

a : Prices of herbicides are : 2, 4-D Ester, Rs. 40/kg, 2, 4-D Salt Rs. 40/kg, MSMA, Rs. 100/kg; Propanil, Rs. 110/kg; Diuron, Rs. 118/kg; Alachlor, Rs. 80/kg ; Paraquat, Rs. 315/kg ; Atrazine, Rs. 128/kg ; Prpmetryn, Rs. 120/kg ; and Nitrofen, Rs. 120/kg.

b : Application by knapsack sprayer, handoperated. A charge of Rs. 10 per application is assumed-Rs. 5 for labour and Rs. 5 for sprayer. For the 50% higher wage rate, the charge thus comes to Rs. 12.50.

c : For detailed cost calculations see Appendix Table-1.

Appendix Table-1. Cost of handweeding and interculture per hectare operation

	Hand weeding						Interculture				
	day/ ha.	Full Cost[a]	Opp. Cost	Bullock pair hours per ha	Full Bullock Cost[b]	Opp. cost of bullocks[b]	Labour days per ha. for interculture	Labour[c] Cost	Opp. cost of labour[c]	Total cost of interculture	Total Opp. cost of interculture
Cotton[d]	6.75	12.56	9.65	6.75	8.27	6.37	1.43	5.38	4.15	13.65	10.52
		(18.84)[g]	(14.48)					(8.07)	(6.23)	(16.34)	(12.60)
Groundnut[d]	5.4	10.04	7.72	5.4	6.53	5.03	1.35	5.08	3.92	11.61	8.95
		(15.06)	(11.58)					(7.62)	(5.88)	(14.15)	(10.91)
Castor[e]				25.5	31.28	24.16	3.19	11.99	9.25	43.24	33.41
								(17.99)	(13.88)	(49.27)	(38.04)
Cereal[f]	7.25	13.49	10.37	7.25	8.87	6.84	1.81	6.81	5.25	15.68	12.09
Crops		(20.24)	(15.56)					(10.22)	(7.88)	(19.09)	(14.72)
Paddy	33	61.38	47.19								
		(92.07)	(70.79)								

a Female wage rate of 1.86 and opp. cost of 1.43 per 8 hour day for Kanzara, August to Septembar 1975, Source : Subrahmanyam and Ryan [4]

b 1975/76 average bullock hire rate of 8.70 per day per pair per day of 7.1 hour without driver. Opp. cost assumes same probability of employment than for men.

c Male wage rate of Rs. 3.76 per 8-hour day, opp. cost of Rs. 2.90 for Kanzara village. Source : Subrahmanyam & Ryan [4]

d Based on 1975-76 data for Kanzara and Kinkheda, Akola district.

e Based on 1974-75 data for Aurepalle, Mahabubnagar district.

f Based on 1974-75 data for Dokur, Mahabubnagar district.

g Values in brackets are computed assuming a 50% rise in all wage rates.

SUGGESTIONS FOR INITIATING OR IMPROVING A WEED RESEARCH PROGRAM[1]

HERBERT H. FISHER[2]

ABSTRACT

Practical suggestions are offered concerning the planning and execution of field weed control research in developing nation. Helpful hints regarding equipment, facilities and materials are given. Other useful information, including lists of partinent publications and weed science societies are presented.

INTRODUCTION

Many developing countries can afford neither the luxury of full time weed specialists nor sophisticated equipment for developing research systems. A plant protection scientist commonly may only be able to devote 10-20 percent of his time toward weed control. In addition, he may not be highly paid and have to supplement his income with another job such as teaching and this may further dilute his efforts in weed control. It may also be difficult for him to obtain equipment and materials from his parent organization. Weed control literature may be in short supply and transportation may be inadequate. These are a few inconveniences that such a researcher could face.

Coupled with the above hindrances is the fact that weeds have recently become more serious proplems in many of these nations than they were previously. "Green Revolution" inputs have allowed significant increases in crop production, however "second generation" problems have arisen. In many cases the weeds have profited from the increased technology as much as, or more, than the crops.

Moreover, lack of adequately trained scientists and pressure to increase food production continue to reinforce the necessity of intensified efforts in weed control research. The job must be done-and more efficiently.

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1. This discussion will pertain primarily to government researchers in developing nations involved in beginning field weed control res arch or trengthening an on-going program.
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DISCUSSION

Very little is actually needed to begin a field weed research program. Assuming the government worker has a basic knowledge of weed control research techniques,[3] an adequate field research plan, a suitable experimental area and a minimum of field help, he may get started with an inexpensive, but dependable, backpack sprayer[4] capable of applying herbicide uniformly and accurately along with minimal equipment for weighing and measuring the herbicides. The sprayer will necessitate some spare parts and a few tools for in-field adjustments and repairs. A few implements and some equipment commonly found at agricultural experiment stations will be needed such as tapes for measuring plots, and hoes, etc. for hand weeding the checks.

The following is a partial list of additional suggestions one may want to consider in beginning or improving a field weed research program :

1. A. definite research plan : Firstly, it must be remembered that obtaining useful information for the farmer is the primary aim of agricultural research. Considering the magnitude of the weed problems and the scarcity of trained manpower and funds in the developing countries, research that is not channeled toward solving practical problems cannot be justified.

In many of the world's emerging nations information on weed losses is insufficient. Which weeds are causing the most crop losses ? In which crops ? when and for how long do these weeds cause losses ? Data must be generated quantifying these weed-caused crop losses. Government policy makers must be convinced of a need for weed control before allocating research funds.

How do weeds compete with the crops ? Why are some more competitive than others ? How do weeds spread ? Are certain weeds more problematic now than a few years ago ? Why ? Have certain cultural practices favored the increase of certain weeds ? How ? Have some weeds become resistant to certain herbicides ? Are there new weed species in the region ? More information concerning the weeds themselves would help answer these questions. Research can thus focus on weed biology (anatomy, morphology, physiology, etc.) and ecology.

Which crops need the most immediate attention as regards weed control ? Can weed problems be prevented ? It was noticed recently that *Rottboellia exaltata* was spreading rapidly in several areas of Colombia, South America, Centro International

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3. The "Field Manual for Weed Control Research", written by L. C. Burril, J. Cardenas and E. Locatelli, of the International Plant Protection Centre, contains much helpful information for setting out practical, field, weed control research.

4. Many such manually operated, liquid applicators are presently available throughout the world. "A Worldwide Cotegorized Partial Listing for Manufacturers of Pesticide Application Equipment", edited by A. E. Deutsch of the International Plant Protection Centre, lists 58 firms producing operator carried hand sprayers from 17 countries, including India. Company addressess appear in one section of this manual for those wishing to write for full particulars.

de Agricultural Tropical, CIAT (1975). This weed is a serious, extremely shade tolerant, prolific seed-producing annul grass of the warm regions of the world, associated primarily with maize, sorghum and sugarcane. *Rottboellia* was first seen in 1972 in CIAT fields. With constant vigilance and immediate removal (often by hand) this weed was eradicated in three years; in most areas within 18 months Based on this experience, an educational program was conducted mutually by the Colombian Agricultural Research Institute (ICA), the Colombian Weed and plant physiology Society (COMALFI) and industry. A total of 250 farmrrs, chemical company representatives, researchers and extension agents, participated in intensive, practical one-day session covering identification, biology, prevention, control and eradication of *Rottboellia* This type of a practical and successful weed prevention program must be repeated in other regions of the world.

If herbicide use is increasing within the nation in question, are herbicide residues being monitored ? Are last year's herbicides going to adversely affect future crop ? A practical way to find out is to plant several test crops each the second year within the exact boundaries of last year's herbicide plots.

The above are but a few suggestions concerning types of research one may need to execute. Resources, time and other constraints dictate priorities.

2. *Sufficient time to properly manage experiments :* It was mentioned previously that the researcher may not be able to devote his full efforts to weed control ; however, the question of time is crucial. Will the scientist have sufficient time to properly execute the experiment ? Land must be prepared, the crop established, all cultural practices (weed control being only a part) need to be carried out and the crop must be harvested. Correct timing is of utmost importance in all of these operations. If herbicides have been used one may want to evaluate stand and growth reduction for crop and weeds. Other useful data may stem from weed counts and weed weights, in addition to final crop yield. Economic analyses will require data on time required for many operations during the crop cycle. The answers to socio-economic questions in weed research may require farm and labour surveys. All of these require time and even if the researcher has manpower support many of these persons will require personal supervision-Better a few well - conducted experiments than many of questionable value.

3. *Research and office space :* Ideally, these should be located close enough to one another so that research can be realized with a minimum loss in travel time. Some workers have found it convenient to have the bulk of their field plots located close to office and home. Weeds don't stop growing over the week-end or on holidays — one must keep on top of his experiments.

By necessity, some trials have to be established at a distance. Data must be generated under varying soil, climatic, weed population and other conditions. Hopefully, this outlying research can be managed by competent personnel in the researcher's absence.

4. *Mobility :* The weed scientist must have good transportation if he is to perform research effectively. The importance of good timing in performing cultural practices has already been mentioned. In addition, one must be able to talk with growers and extension personnel, attend meetings, assist scientific conferences, collect plant specimens, make weed surveys, etc. Many projects have failed for lack of sufficient mobility.

5. *Labour:* Reliable field or glass house manpower is essential. Much responsibility can be placed with dependable persons, thus relieving the scientist for more important tasks.

One must never forget the folk wisdom or common sense of humble field workers. Often they are farmers themselves and posssess a wealth of practical information concerning weed growth and associations, manual weed control, etc. The wise researcher will recognize this and ask many questions. Good personal relations between researcher and workers are highly valued. These good relations may require an occasional sign of appreciation from the researcher.

Another extremely valuable asset for the weed researcher is a dependable field worker foreman who can oversee experiments conducted at a distance. If the experiments are located on the helper's property or an adjacent parcel, then pest control (including insects, birds, a neighbor's cow or a "neighbor" himself harvesting fodder from a weedy check plot for his animal) and othe practices can be taken care of opportunely.

6. *Collaboration :* Mutual assistance among weed researchers, extension personnel, educators, industry representatives and certainly farmers is much desired. All are laboring toward the same end-better crop production to enable better living standards for more persons. However, there is often a reluctance on the part of researchers to help and be helped by association with these, for a number of reasons. But, mutually beneficial relationships can be had among all of these. The researcher can profit from years of experience that industry may have on weed control in a specific crop. For example, one company[5] in Northeast Brazil has developed excellent weed control systems involving cultural, manual, mechanical and chemical methods for sugarcane in four basic topographic situations typical of the total crop area, during a period of 12 years, dos Reis (1975). The author spent nearly an hour convincing a young government researcher that the company regional manager could offer many suggestions for initiating a program in this crop. His first reaction was, "But a company never conducts research."

The government researcher can run unbiased tests concerning efficacy and safety of experimental herbicides from a number of companies. The information

5. Inclusion in this paper of a chemical company name does not constitute an endorsement of that company by Oregon State University or the International Plant Protection Center. Likewise, exclusion of any such name should not be interpreted as criticism by these entities.

developed can be useful to many groups. Industry, in turn, can supply the researcher with sample herbicides, technical information, some equipment and personal assistance in putting out research with its products. Also, the companies are an excellent source of funds for special projects such as publications, short courses and farmer demonstrations. Industry often can supply excellent films and other teaching materials to educators, extension personnel and researchers.

Government weed scientists and industry must work together in registering herbicides; but often they don't. More collaboration is needed here if all are to ultimately benefit.

Educators often contribute substantially to the pool of scientific information on weed control by coordinating graduate student thesis research using promising new products from industry. Contact with industry and conducting practical research thus benefits students and the entire weed worker community.

Farmers, county agents, research workers, educators and industry itself benefit from on-farm demonstrations and field days.

Besides local cooperation, mutually beneficial contacts can be had with personnel within the national and regional weed control societies and the International weed Science Society.[6]

There are many other examples of mutual cooperation among weed workers; suffice it to say that improvements can be made in this area.

7. *Library :* It has been said many times that, "Research begins in the library." The importance of access to the literature cannot be overemphasized. Even though library facilities may be meager, attempts should be made to gradually increase the useful literature available. With this in mind the IPPC has prepared the following two information sources which are cited in the appendix :

a. "Lists of Selected Publications and Periodicals to Assist in Supplementing, Expanding, or Establishing a Weed Science Library" and.

b. "IPPC Papers," an ongoing series of papers, reprints, and adaptations.

Many of the developing countries' weed problems are similar; if not the same. Much faster progress in research could be made if only the researcher were made more aware.

8. *Taxonomic facilities :* To compare his results with those of other scientists, the researcher must be able to have weed specimens correctly ideniffed. Most nations in development have, at least, several qualified plant taxonomists and herbaria. The weed scientist must avail himself of these very early in his weed research program.

6, A list of Asia's weed societies (other than the Indian Society of weed Science) and their addresses is included in the appendex to this paper.

Often it is advantageous for the researcher to establish his won small herbarium. Techniques of collecting, labeling and storage of weed specimens can be developed with assistance from those engaged in plant systematics. Plant taxonomists often welcome the opportunity to make practical presentations at weed control short courses, etc.

9. *Backup support :* Access to soil testing facilities, data analysis service, special laboratory equipment and materials and apparatus for drying plant material, weighing agricutural samples, checking seed germination and moisture content and field equipment for tillage, seeding, harvesting, etc, should be thoroughly investigated-with ample lead time.

10. *Equipment, facilities and materials.*[7] *:* What basic equipment is required for a field weed research program? What facilities and materials are needed? These questions arise ever more frequently as more and more agricultural research organizations around the world increase formal weed research and control efforts. To decide what is necessary one must first assess local conditions. Budget, size and type of research program, plot size, availability of field labor and many other factors can affect the type of equipment, materials and facilities one will eventually choose.

The following is a partial list of equipment, facilities and materials other researchers in developing nations have found to be useful :

1. Facilities
   a. a well-ventilated chemical storage area which can be locked, preferably away from rooms of habitation
   b. a chemical preparation area (which can be a part of storage area, preferably with easily cleanable floor (concrete)
   c. land for research plots; either on-station or privately owned, preferably not far from office - and space in glasshouse or screenhouse
   d. suitable office space, preferably near storage and preparation areas
2. Preparation and mixing apparatus
   a. triple beam balance plus extra weights for weighing chemicals (including small amounts of fertilizer) and small plant samples

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7. The IPPC is now offering an *Equipment and facilities consultation service* for weed reseachers in less developed countries. Those wishing such information are requested to complete and return a questionnaire describing their local conditions and limitations. From this information useful advice will be prepared and sent to the researcher concerning the best (most simple and most economical) equipment and facilities to get the job done within his resources.

   Questionnaires may be obtained from : Mr. L. C. Burrill, IPPC Gilmore Annex, Oregon State University, Corvallis, Oregon 97331/USA.

b. various graduated cylinders (25 and 50 ml. capacity), preferably non-breakable (Nalgene)[8]

c. various graduated mixing beakers (100 and 250 ml.), also non-breakable

d. several graduated mixing pitchers or pots (2000 ml)

e. several pipettes and pipette bulbs (A pipette should *never* be filled with chemical by mouth-use bulb.)

f. several plastic wash bottles with squirt tip

g. small, durable envelopes and metal (stainless steel best) spatula for weighing dry chemicals

h. detergent, acetone[9] and weak ammonia[10] for cleaning sprayer and equipment[11]

3. Protective gear/apparatus/materials

a. gloves.[12]

b. durable apron.

c. goggles or face shield.

d. respirator (s) and replacement filters.

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8. Inclusion in this paper of a trade name dose not constitute an endorsement by Oregon State University or the International Plant Protection Center. Likewise, exclusion of a trade name should in no way be interpreted as criticism by these entities.

9. An acetone-water mixture is useful as a last rinse of sprayer, wand (boom) and nozzles since it cleans well and evaporates the water leaving dry apparatus. Acetone may also be required as the carrier in some experimental herbicides.

10. Aftet the use of hormonal type herbicides (2,4-D, dicamba, picolinic acid, etc.) the sprayer, boom and nozzles should be thoroughly flushed immediately with a water-detergeet solution. Then add a weak ammonia solution (if household ammonia, 1.0-2.0% by volume) to tank and spray some to thoroughly wet inside surfaces of sprayer and boom. Leave ammonia solution in tank overnight, remove and flush with clear water. Activated charcoal will also absorb 2,4-D, etc. from the sprayer. Agitate a 0.3% suspension for several minutes. Drain and rinse with clear water. For complete assurance, after the above decontamination, the sprayer can be tested by filling with water and spraying susceptible test plants such as tomato, grape or cotton. If the sprayer is still contaminated injury will appear within several days to a week.

11. For best results in cleaning sprayers the nozzles must be removed and disassembled. Nozzle parts (base, tip, screen, etc.) can then be cleaned effectively in a small basin or pitcher with the proper cleaning agent.

12. In hand protection, disposable gloves are desirable if one can afford the quantity that is necessary. Natural rubber or latex are superior in both comfort and resistance to most chemicals, especially acetone. But they are the most costly. Vinyl disposable gloves are considerably cheaper, but are not at all resistant to acetone. Use of semi-permanent gloves is the more practical way to go, but they can be bothersome in their proper care, maintenace and storage. These are usually neoprene, rubber or PVC and are quiten durable.

e. fire extinguisher (dry chemical type).

f. first aid kit.

g. phone number and/or address of doctor or clinic in case of burning or poisoning.

h. extra clean water for quick washing in case of eye or skin contamination.

i. activated charcoal to absorb spilled herbicide (soil can also be used to help contain and absorb liquid herbicide when spilled, such as on the floor.)

4. field equipment and tools.

a. durable, economical, herbicide sprayer, preferably with 2 or 4 nozzle boom and with easily obtainable spare parts and service.

b. assorted nozzles and spare parts for sprayer.

c. hand tools in lockable, sturdy box including :

—large, adjustable (Crescent type)[8] wrench (14 inches).

—small, adjustable (Crescent type)[8] wrench (8 or 10 inches).

—large, pipe wrench (14 inches).

—small, pipe wrench (8 or 10 inches).

—various open-end wrenches.

—Vise Grip[8] type pliers.

—regular pliers.

—thin-nosed pliers.

—assorted screwdrivers (regular and Phillips types)[8].

—claw hamer.

—two or more small sledge hammers for plot stake driving.

—hack saw extra blades.

—hand drill and assorted bits.

—hexagonal (Allen)[8] wrench set.

—tap and die set applicable to equipment.

—ratractable, pocket, steel, tape measure.

d. wood saw.

e. small shovel, hoe and axe or hatchet.

f. oil can and oil, penetrating oil, pipe joint compound.

g. steel tapes (100 m) (two, if possible).

h. stakes or plot markers.

i. marking pen with rain-resistant ink for marking stakes or stake tags.

j. heavy duty stake tags (various colors).

k. twine and rope (useful in planting and for emergencies).

l. various sized plastic bags and ties (for plant samples).

m. various sized paper or plastic envelopes.

n. large balance for weighing plant and other material.

o. thermometers (for measuring soil and air temperatures).

p. 2-cell flashlight with long-lasting batteries.

q. weed count/weight quadrats (easily made to desired area from wire)

r. roll of plastic tape (for repairs, etc.)

s. letter board with adequate letters. numbers, etc.,

t. Sturdy, wooden, compartmentalized boxes for carrying some of above equipment and which also serve as a work area

5. Miscellaneous

a. vehicle (Both equipment/material and personnel carrying-capacity may be useful). A crew-cab pickup does this. It also keeps toxic chemicals separate from personnel.

b. field notebook[13].

c. water containers (for mixing and cleaning) and water.

d. drinking water.

e. 35 mm camera (with supply of color and black and white film)

f. watch with sweep second hand or stop watch.

g. hand calculator.

h. air compressor or propellant gas (CO_2 or nitrogen) for larger area plot sprayer.

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LITERATURE CITED

Centro Internacional de Agricultura Tropical, *CIAT*. 1975. *Annual Report*. pages G-33 to G-35. Cali, Colombia.

Dos Reis, A.P. 1975. Personal communication. *Ciba-Geigy* of *Northeast Brazil*. Recife, Pernambuco, Brazil.

13. All data, observations, notes, etc. should be kept neatly in a field recording book. Data should not bescribbled haphazardly on scraps of paper, etc. A duplicate copy (Photocopies are quickest and prevent transcribing errors.) of *all* such material should be maintained in the program office.

APPENDIX - 1

A list of weed socicties in Asian-Pacific Region (other than the Indian Society of Weed Science) with addresses.

International Weed Science Society : Mr. L.C. Burrill, Secretary, Oregon State University, Corvallis, Oregon 97331/USA.

Asian-Pacific Weed Science Society : Dr. M. Soerjani, Chairman, *Biotrop* P. O. Box 17, Bogor, Indonesia. (c/o Dr. Roy K. Nishimoto, Treasurer, University of Hawai, Department of Horticulture, Honolulu, Hawaii 96822/USA).

Council of Australian Weed Science Societies : W. H. Haseler, President. Land Administration Commission, Department of Lands, The Alan Fletcher Research Station, Box 36, Sherwood, Queensland, Australia 4075.

Australian Weeds Committee : Mr. K. K. Lance, Secretary. CSIRO, Limestone Avenue, Canberra, P. O. Box 225, Dickson, ACT 2602, Australia.

Australian Weeds Conference : G. R. W. Meadly, Department of Agriculture, Jarrah Road, South Perth, WA. 6151, Australia.

Weed Seience Society of Indonesia : Dr. M. Soerjani, *Biotrop*, P. O. Box 17, Bogor, Indonesia.

Weed Science Society of Japan : Dr. Shooichi Matsunaka. National Institute of Agricultural Sciences, Konosu. Saitama 365, Japan.

Malaysian Crop Protection Society : Mr. Lim Tow Ming, Secretary, Rubber Research Institute of Malaysia, P. O. Box 150, Kuala Lumpur, Malaysia.

Newzealand Weed and Pest Control Society : Mr. Les Matthews, Ruakura Agricultural Research Centre, Private Bag, Hamilton, Newzealand.

Weed Science Society of the Philippines : Ms. J. N. Sierra-Manuel, Secretary. Bio-Science Bldg C-222, UPLB, College, Laguna, philippines.

Weed Science Club of Thailand : Mr. Prachern Kanchanomai, Chairman, c/o Technical Division, Weed Control Research Unit, Department of Agriculture, Bangkok, Thailand.

APPENDIX - 2

Lists of selected phblications and periodicals to assist in supplementing, expanding, or establishing a weed science library.

Material has been assembled from several sources by the International Plant Protection Center. The various lists make no pretense of being comprehensive, nor are they intended to be. They are offered only as information to assist with library enrichment. A useful collection of published material obviously should include

numerous other publications and periodicals of a national or local nature, such as extension leaflets, conference proceedings, research station reports, etc.

While older materials generally have been omitted from the IPPC lists, some older items still may be highly pertinent and warrant consideration. Where possible, the lists include the per copy (or subscription) price of an item as well as the address of the publisher.

a. General Publications:

Akesson, N.B., and W.E. Yates. 1974. The use of Aircraft in Agriculture. *FAO Agricultural Development Paper No.* **94.** 217p. Paperback. English US$4. FAO Sales Agents.

Andersen, R.N. 1968. Germination and Establishment of weeds for experimental purposes. 236p. Hardback. English. US$5. Weed Science Society of America, 113 N. Neil Street, Champaign, IL 61820/USA.

Anon. 1973. Guide to chemical weed control. Publ. ±75. 86p. Paperback. English. US$. 30. Information Branch, Ontario Ministry of Agric. and Food, Parliament Bldgs., Toronto 5, Ont./Canada.

Anon. 1974. Herbicide Handbook of the Weed Science Society of America. 430p. Paperback. English. US$5. Weed Science Society of America, 113 N. Neil St., Champaign, IL 61820/USA.

Anon. 1973. Outline of Weed Control. 200p. Hardback. Japanese. US$5. Yokendo Publisher, Hongo 5-30-15, Bunkyo-ku, Tokya/Japan.

Anon. Annual. Weed Control Manual and Herbicide Guide. 108p. Paperback. English. US$5. Meister Publishing Co., 37841 Euclid Avenue, Willoughby, OH 44094/USA.

Ashton, F., and A. Crafts. 1973. Mode of Action of Herbicides. 504p. Hardback. English. US$24.95. John Wiley & Sons, 605 Third Avenue, New York, NY 10003/USA.

Audus, L. J. (ed.) 1976. Herbicides: Physiology, Biochemistry, Ecology. Vol. I, 2nd edition. 608p. Hardback. English. US$50. Academic Press, Inc., 111 Fifth Avenue, New York, NY 10016/USA.

Burrill, L.C., J. Cardenas, and E. Locatelli. 1976. Field Manual for Weed Control Research. 59p. Paperback. English. US$5. International Plant Protection Centre, Oregon State University, Corvallis, OR 97331/USA.

★Cardenas, J., *et. al.* 1970. Malezas De Clima Frio. 127p. Paperback. Spanish. US$50. International Plant Protection Centre, Oregon State University, Corvallis, OR 97331/USA.

Crafts, A.S. 1975. Modern Weed Control. 440p. Hardback. English. Approx. US$16. University of California Press, Berkeley, CA 94720/USA.

Delorit, R.J. 1970. An Illustrated Taxonomy Manual of Weed Seeds. 175p. Paperback/Hardback. English. US$5.95/US$7.75. Agronomy Publications, River Falls, WI 54022/USA.

Detroux, L., and J. Gostinchar. 1967. Los Herbicidas Y Su Empelo. 488p. Paperback. Spanish. US$13. (approx.) Oikos-tau, S.A., Ediciones, Apartado Correos 5347, Barcelona/Spain.

Dunham, R.S. (ed.) 1964. Losses from weeds. Spcl. Rept. ‡13. 43p. Paperback. English. US$1. Agric. Extension Svc., University of Minnesota, St. Paul, MN 55101/USA.

Fryer, J., S.A. Evans, and R.J. Makepeace (ed.). 1970/1973. Weed Control Handbook. Vol. I, 494p. Vol. II, 33lp. Hardback. English. US$11.50/US$16. (approx.) Blackwell Scientific Publications, OSney Mead, Oxford OX2 OEL/England.

Hanf, M. 1972. Weeds and their Seedlings. 348p. Hardback. English. US$7.95. BASF, Agric. Div., St. Francis Tower, Ipswich IP1 1LE/England.

Huffaker, O.B. (ed.) 1971. Biological Control. 511p. Paperback. English. US$7. (approx.) Plenum Publishing Corp., 227 W. 17th Street, New York, NY 10011/USA.

Joshi, N.C. 1974. Manual of Weed Control. 365p. Hardback. English. US$14. (approx.) Research Publications, 75/1A, East Azad Nagar, Delhi-51/India.

Kasasian, L. 1971. Weed Control in the Tropics. 307p. Hardback. English. US$8. (approx.) Agraria Press, 9 Botolph Alley, London, EC3R 8DR/England.

Kearney, P. C. and D. D. Kaufman. (ed.) 1975. Herbicides - Chemistry, Degradation and Mode of Action. Vol. I, 394p. Hardback. English. US$39.50. Mercel Dekker, Inc., 95 Madison Avenue, New York, NY 10003/USA.

Klingman, G.C. and F.M. Ashton. 1975. Weed Science Principles and Practices. 431p. Hardback. English. Approx. US$15. Wiley-Interscience, 605 Third Avenue, New York, NY 10017/USA.

Matthews, L.J. 1975. Weed Control by Chemical Methods. 710p. Hardback. English. NZ$35. Publications Section, Government Printing Office. Mulgrave Street, Wellington/New Zealand.

Miller, J. (ed.) 1972. Research Methods in Weed Science. 198p. Paperback. English. US$4. Southern Weed Science Society (US), Agric. Extension Annex, Univ. of Georgia, Athens, GA 3060/USA.

Morales T., L. *et al.* 1974. Algunas Malezas De Potreros Tropicals, Manual de Asistencia Tecnica No. 19. 274p. Spanish. US$4. ICA Oficina Publicaciones, Apartado Aereo 7984, Bogota/Colombia.

Muzik, T.J. 1970. Weed Biology and Control. 273p. Hardback. English. US$12.50. McGraw-Hill Book Co., 330 W. 42nd Street, New York, NY 10036/USA.

Subcommittee on Weeds, Committee on Plant and Animal Pests, Agricultural Board, National Research Council. 1968. Weed Control—Principles of Plant and Animal Pest Control, Volume 2; Publ. ‡1597. 471p. Paperback. English. US$8. National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418/USA.

Swarbrick, J. T. 1974. The Australian Weed Control Handbook. 325p. Paperback. English. A$4. Herbicide Recommendations, 3A Ipswich Street, Toowoomba, Qld. 4350/Australia.

Thompson, W.T. 1972. Agricultural Chemical Book II (Herbicides). 250p. Paperback. English. US$10. Thompson Publications, P.O. Box 50160, Indianapolis, IN 46250/USA.

Tutui, K. 1970. Control of Weeds. 218p. Hardback Japanese. US$4. Ie-no-hikari Association, 11 Funagawara-cho, Ichigaya, Shinjuku-kui, Tokyo/Japan.

Wilkinson, R.E., and H.E. Jaques. 1973. How to know the Weeds. 224p. Paperback. English. US$3.75. Wm. C. Brown & Co., 135 S. Locust, Dubuque, IA 52001/USA.

b. Regional Taxonomy

Adams, C.D., L. Kasasian, and J. Seeyave. 1970. Common Weeds of the West Indies. Hardback. English. US$3. Univ. of the West Indies, St. Augustine/Trinidad.

Anon. 1970. Selected Weeds of the United States. Agric. Handbook ‡366. 462p. Paperback. English. US$4. Supt. of Documents, U.S. Government Printing Office, Washington, D.C. 20402/USA.

Anon. 1970. Weeds of Canada. Publ. ‡948. 217p. Paperback. English. C$1. Canada Dept. of Agric., Botany and Plant Path. Div., Ottava, Ont./Canada.

Bar-Droma, M., M. Horowitz, and S. Osherov. 1968/1970. Weeds of our Fields. 190p. Hardback. Hebrew. Isr. P. 10. Min. of Agric., Educational Extension Svc., Hakirya, Tel-Aviv/Israel.

Barnes, D.E., and M.M. Chandapillai. 1972. Common Malaysian Weeds and their Control. 146p. Paperback, English. M$ 10. Ancom Sdn. Berhad, P.O. Box 465, Kuala Lumpur/Malaysia.

* Cardenas, J., *et al.* 1970. Tropical Weeds/Malezas Tropicales. 342p. Paperback. English/Spanish. US$ 3.50. International Plant Protection Center, Oregon State University, Corvallis. OR 97331/USA.

Edgecombe, W.S. 1970. Weeds of Lebanon. 457p. Paperback. English. US$ 8. Herbarium, American University, Beirut/Lebanon.

Garcia J.G.L., B. MacBryde, A.R. Molina and O. Herrera-MacBryde. 1975. Malezas Prevalentes DE America Central/Prevalent Weeds of Central America. 162p,

Paperback. Spanish/English. Price on request. International Plant Protection Center. Oregon State University, Corvallis, OR 97331/USA.

Haselwood, E., and G. Motter. 1973. Handbook of Hawaiian Weeds. 479p. Paperback. English. US$ 6. HSPA, 1527 Keeaumoku Street, Honolulu, HI 96822/ USA.

King, L.J. (ed.) 1966. Weeds of the World. 526p. Hardback. English. US$ 18. Interscience Publishers, Inc.. 250 Fifth Avenue, New York, NY 10003/USA.

Kingsbury, J.W. 1964. Poisonous Plants of the United States and Canada. 626p. Hardback. English. US$ 15. Prentice Hall, Englewood Cliffs, NJ 07632/USA.

Lin, C.I. 1968. Weeds Found on Cultivated Land in Taiwan. Vol. 1, 505p. Vol. 2, 444p. Paperback. Chinese/English. Free. J.C.R.R., 37 Nan Hai Road, Taipei 107. Taiwan/R.O.C,

Numata, M. and N. Yoshizawa (eds,). 1275. Weed Flora of Japan Illustrated by Colour. 414p. Aardbark. Japanese. US$ 40. Zenkoku Noson Kyoiku Kyokai Publishing Co., Ltd., 9th Mori Building, 1-3 Shiba Atago-cho, Minato-ku, Tokyo 105/ Japan.

c. Aquatic vegetation :

Anon. 1974. Aquatic Weed Identification and Control Manual. 100p. Paperback. English. No cost. Bureau of Aquatic Plant Research and Control, Department of Natural Resources, Crown Building, 202 Blount Street, Tallahassee, FL 32304/USA.

Anon. 1969. Common Aquatic Weeds. Agric. Handbook 352. 43p. Paperback, English. US$. 50. Supt. of Documentcs, U.S. Government Printing Office, Washington, D.C. 20402/USA.

Aston, H.I. 1973. Aquatic Plants of Australia. 368p. Hardback. English. US$ 34.65 (approx.) Melbourne Univ. Press, Carlton, Victoria 3053/Australia.

*Bristow, J.M., *et al*. 1970. Malezas Acuaticas/Aquatic Weeds. 116p. Paperback. Spanish/English. US$ 3. International Plant Protection Center, Oregon State University, Corvallis, OR 97331/USA.

Cook, C.D.K. *et al*. 1975. Water Plants of the World, A Manual for the Identification of the Genera of Freshwater Macrophytes. 561p. Dutch Glds. 120. Dr. W. Junk EV Publishers. The Hague/Netherlands.

Gupta, O.P. 1972. Aquatic Weed Control for Efficient Water use 97p.Paperback. English. US$ 3. Rajasthan College of Agric., Univ., of Udaipur, Udaipur/ India.

Meyer, J. 1971 Aquatic Herbicides and Algaecides. 177p. Paperback. US$ 35. Noyes Data Corp.. Mill Rd. at Grand Avenue, Park Ridge, NJ 07656/USA.

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* Requests originating in latin america for these titles should be addressed to : COMALFI Apartado Aereo 29688 Bogota, D. E. Colombia.

Mitchell, D.S. (ed.) 1974. Aquatic Vegetation and its use and Control. 121 p. Paperback. English. US$ 6.50 (approx.) Unesco, Place de Fontenoy, 75700 Paris/France.

Sainty, G.R. 1973. Aquatic Plants. 110p. Hardback. English. A$ 3. Water Conservation and Irrigation Commission. 201-211 Miller Street, North Sydney, NSW 2060/Australia.

Stryckers, J. 1968. Les Vegetations Aquatiques et Palustres et Leur Destruction. 100p. Paperback. French. Price unknown. Ministry of Agriculture, 36 rue de Stassart, 1050 Brussels/Belgium.

d. Current periodicals:

Infoletter. Quarterly. English. Free. International Plant Protection Center, Oregon State University, Corvallis, OR 97331/USA.

Journal of Aquatic Plant Management. Annual. English. No price stated. Aquatic Plant Management Society, P.O. Box 2237, Fort Myers, FL 33902/USA.

Pans, Quarterly. English. £3 annually. Centre for Overseas Pest Research, College House, Wrights Lane, London W8 5 SJ/England.

Weed Abstracts. Bimonthly. English. US$ 52 annually. Central Sales Branch, Commonwealth Agricultural Bureaux, Franham Royal, Slough SL 2 3 BN/England.

Weed Research. Bimonthly. English. US$ 52.50 annually. Blackwell Scientific Publications, Osney Mead, Oxford OX 2 OEL/England.

Weed Science, Bimonthly. English. US$ 25 annually. Weed Science Society of America, 113 N. Neil Street, Champaign, IL 61820/USA.

e. Contacts for additional information:

Asian-Pacific Weed Science Society. R. Nishimoto, Secretary, Hawaii Ag. Exp. Sta. Univ. of Hawaii, Kapaa, HI 96746/USA.

Associacion Latino American de la Ciencia de Malezas. Apartado Aereo 15024, Bogota/Colombia.

European Weed Research Society. Secretariat, Postbus 14, Wageningen/The Netherlands.

Aquatic Plant Management Society.P.O. Box 2237, Fort Myers, FL 33902/USA. International Plant Protection Center. Oregon State University, Corvallis, OR 97331/USA.

Weed Research Organization. Begbroke Hill, Yarnton, Oxford OX 5 1 PF/England.

Weed Science Society for Eastern Africa. c/o T.P.R,I. P.O. Box 3024, Arusha/Tanzania.

APPENDIX-3

IPPC Papers. This is an ongoing series of papers, reprints, and adaptations. Complimentary copies may be requested by number and title from : IPPC, Oregon State University, Corvallis, Oregon 97331/USA.

1. 1971. *Weed control in cacao.* Myron D. Shenk. Reprintd from : World Farming, October 1971.
2. 1972. *New weed control equipment and techniques.* Allan Deutsch. Reprinted from : Agricultural Mechanization in Asia, Vol III, No. 2, Summer 1972.
3. 1972. *Spray adjuvants make pesticides do a better job.* Lyall F. Taylor. Reprinted from : World Farming. September 1972.
4. 1972. *El papel de la ciencia de malezas en paises en desarrollo.* Chris Parker Translation of a paper presented at the annual meeting of the Weed Science Society of America, St. Louis, MO/USA, February 1972.
5. 1972. *Reviewing the small applicators.* Allan Deutsch. Reprinted from : World Farming, December 1972.
6. 1973. *New techniques in weed control.* Larry C. Burrill. Paper presented at the annual meeting of the Asian-Pacific Weed Science Society, Rotorua/New Zealand, March 1973.
7. 1974. *Small pesticide application equipment its selection, use and maintenance.* Allan Deutsch. Reprinted from : World Farming, January 1974.
8. 1974. *Equipos pequenos para aplicar plaguicidas su selection, uso Y mantenimiento.* Allan Deutsch. Reimpresionde: AGRICULTURAL DE LAS Americas, Febrero 1974.
9. 1974. *Con los plaguicidas - evite peligros.* Allan Deutsch. Reimpresion de : AGRICULTURA DE LAS Americas, Marzo 1974.
10. 1974. *Problems of herbicide use in peasant farming.* John L. Hammerton· Adaptation of a paper presented at the annual meeting of the Weed Science Society of America, Las Vegas, NV/USA, February 1974.
11. 1974. *Crop varieties : can they suppress weeds?* R. D. Sweet, C.P. Yip, and J.B. Sieczka. Reprinted from : New York Life Sciences Quarterly, Vol 7, No. 3, July-September 1974.
12. 1974. *Biological suppression of weeds. evidence for allelopathy in accessions of cucumber.* Alan R. Putnam and William R. Duke. Reprinted from : Science, Vol 185, July 26, 1974.
13. 1975. *Weed control with plant pathogens.* R. Charudatten. Reprinted from ; Agrichemical Age, January-February, 1975.

14. 1974 *Calibrating and adjusting granular row applicators*, J. Siemens. Reprinted from : World Farming, January 1974.

15. 1975. *Statement on 2,4,5-T and TCDD.* Dost *et al.* Oregon State University, Corvallis, Oregon/USA.

16. 1976. *Herbicides used in and around water for management of aquatic vegetation.* Reprinted from : Journal of Aquatic Plant Management, Vol 14, June 1976.

17. 1976. *Residuos de herbicidas en el suelo.* Eduardo Locatelli. Reimpresion de ; Revista Comalfi, Vol III, No. 1, Marzo 1976.

18. 1976. *Weed control problems causing major reductions in world food supplies.* C. Parker and J. D. Fryer. Reprinted from : FAO Plant Protection Bulletin, Vol. 23, 3/4. June-August P975.

19. 1976. *Problemas que presenta el control de las malezas que causan reducciones importantes in los abastecimientos mundiales de alimentos.* C. Parker Y.J.D. Fryer. Reimpresion de: FAO Boletin Fitosanitario, Vol. 23, 3/4, Junio-Agosto 1975,

20. 1976. *Lutte contre les mauvaises herbes occasionnant d' importantes reductions des ressources alimentaires mondiales.* C. Parker et J. D. Fryer. Extrait de : FAO Bulletin Phytosanitaire, Vol. 23, 3/4, Juin/Aout 1975.

APPENDIX–4

IPPC Publications. Non-commercial researchers, educators, agriculturalists and government officials or non-commercial organizations *working in less developed countries* qualify for *single* complementary copies of any IPPC publication (s). Several such publications are currently available.

1. Malezas Acuaticas/Aquatic Weeds

by J. M. Bristow, Juan Cardenas, Thomas Fullerton, and J. Sierra

This guide to aquatic weeds is useful for agronomists, farmers, educators, and researchers. It contains 50 full colour plates of common and noxious aquatic weeds with detailed descriptions plus common names (in both English and Spanish). Family, genus, and species are also noted for each example. A bibliography and glossary (bilingual) are included. 1972. Paperback. 116 pages. 11×20 cm. ($4\frac{1}{2}\times 8$ inches).

2. Malezas DE Clima FRIO

by Juan Cardenas, Octavio Franco, Carlos Romero, and Dario Vargas

A taxonomic guide, in spanish, to 50 economically important weed species of higher, cooler climates, with a color plate for each. Also includes a glossary. 1970. Paperback. 125 pages. 13×20 cm. (5×8 inches).

3. Semillas DE Malezas Tropicales/Tropical Weed Seeds

by Jerry Doll, Carlos Reyes, Herb Fisher, and Juan Cardenas

Magnified photos, in full color, of seeds of 24 weed species (per sheet) with a bilingual introduction and trilingual index of common names (Spanish, English Portuguese). Sheet I contains monocots and Sheet II dicots. 1973, 1974. 4 pages (each). 20×28 cm. (8½×11 inches).

4. Malezas Prevalents DE America Central/Prevalent Weeds of Central America

by Jose Guadalupe L. Garcia, Bruce MacBryde, Antonio R. Molina, and Olga Herrera MacBryde

This identification manual presents bilingual nomenclature, descriptions, and full color plates for 277 weed species of Central America. Includes a glossory. 1975. Paperback. 162 pages. 20×28 cm. (8½×11 inches).

5. Algunos " Trucos " Utiles EN Estadistica

por Eduardo Locatelli Y. Roger G. Petersen

Tanto la planification como la interpretacion de resultados de investigacion en ciencia, implican el uso de la estadistica. A menudo esto representa arduos trabajos de computacion. En esta publicacion se ofrecen varias technicas utiles Y simples al mismo tiempo que ejemplos practicos que permitten una rapida estimacion devarias situaciones. En espanol, encuardernado en papel. 1975. 24 paginas. 20×28 cm. (8½×12 inches).

6. A Worldwide Categorized Partial Listing for Manufacturers of Pesticide Application Equipment/UNA Lista Parcial Mundial Y Clasificada DE Fabricants DE Equipos Para LA Applicacion DE Pesticidas

by Allan E. Deutsch

This bilingual publication from IPPC lists the products of more than 400 firms worldwide grouped under 120 separate categories. The 56-page paperback contains the names and addresses of sprayer, duster, and component manufacturers - from hose clamps to field rigs - in 26 countries. Safety gear is also included, but aerial equipment is not. Sections of the publication include a graphic listing of categories, a listing of firms by category of equipment manufactured, and an overall alphabetic summary of manufacturers by country. Publication was undertaken in an effort to generate a single source of heretofore scattered data and to provide an information tool for all who may need a comprehensive reference for pesticide application equipment. 1976. Paperback. 56 pages. 20×28 cm. (8½×11 inches).

Field Manual for Weed Control Research, 1976.

by L. C. Burrill, J. Cardenas, and E. Locatelli.

Paperpeck. 59 pages, and USS 5. International Plant Protection Center, Oregon State University, Corvallis, OR 97331/USA. (Spanish versian expected by mid-1977.

WORKSHOP PAPERS

A. Weed Science Education and Curriculum in the University.

THEORETICAL AND PRACTICAL INSTRUCTION IN WEED SCIENCE.

V. S. Mani, K. C. Gautam and (Mrs.) Gita Kulshrestha.
Division of Agronomy, Indian Agricultural Research Institute, New Delhi.

Weed scienec is a distinct discipline embracing so many other fields such as biology, plant physiology, biochemistry, organic and residue chemistry, soil science, microbiology, ecology, and environmental pollution and beautification. The immediate users of this discipline are agronomy and horticulture.

The writers of this note, from their experience as teachers in this field, have listed topics for instructions at the B.Sc., postgraduate, and Ph.D. levels. These could be followed by different universities in order that weed science may play its intended role in the agricultural sciences. At the B. Sc. level the course contents for theory should relate to biology and ecology of weeds and methods of weed control, the emphasis being placed mainly on the principles. The practical courses should have the following : identification of weeds in their cotyledonary, seedling, flowering and maturing stages; and mode of weed reproduction.

At the M.Sc. level the theoretical instructions should consist of : the fundamental and applied aspects in weed control research, crop-weed competition, techniques of chemical weed control including minimal tillage, soil sterilants, chemical weed control as an aid to crop husbandry, problems involved in chemical weed control, special weed problems of India and methods of attack. Contents of the practical course should include : experiments to illustrate dormancy, viability and periodicity in germination of weed seeds, crop-weed competition effects and methods of study, reaction of weeds and crop plants to contact, translocated, and residual herbicides.

At the Ph. D. level, instruction in theory should relate to : concepts in herbicide research, physiology and biochemistry of herbicides, lethal and selective mechanisms, herbicides and soils, radioactive isotopes in weed research, parasitic and aquatic weeds; herbicides and soil microflora; interaction of herbicides with fertilizers, insceticides and fungicides; long term effects of continued use of herbicides, and herbicides residue problems. The contents of practical course may include : field and laboratory experiments to illustrate lethality and selectivity of herbicides, study of toxicity, leachability, persistence and degradation of herbicides, mode of action of foliar and root-acting chemicals; field and laboratory bioassays, determination of herbicide residues in soils and plants, pot culture experiments to determine the ED 50 values for some crop plants and seasonal weeds; growth regulation and metabolic changes due to herbicides, and protective measures against herbicide injury to crop plants.

WEED SCIENCE IN THE UNIVERSITY CURRICULUM.

P. S. Lamba. University of Udaipur, Udaipur.

Undoubtedly, there is urgent need to give priority to weed control particularly when we have embarked upon growing synthetic high yielding varieties which are copiously irrigated and fertilized. These varieties appear to possess low competitive ability and, therefore, weed control by cultural and/or chemical means can play a significant role. Furthermore, several tropical noxious weeds already exist and have also been introduced which, besides competing with crops, also cause ailments in human beings and disorders in animals who feed upon the same.

To start with, in each teaching and/or research institution under the Department of Agronomy, a cell for weed Control may be created. This should be staffed with one Associate Professor/Agronomist and one Research Assistant along with necessary secretarial and financial provisions. One Research Assistant should be provided for each regional station depending, of course, on the magnitude of weed problems. In my considered opinion we could start with this humble beginning and undertake survey of weed problems and devise control measures for weeds in different crops and pastures. Advice for prevention of introduction, and eradiation of some of the noxious weeds already existing in the state or country should also be the responsibility of the weed control cell.

At undergraduate level weed control should be an elective course. However, control of weeds in different crops and situations should be taught along with the teaching of production of every crop without exception. Since many agricultural graduates will not go for weed control even if it be a separate department it may not be advisable to have a compulsory course for weed control at this level owing to a heavy curricular load already existing at undergraduate level.

At M.Sc. level in Agronomy there should be a compulsory course of 3 semester credits in the Department of Agronomy the contents of which followed in this University are given in Agron. 622 (weed control). At Ph.D. level there should be another course of advenced nature preferably titled as Physiology and Biochemistry of herbicides compulsory for all students majoring in either crop production or weed control aspects of Agronomy. The contents of this course as are followed in our University are given in Agron.721 (Physiology and Biochemistry of Herbicides).

At this stage it shall be premature to have a separate department of weed science at post-graduate level. Its status is similar to that of Agrometeorology and it will not be able to attract good students or faculty for want of limited job openings as in this country there is still a craze for Government or Institutional services. Also, persons majoring in weed control would not be suitable for working or designing and development of new herbicides and for which persons trained in biochemistry, organic chemistry, etc. shall be needed. Even in many U.S.Universities separate Department of weed science does not exist.* What at present, therefore, is needed is to strengthen

* Colorado State University has now a Department of Weed Science and many other Universities are in the process of organizing separate weed science departments. (ED.)

the research work and limited teaching work which we can instead of having a separate department of weed science. As at present it should remain with Agronomy Department.

Short term weed control trainings may be organized from time to time to meet the need of Agriculture Department for designing weed control strategy for a particular situation. Regular issue of newsletter from the Indian Society of Weed Science can be very useful in this direction.

Agron. 622 – Weed Control (2+1)

Theory :

Common herbicides, their properties, type of action and uses-
Bases of selective weed control with herbicides. Herbicide formulations.
Nature of weed problems, weed control principles and practices in important grain crops, oil seeds, pulses, sugar and fibre crops, tuber crops, forages and grasslands with special reference to Rajasthan conditions.

Noxious weeds and their control.
Impact of use of herbicides in modifying agronomy of certain crops.
Herbicides and crop quality.
Economics of herbicides use in field crops.
Herbicide-insecticide-fertilizer interactions.
Problems of aquatic weeds in Rajasthan and possible control measures.
Vegetation control in non-crop areas.
Weed control in horticulture and farm forestray.

Practical :

Evaluation of herbicides in laboratory and field, determination of ED 50 values.
Familiarity with different herbicides.
Testing certain herbicide residues in plants and soils, calculating herbicide rates
Practice in the field application of herbicides.

Agron. 721 Physiology and biochemistry of harbicides (3+0)

Chemical classification of herbicides.
Mechanism of absorption, translocation and action of herbicides in plants.
Fate of herbicides in plants, soils, water, and animals, including partitioning and degradation of specific herbicides, Physiological and biochemical aspect of selectivity of herbicides and factors affecting it.
Herbicides and environment interaction; environment pollution due to herbicides.
Factors in the persistence of herbicides in soils and plants.
Chemistry and properties of herbicidal formulations and adjuvants.
Hormonal control of plant growth ; effects of sublethal doses of herbicides on yield & biochemical composition of crop plants & its exploitation in agriculture.
Herbicide and other agricultural chemical interactions. Synergism and antagonism in herbicides.

WEED SCIENCE CURRICULUM AT THE UNIVERSITY-SUGGESTIONS

S. V. RAO[1]

Although the crop loss due to weeds is far greater in proportion than that caused by insects and diseases, Weed Science as a profession is very much neglected in India. The number of weed scientists working in the universities and colleges of agriculture is pathetically low compared to the number of entomologists and plant pathologists. This was mostly due to the following factors :

1. Non recognition of weed control as an important agricultural practice to effect efficient utilization of various crop inputs, i.e., nutrients, water, insect and disease control etc., and raise yield levels significantly.
2. Lack of enthusiasm by the university and college administrators to include weed science as a mandatory subject of the students' curriculum.
3. Reluctance by the universities and colleges to create top-level teaching positions in weed science and appoint weed scientists to fill them.
4. Paucity of adeduate funds to develop strong teaching and research programmes in weed science in the universities and colleges.

This malady and indifference towards weed contol and the discipline of weed science in the universities can be remedied by a vigorous implementation of a strong curriculum in weed science both at undergraduate and graduate levels. After all, an efficient plant protection management includes protection of crop not only from insects diseases, and nematodes, but weeds and weed competition as well. The occurrence of one pest is related to the presence or absence of the others. A good weed control programme eliminates weed competition to crop, as well as an alternate host for insects, pathogens, and nematodes prevailing in the same crop. Thus, it is very essential to bring up the level of education and training in weed science to that now exists in the areas of entomology and plant pathology.

Separate courses in weed science should be offered at the undergraduate as well as graduate level.

CURRICULAM CONTENT

1. Undergraduate Level

1. Name of course : Introduction to Weed Science
2. Course duration : 3 credits (2+1)

1. Weed Agronomist, Tocklai Experimental Station, Jorhat.

3. When to offer : Preferably in final year of B. Sc. (Ag.) degree. One trimester a year- between August and November.

4. Optional/Mandatory : Mandatory-a prerequisite to obtain degree in agriculture.

5. Course outline :

Lectures

a. Biology and identification of weed species.
b. Weeds and weed competition.
c. Factors affecting weed germination, propagation and growth.
d. Mechanical methods of weed control.
e. Biological methods of weed control.
f. Chemical weed control with herbicides.
g. Herbicide formulations, classification, and general modes of action.
h. General discussion on herbicide metabolism and residues.
i. Herbicide equipment and spraying.
j. Research methodology in weed control.
k. Cost and economics of weed control.

Laboratory

a. Indentification of weeds.
b. Herbicide testing and screening-bioassary techniques.
c. Determination of herbicide rates.
d. Herbicide activity in two or three types of soils and environmental conditions.
e. Effect of additives and rainwash on herbicide activity.
f. Herbicide absorption and translocation.
g. Herbicide persistance.
h. Herbicide equipment and spraying.

6. General and supportive courses :

Agronomy, botany, (taxonomy and anatomy), plant physiology, soil science, statistics, extension, horticulture, vegetable crops, etc.

II. Graduate Level

At the graduate level, students interested in majoring and minoring in weed science should be offered specialized courses.

A. Masters degree

1. Name of course : Advances in Weed Science
2. Course duration : 3 credits (2+1)

3. When to offer : First year of the two-year M.Sc. degree. Once a year.
4. Optional/Mandatory : Mandatory
5. Course outline :

Lectures

a. Biology and control of weeds.
b. Absorption and translocation of herbicides.
c. Biochemical and physiological mechanisms of action of herbicides.
d. Metabolism and residues of herbicides.
e. Absorption, retention, and persistance of herbicides.
f. The use of radioisotopes in weed research.
g. Quality testing of herbicides.
h. Integrated approach to weed control.
i. Herbicide equipment and spraying.
j. Herbicide formulations and manufacturing.
k. Herbicide toxicology.

Laboratory :

a. Three laboratory oriented experiments.
b. Three field oriented experiments.

6. Dissertation : Research work done in the field or laboratory on any selected problem.

7. General and supportive courses :

Agronomy, plant anatomy, plant physiology, biochemistry, soil science, entomology or plant pathology, a laboratory course in plant physiology or biochemistry, etc.

B. Doctoral Degree (By course work and dissertation)

All Ph. D. students minoring in weed science must take the course "Advances in Weed Science" offered at the Masters degree level.

Those majoring in weed science should be offered a course mentioned below :

1. Name of course : Current developments in Weed science.
2. Course duration : 2 credits — only Lectures.
3. When to offer : Once in two years ; the student may take it in the first or second year of the 3-year degree period.
4. Optional/Mandatory : Mandatory.

5. Course outline :

   a. Review of current literature on various topics in weed science,

   b. Seminars on selected topics by students.

   c. Guest lectures on selected topics.

   d. Group discussions on practical problems and solutions.

6. Dissertation :

   a. Research work on a fundamental aspect in weed science conducted in the laboratory, or

   b. Research work on any immediate practical problem conducted in the field as well as laboratory.

7. General and supportive courses :

   As in case of Masters degree.

C. Doctoral degree (by dissertation only)

1. All candidates working for Ph. D. degree by submitting only the dissertation, should have had taken the course listed for Masters degree.
2. They should review current literature on selected topics in weed science and prepare review reports.
3. They should give seminars on the topics reviewed in (2).
4. They should attend guest lectures on weed control and prepare summaries.
5. Dissertation : As in case of doctoral degree candidates by course work and dissertation (B).

III. *Diploma Course in Plant Protection* (D.P.P.)

1. The university may also offer one-year diploma course in the various disciplines of plant protection : weed science, entomology, plant pathology, nematology, etc. This should preferably be a practical-oriented course, with the requisite amount of teaching of theory, to train diploma candidates thoroughly in the area of plant protection which has now become a major source of expenditure in crop production.
2. Who should be offered this course to ?

   a. Those who have a minimum of B, Sc. (Ag.) degree.

   b. Research and extension personnel of the university, state government, and research institutions.

   c. Personnel from private industry.

   d. Self-employed personnel.

   e. People who wish to make plant protection as profession either in a public or private enterprise.

3. Course in Weed Science : 4 Credits (2+2)

This course may be offered separately. If it is to be offered in conjunction with the course suggested for M.Sc. degree candidates, the extra one credit for laboratory should be utilized by undertaking adoption of a village or part of a village to effectively disseminate weed control practice to the farmers.

Implementation :

1. The university must creat new faculty positions in weed science to offer these courses in the various agricultural colleges affiliated to it. One position should be created at Professor level in colleges where M. Sc. and Ph. D. degrees are offered and few positions at Associate and Assistant Professor level where only B. Sc. degree is offered. A sufficient number of positions may also be created at the level of Scientific Assistant.
2. The university should offer fellowships to M. Sc, and Ph. D. degree candidates and employ them as part-time research and teaching assistants.
3. The required funds must be provided by the university and State Government.
4. National research and educational bodies like ICAR, CSIR, UGC, etc. may provide grants to result-oriented weed research projects of specific duration(with possibility of extension) to be conducted by the faculty and students. As a part of training, the masters and doctoral degree candidates must be made involved in the work of these projects. These national bodies should offer research and teaching fellowships to students specializing in weed science.
5. The private herbicide industry also should provide funds to support weed research projects and work in close coordination with the universities.

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TEACHING PROGRAMME IN WEED SCIENCE

V. M. BHAN & K. C. SHARMA[1]

INTRODUCTION

One of the major hindrances in the development of weed science in India is the lack of trained personnel in this subject. This has resulted in poor programmes of weed research and extension. The benefits of new technology in weed control, especially the use of herbicides, have not been achieved yet in this country. Very little information is available on effective control of weeds in various cropped and non-cropped situations especially under different agroecosystems. Wherever some work has been done it has not been transmitted effectively to farmers' fields to the benefits of the masses.

Farm communities near some of the Agricultural Universities have shown large use of new methods of weed control which gives a feeling that probably better training and demonstration by weed science personnel has led to such success and indicates that availability of trained personnel is of utmost importance to develop understanding of problems of weeds and their control. Herbicides, unlike other pesticides, require deep understanding of the subject before being used under specific conditions. Sound knowledge is required about biology of weeds, crop-weed competition, and the residual effect of herbicides.

EXISTING PROGRAMMES IN WEED SCIENCE

The academic study in weed science are included at the B.Sc., M.Sc., and Ph.D. levels in many of the Agricultural Universities and Institutes in India. Almost all these universities are teaching weed control in one course in their advanced elective programme at the undergraduate level. This course deals mostly with identification, biology, and control of weeds. Agricultural University at Pantnagar offers two courses in Weed Science :

1. **Weed Control (APA - 204) - 3 Credits (2 lectures + 1 lab/week)**

   Classification and biology of weeds

   Principles of weed control

   Introduction to herbicides

   Factors influencing herbicide use

   This course is offered to all students of elective programme in crop production. and plant protection.

1. Department of Agronomy, G. B. Pant University of Agriculture and Technology, Pantnagar, U. P.

M.Sc. Agronomy students who have not taken this course at the undergraduate level are advised to take this course as a noncredit course.

2. Mechanism of Weed Control Through Herbicides (APA - 402) - 4 Credits (3 lectures + lab/week)

Historical development and definition of herbicides

Mechanisms of phytotoxicity

Persistence and disintegration of herbicides

Surface active agents

This course is given to students of M.Sc. and Ph.D. programmes who are having research problems in weed or their related field.

Basic Teaching Programme at Agronomy of M Sc and Ph D Levels with Research in Weed Science

Students working on research problems in Weed Science at the M.Sc. level have to complete 45 credits for theory and 15-20 credits for their research work. A Ph.D. student has to complete a minimum of 55-60 credits for throry and 45 credits for research work. This includes 15 credits for minor which may be taken in either plant physiology, biochemistry, or physical chemistry.

At present, course work in major and minor programmes which also include two courses related to weed control along with research problem which essentially is on weeds provides students a degree in Agronomy. There is no mention of specilization in weed science unless one reads the thesis or published work of the student.

LIST OF COURSES FOR STUDENTS WORKING IN WEED RESEARCH

1. M. Sc. Programme :

Major courses :		*Credits*
Field crops I	.....	5
Field crops II	.....	5
Field crops III	.....	5
Principles and practices of irrigation	.....	5
*Mechanism of weed control through herbicides	.....	4
Statistical methods	.....	3
Elements of experimental design	.....	3
Plant physiology	.....	4
Use of scientific and technical literature	.....	1
Seminar	.....	2
Thesis research	.....	20
	TOTAL	57

Minor courses

Plant nutrition	.....	4
Plant biochemistry	.....	5
Chromatography	.....	2
Optical methods of analysis	.....	2
	TOTAL	13

Noncredit courses (if not taken at U. G. level)

Weed control	.....	3
Crop management	.....	3
Soil and water management	.....	4
	TOTAL	10

2. Ph. D. Programme :

Major courses

Concepts in crop production	.....	5
Environment and productivity in plant community	.....	4
Soil fertility management	.....	5
Mineral nutrition of crop plants	.....	4
Advanced experimental designs	.....	4
Soil and plant analysis	.....	3
Seminar	.....	3
General biochemistry	.....	5
Microbiology and biochemistry of soils	.....	4
Mechanisms of weed control through herbicides	.....	4
	TOTAL	41

Minor courses :

Physical chemistry

Physical chemistry	.....	4
Electro chemistry	.....	3
Radio chemistry	.....	2
Use of radio isotopes in research	.....	2
Quantitation inorganic analysis	.....	2
Identification of organic compounds	.....	2
	TOTAL	15

Biochemistry

General biochemistry	.....	5
Biochemical preparations	.....	3
Enzymes	.....	4
Instrumental methods of analysis	.....	4
	TOTAL	16

Plant physiology

Plant physiology	.....	4
Plant nutrition	.....	4
Plant biochemistry	.....	5
Research technique in plant physiology	.....	2
	TOTAL	15

Noncredit courses:

Elementary differential and integral calculus	.....	3
Elementary trigonometry and coordinate geometry	.....	3
Elementary biochemistry	.....	5
	TOTAL	11

SHOULD THERE BE MINOR IN WEED SCIENCE

There seems to be a positive need for having persons trained specially in this branch of science. The job opportunities are and will be available in government organization, teachning, and research. With the increase in the awareness of the problems related to weeds and their control, these graduates may also establish their own consultancy and custom service or may work with industries and develop pest management programmes.

COURSES FOR A MINOR IN WEED SCIENCE

The following courses for a minor programme in weed Science with major in Agronomy are suggested.

1. **Mode of Action of Hebicides – credits (3 lectures + 2 lab)**

   Historical developments of herbicides
   Absorption, translocation, and mechanism of phytotoxicity of herbicdes
   Reasons for selectivity in crops and weeds, intra-specific selectivity of herbicides
   Behaviour of herbicides in soil
   Compatibility of herbicides

2. **Degradation of Herbicides in Plant and Soil – 4 credits (3 lecture + 1 lab)**

   Fate of herbicides in plant and soil
   Detoxification mechanisms in plants
   Loss of herbicides in soil with special reference to biological degradation, photodecomposition

3. **Advances in Weed Science – 3 credits (3 lectures)**

   Principles and methods of weed control
   Relationship of weed control to various factors involved in agricultural production
   Labour utilization and economics of herbicide use

4. Application Equipment – 3 credits (2 lectures + 1 lab)

Methods of application

Principles of spraying

Equipment required for herbicide use under different situations

Common problems experienced in the use of herbicides

This programme of 15 credits with minor in weed science fits very well in the curriculum requirement like any other minor programme and will help provide relatively better trained personnel in this line of specialization.

TEACHING PROGRAMME OTHER THAN FOR DEGREE REQUIREMENT

There is long felt need for effective programme to train field workers in weed control. Priorities should be given to train personnel working in various extension agencies, manufacturing organizations. etc., who come in direct contact with th farmers. Apart from this there should also be a regular training of plant protection officers and inspectors, agricultural extension officers and subject matter specialists wh o train village level workers and lay demonstrations in crop fields.

The training programmes should be designed in such a way that suffi c understanding on the subject is imparted at the field level. The problems related to weeds in crops, soil herbicide interactions, increasing the efficiency of herbicides, application equipment should be discussed. These programmes may vary from 2 to 1 week duration. The problems raised in such trainings may also provide a back to scientists in teaching and research.

SYLLABUS FOR THE WEED CONTROL COURSES OFFERED TO POSTGRADUATE STUDENTS AT TAMIL NADU AGRICULTURAL UNIVERSITY, COIMBATORE

S. SANKARAN[1]

Agron. 603–Weed Control I (Credits 2+1)

Scope of weed control
Principles of weed control
Cultural, biological and chemical methods of weed control
Different herbicides and their use
Pre-emergence and postemergence sprays for field crops
Special weed problems in cropped and uncropped areas
Equipment used for herbicide sprays
Common weeds, their characteristics and identification

Agron. 618–Weed Control II (Credits 2+1)

Herbicides
Behaviour of herbicides in plant and soil
Mechanism and mode of action of herbicides
Effect of herbicides on biological process in plants
Microbial activities in soil
Herbicides and general nutrition of crops, residue problems, and crop rotations
Degradation of herbicides in soil and plants
Techniques to evaluate uptake and residue of herbicides

Agron. 603–Weed Control I (2+1): Lectures and practicals Theory (lectures)

1. Historical aspects of weeds in agriculture
   Climax vegetation and take over
   Weed growth in crops and its causes
2. Definition of weed
   Crop-weed competition - critical period
   Principles of eradication and control
3. Dormancy of weeds and its significance
   Factors affecting dormancy
   Periodicity of weed germination

1. Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3

4. Principles of weed control
Weed control practices with reference to nature of weed and crop and crop management
5. Weed control methods
Preventive measures and curative methods
Principles in mechanical methods
6. Cropping and competition method and their combination with intensive tillage
Principles of biological method and their relative merits
7. Chemical weed control and its developments
Herbicide selectivity
Application on foliage and soil
Contact and translocated action of herbicides
8. Methods of herbicide application-pre and post, presowing, preplanting, directed, and band applications.
9. Selectivity
Physiological or biochemical mechanism of detoxification, b-oxidation mechanism
10. Selectivity (continued)
Differential absorption, polar and nonpolar nature and wetting agents
Differential translocation through xylem and phloem.
11. Role of surfactants with herbicides - surfactants as coupling and wetting agents, adhesives and detergents Carriers
12. Mode of a action of herbicides – lipoid and aqueous routes Herbicidal action at cellular level
13. Herbicide formulations - emulsifiable and aqueous concentrates, wettable powder, granules, pastes, and dusts.
14. Classification of herbicides - inorganic and organic
15. Structure and properties of herbicides under different groups-substituted phenols, nitriles, and phenoxy acetic and butyric acids.
16. Benzoic acids, phenylacetic acids, halogenated aliphatic acids, carbamates, and thiocarbamates.
17. Amides. ureas, diazines or uracils.
18. Triazines, quaternary ammonium compounds and miscellaneous herbicides.
Suboptimal doses of triazine herbicides on yield and quality of cereals.
19. Recommendations of herbicides - susceptibility and selectivity on associated crops.
Mixtures of herbicides and rotation of herbicides.
20. Tailoring of herbicides.
Spraying time related to weather, method of application.
Calibration of spray volume and spread of application.
Decontamination procedures.
21. Parasitic weeds and their control ; Loranthus, Cuscuta, Orobanche spp and Striga spp.
22. Classification of aquatic weeds and their damage : submerged, surface, emerged weeds.
Control measures.

23. Aquatic weed control by design-hydrologic, laser, chemical, and biocontrol methods.
Chemicals used and their formulations.

24. Guidelines for herbicide research-selection of problems, layout and sampling procedure.
Prepration of spray solution and control of herbicidal drift.

25. Future scope of weed research.
Impact of weed control on choice of crop variety, crop rotation, seed bed preparation, sowing methods, time of application of fertilizers, irrigation and economics of cultivation.

Practical :

1. Identification and classification of weeds in wet, garden, and dry lands
2. Estimation of weed seed population in soils at different depths
3. Determination of weed density in cropped fields. Training in weed counting method
4. Identification of herbicides and their formulations
5. Practical training in mixing and spraying of herbicides in crop fields
6. Calculations of doses and carrier required Cost comparisons.
7. Study of different sprayers and their parts; nozzle types.
8. Decontamination of herbicide spraying equipment for dinitro, ureas, carbamates or triazine compounds and for growth regulating herbicides.
9. Practical training in scoring and transformation of data; analysis of experimental data.
10. Field evaluation of herbicidal trials in various crops like cereals, pulses, oilseeds and sugar and fibre crops.

Agron. 618 - Weed Control 2 (2 + 1) : Lectures and practicals

Theory (Lectures) :

1. Growth and development of plant in response to herbicides Dose and time of application.
Root growth in relation to herbicide response.

2. Primary and secondary tissues of plants.
Herbicide on shoot and leaf.
Epidermal hairs and their functions.
Translocation of herbicides.

3. Uptake of herbicides - symplast and apoplast pathways Foliage translocation.

4. Translocation and absorption through stem.
Accumulation and bunding effect of herbicides.

5. Soil applied herbicides : absorption by roots ; mobility of different herbicides in plants.
6. Degradation of herbicides.
   Mechanisms of degradation in higher plants - oxidation, decarboxylation, hydroxylation.
7. Different degradation mechanisms : hydrolysis, dealkylation, conjugation.
8. Biochemical response of herbicides in plants : effect on respiration.
9. Effect on photosynthesis and Hill reaction.
   Effect of herbicides on nucleic acid and protein metabolism, Repression and feed back inhibition.
10. Effect of herbicides on enzymes.
    Metabolism of herbicides : phenoxy acids, carbamates.
11. Metabolism of herbicides (continued) : triazines, amides, inactivation of propanil by various plants; Halogenatedaliphatic acids, thiocarbamates.
12. Fate of herbicide molecule in plants : ureas, bipyridylium, triazoles, arsenicals, and others.
13. Herbicide behaviour in soil : adsorption and dissipation of herbicides.
14. Mechanism of adsorption : reversible and irreversible adsorption; water, clay, herbicide complex.
15. Herbicide residues in soils : rate of dissipation of herbicides.
    Persistence of herbicides.
16. Loss of herbicides from the soil : evaporation, leaching, chemical destruction, Biological decomposition.
17. Herbicide and microorganisms interaction : effect on ammonification, nitrification and nitrofen fixation.
    Herbicides in rhizosphere : effect of herbicides on bacteria, fungi, and actinomycetes.
18. Herbicide activity : basic principles on measurement of activity; dose response and comparative potency.
    Selectivity index.
19. Herbicide mixtures : synergistic and antagonistic actions
20. Herbicide resistance.
    Zero tolerance.
    Effect of suboptimal doses of herbicides on protein content.

Practicals :

1. Study on the effect of 2, 4-D on wheat seed germination : Potculture trials in Solanum weed-root sprout studies.
2. Biological tests for detection of herbicides.

3. Gas liquid chromatography : different parts and their functions ; uses and methods of working GLC.
4. Residue analysis for alachlor by GLC.
5. Instrumental method of herbicide analysis : spectrophotometry ; electromagnetic spectrum; infrared spectrophotometry.
6. Different chromatographic methods.
   Warburg apparatus for respiration studies.
7. Extraction and purification methods for herbicides : analytical methods for important herbicides.
8. Estimation of herbicidal effect on soil microorganisms in different soils.
9. Studies on the effect of herbicides on leguminous crops ; counting of nodules.
10. Studies on amino acid analyser with refference to herbicide effect ; use of electron microscopy.
11. Herbicide residue accumulation; calculating the residues in soils.

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WEED SCIENCE - CURRICULUM SYLLABI FOR UNDERGRADUATE AND POSTGRADUATE

P. RETHINAM[1]

Weed Control for Undergraduate Students (Credits 1+1)

Weeds :

Definitions
Beneficial and harmful effects of weeds.
Classification of weeds
Ecology of weeds
Nature of weed seeds ; dormancy, viability and dispersion

Weed Control :

Importance of weed control
Different weed control methods
Origin and development of chemical weed control
Techniques of chemical weed control ; selectivity of herbicides
Classification of herbicides and formulations
Dosage and calculations
Weed control in field crops

Equipment :

Maintenance of spray equipment
Precautions to be followed in chemical weed control

Practical :

Identification of weeds, weed seeds of wet, garden, and drylands.
Weeds in different crops.
Competition at different stages
Spraying practice of herbicides.

Weed Control for Postgraduate Students :

Weed Control I (Credits 2+1)

Scope of weed control.
Methods of weed control—cultural, mechanical, biological, and chemical.
Principles of weed control.
Classification and properties of herbicides and structural formulae.

1. Sugarcane Breeding Institute, Coimbatore - 7.

Techniques of spraying herbicides—presowing, preemergence, and postemergence techniques.

Herbicides for different field crops-suitable herbicides for inter and mixed cropping conditions and cropping systems.

Absorption and translocation of herbicides in plants.

Selectivity of herbicides

Formulations of herbicides

Factors affecting the preformance of herbicides

Special weed problems in cropped and noncropped lands ; control of perennial weeds, parasitic and acquatic weeds.

Equipment used for herbicide application

Decontamination of herbicide applicances.

Weed Control II (Credits 2+1)

Herbicides

Growth response to herbicides

Movement and behavior of herbicides in soil and plants

Mode of action of different groups of herbicides

Metabolism of herbicides

Effect of herbicides on the metabolic process of plants: photosynthesis, respiration, etc.

Effect of sublethal dose of herbicide application

Role of herbicides in the uptake and availability of nutrients. moisture, etc.

Degradation and loss of herbicides by physical, chemical, and biological means

Different methods of estimation of herbicide residues

Effect of herbicide, insecticside and fungicide mixtures on soil and plant.

Tailoring of herbicides to different cropping systems

Herbicide toxicity - role of absorbents and other agronomic practices to reduce toxicity

Principles involved in the field study, on dose response, relative potency and selectivity index of herbicide

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SHORT COURSE IN WEED SCIENCE - COURSE OUTLINE

J. VENKATESWARLU & G. FRIESEN[1]

A. Weed Characteristics

1. *Introduction*—Weeds defined ; historical references to weed problems.
2. *Activities of man contributing to increased weed problems :*
   a. seeding unclean seed
   b. overgrazing of pastures and rangelands
   c. lack of crop rotation-"extensive" system of farming
   d. improper land use
   e. allowing ornamentals to escape
   f. neglect of weed control practices in uncropped araas
   g. movement of machinery and equipment
   h. transporting grain in open wagons and trucks
   i. spreading of manure to fields and cities
   j. permitting livestock to wander over a wide area
   k. lack of interest and knowledge of control methods
3. *The significance of weeds :*
   a. Weeds in field and horticultural crops :
      —reduction in yield of crops due to competition for light, mineral nutrients, and moisture ; toxic substances exuded by roots of some weeds.
      —added cost of handling crops
      —added cost of controlling weeds: cost of cultivating land, extra equipment and labour needed ; cost of chemical weed control ; cost of cleaning grain for milling.
      —lowered quality of products : grains have objectionable ordors, tainted, hard to-clean-out weeds ; hay and fodder containing spines, awns, etc. ; vegetables containing weed seeds.
      —interference in plant beds and nurseries
      —reduction in land values

1. All India Coordinated Research Project for Dryland Agriculture, 2-2-58/60 Amberpet, Hyderabad - 500013.

b. Weeds in pastures and range lands

—effect on grazing potentials and livestock production

—lowered quality of animal Products :

—livestock losses : poisonous weeds causing death ; chronic diseases ; irritational effects (internal and external)

—potential menace to cropland

c. Host for insects and disease organisms

—plant diseases spread by weeds

—insects harbouring on weeds

d. Weeds along right of ways

—potential menace to cropland, livestock

—obstruction of vision on highways

—interfer with operations

—hazards on railroad beds

—interfere with power transmission and telephone dial impulses

—fire hazard

e. Weeds on and in waterways (drainage and irrigation ditches, breache, etc.)

—effects on stream flow

—menace on stream bank : deposition of silt : rodent protection leading to bank damage

—source of infestation for cropland

f. Weeds of game refuges

—interference with fishing and hunting

—source of infestation for other lands

—source of food for game

g. Weeds of turf

—weed in golf courses

—weeds in lawns (home and public)

h. Weeds of industrial areas

—fire hazard

—interference with operations, unsightliness

—increase rate of decay and deterioration of buildings, machinery and equipment

i. Weeds and human health

—allergies : skin diseases, skin irritations, hay fever

—poisoning

j. Cost of legislation

k. Summary of losses caused by weeds : comparison with animal diseases,

—plant diseases, insect pests

4. *Characteristics of weeds :* (related to control)

a. Life cycles of weeds

—annuals (winter, spring, summer)

—biennials

—perennials (creeping with rootstocks, rhizomes. or stolons; simple tap or fibrous roots; bulbous, tuberous)

b. Propagation of weeds by seeds

—Seed formation-influenced by : genetic make-up, growing conditions, incidence of insect and fungal attacks, presence of cross-pollinating agents

—seed dissemination : seed adaptitions for disseminations : agents of dissemination (wind, water, animals, birds, machinery, man)

—seed germination : factors affecting germination (dormancy, seed morphology, location in soil)

—weed seed viability

—periodicity of germination

—vegetative reproduction-influenced by : plant morphology, physiology, environment

5. *Establishment of weeds :*

a. Environmental conditions affecting establishment

—competition (relationship to other plants) : dependent on time of germination, rate of seedling growth, time of maturity, tolerance of shade, competitive ability of crop grown, ability to develop extensive root system

—tillage and cropping practices

—soil factors (condition, reaction, fertility, salinity, moisture)

—animal factors : general impalatability of weeds (barbs, spines, smell, taste), grazing of associated plants

—climatic

b. Plant characteristics favoring establishment

—seed : number, maturing characteristics, dormancy habits, size of seed, time of germination

—vegetative : top growth, roots

—growth patterns : rate of growth (rapidity of growth dependent on ready and uniform germination, large photosynthetic area, number of stomates, rapid development of root system)

—genetic variability : range of adaptability, ability to survive adverse conditions, temperature tolerance

B. CONTROL METHODS, MATERIALS AND EQUIPMENT

1. Weed control vs eradication
2. Fundamental principles of weed control
   a. Prevention of weeds
   b. Objectives in weed control

—annual weeds : prevent seed production by timely fallow cultivations, mowing of noncrop areas ; cooperate with nature to break dormancy of weed seeds ; destroy seedlings

—biennials : usually controlled by thorough fall or spring cultivations

—perennials : prevent seed production; exhaust food reserves in roots (starving out) by intensive cultivation

3. Mechanical control of weeds
   a. Machinery (uses and limitations) : plows, discs, cultivators, harrows
   b. Mowing or clipping
   c. Burning: complete burning, selective burning (flame cultivation), burning straw or crop refuse
   d. Alterning moisture supply: drainage, flooding
   e. Smothering with nonliving material
4. Cropping and competitive methods of control
   a. Annual smother crops: fall rye, winter wheat, millets, sorghum, sweet clover, early maturing barley
   b. Perennial crops : grasses and legumes
   c. Row crops (summer fallow substitues)
   d. Application of fertilizers and seed dressings
   e. Adequate seeding rates
5. Biological control
   a. Insects
   b. Diseases
   c. Animals

C. FACTORS WHICH DETERMINE CONTROL METHOD

1. Weed species : annuals, perennials, etc. ; physiology; morphology
2. Environment : crop association ; neighboring vegetation; soil; moisture and temperature
3. Land use (value of land or crops) : waste land or productive land ; value of crop; accessibility
4. Size of infestation: patches; field scale; large areas
5. Equipment available

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STRATEGY FOR WEED CONTROL IN INDIA

S. B. D. AGARWALA[1]

ABSTRACT

This paper analyses reasons for lack of effective weed control in India and makes specific organisational and technical suggestions to correct the situation. Certain weed problems which can be best solved only by chemical herbicides are listed so that they are declared a preserve for chemical control.

INTRODUCTION

The Executive Director of the Pesticides Association of India estimates that about 33% of the Agricultural GNP is lost every year due to weeds. This loss is equal to Rs. 1500 crores in 1973/74 estimates. The Pest Control Association of India claims that 30 to 40% of the applied fertiliser is lost due to weeds. There are also well-known cases of weeds causing diseases and even death in human beings and cattle. Despite all this, very little is done by way of stopping weeds and whatever little is done is seldom timely and helpful.

PROBLEMS

There are a number of factors which contribute to this state of affairs, some of which are as follows :

1, The country has a large population of itenerant scrub cattle and any vegetation is useful to them as food, Even good establishments like several industries and airports do not show adequate concern for weeds because they feel weeds are profitable to sell to grasscutters or graziers. Weeds in such places are fire and security risks as well as impediments to efficient operations.

2. It is nobody's business to control weeds in rivers, canals, ponds, waysides and uncultivated land. Very little except occasional burning is done by forestry. All these are sources of reinfestations.

3. The people of this country are too poor and so steeped in squalor that they do not appreciate the beauty and utility of good vegetation management in general.

4. There is a great deal of unemployment including those of unskilled labour but to those who want to use labourers, either they are not available, or not available

1. Shaligram House No. 13, D-Road, Maharani Bagh, New Delhi.

when needed, or too expensive. Urban areas do not have enough or at acceptable rates and in villages they may not be available at the right time for weeding because preference is for other work like sowing (of rice), therefore, weeding is done late or in slow stages with manual labour that does not save the crop from weed competition. Consequently, the yield does not increase and the farmer gets confirmed in his belief that weeds do no harm !

5. There is no premium available to farmers for clean, weed-free harvest even though it is known that contamination by some weed seeds can cause serious health problems.

6. For cheap popularity, propaganda and sometimes for other ulterior motives, deliberately wrong weed control methods are adopted. These fail to deliver the goods with the result that the people laugh at these actions and campaigns, lose faith in their guides' ability to help them control weeds and become sceptics. (Example : recent campaigns to control *Parthenium* by manual uprooting, control of water weeds, grasses, and several deeprooted weeds by manual or mechanical methods. Hindustan Times even published a Scientist's statement purported to control *Parthenium* sp. by releasing mites which were known to attack valuable crops !)

7. Sometimes mixed cropping comes in the way of weed control by mechanical or chemical means.

8. Preplanting and preemergence chemicals for weed control are not popular among farmers.

9. Farm mechanisation, specially mechanical harvesting, has also contributed to the aggravation of weed problems.

10. Chemical herbicides have been generally recommended as an omnibus overall treatment like insecticides, whereas this is the field which offers the best scope for integration of a large number of factors.

All these factors have culminated in the present state of widespread and general failure and apathy among farmers and others.

SOLUTIONS

A consideration of the above points leads to some practical suggestions for preventing the expansion of weeds and of controlling them effectively.

1. Floating waterweeds like waterhyacinth should be declared as national problems, and each State should be bound to control them in rivers and other unowned water sources, the Canal administration for all irrigation and drainage canals, the farmers for the field channels and the Gram Sabha or Gram Panchayat for all other places in the territory of each village and roadside. There should be severe penalty for ignoring waterhyacinth and for allowing even one bulb to remain alive.

2. Other serious waterweeds (e.g. *Potomegeton* sp.)should be eradicated by using effective herbicides because manual and mechanical methods are not capable of eradicating them but simply spreading them further down the stream. Effective chemicals like Chloropicrin should be used even though it may kill fish in treated sections Fish can be recolonized after eradication is complete. If a biological control is available it should be used after chemical treatment to mop up remnants and keep the weeds under control.

Control of weeds on roadsides, uncultivated land, and on embankments should be also made the commitment of corporations or local bodies. Likewise, keeping the shrubs and hedges around homes and farmers plots should be the responsibility of the owners. They should be encouraged to do a good job of it by organising 2-3 yearly competitions between villages on an extensive scale. Chemical, mechanical, and manual methods will need to be used simultaneously depending upon the situation to ensure that the results are achieved on a lasting basis and can be maintained relatively after the campaign is over. It is not the object of this exercise to lay the land bare of vegetation but only to eliminate unwanted species and then to manage the rest into a useful, aesthetic, and orderly pattern. Uncultivated land may be turned into good pastureland and for recreational purposes. The shoulders of roads, canals, and embankments should be allowed to grow a thin layer of vegetation to prevent erosion. The layer is maintained then by mowing, chemical treatment or regulating water. Brush is best removed by spot treatment with chemicals like picloram which prevent resprouting. It is seldom realized that brush locks up too much ground water and crowds out all useful vegetation.

Cattle also spread weeds through seeds sticking to their coats in their droppings. If the grazing land is converted to well managed pasture and the number of cattle are restricted to the pasture capacity, this problem can be minimised. It is well accepted that a drastic reduction in cattle numbers and replacement by better breeds which are better fed and housed, is the crying need of animal husbandry in India.

Loss of farm productivity due to weeds is serious enough to justify reorientation of farm extension priorities. The farmers need much greater personalized guidance in weed control than for insect control because each case may need a different combination of weed control inputs to achieve acceptable results at the least expense. There is also less intense competition in herbicides than in insecticides, therefore, the extension agencies of manufacturers of different herbicides may conceivably one day work as a pool to train, extend and augment the efforts of the Government extension agencies in the context of weed control. This is also a field whose organising skill to achieve a pooling of resources on a whole village basis will pay rich dividends. All resources of men and materials should be mobilised and used as appropriate. Human labour being plentiful shoud be used as much as possible and where it can yield good lasting and timely control. Otherwise, chemical, mechanical or biological methods should be deployed selectively. In making a decision for monocropping or mixed cropping its bearing on implementation of weed control should also be considered. Grading and premium price for weed-free crop produce should be introduced.

Some examples where chemical weed control is preferable over other methods are given below :

1. Removal and eradication of perennial grasses and other grasses. Nonchemical methods do not give effective control and only spread the problem wider.

2. Removal of water weeds. Simultaneously, farmers should fit a wire screen into irrigation channels to prevent entry of pieces and seeds of weeds and should keep the ditch banks clean of weeds.

3. Removal of brush and stubborn vegetation which regrow if cut. Spot treatments would be economical and effective.

4. Topical treatment on parasitic weeds or other hardy solitary weeds in crops. This can be done by impregnated toothpicks or toy water pistols.

5. Control of weeds growing in the line of crops. Weeds in between the rows should preferably be controlled by manual or mechanical cultivation with added benefit of mulching and soil aeration. Use of preemergence or preplanting herbicides can give excellent results.

6. Maintenance of right of way for pipelines, railways, telephone and telegraph lines, high tension lines, firebreaks in forests, etc. These can not be supervised frequently, therefore, even if local labour is available good weed control can not be assured. Weed control is essentail in these situations for good and safe operation, and

7. overall weed control in crops where labour is not available timely. An effort should be made to define weeds and locations on which chemical control should be given top preference. This is necessary to remove the confusion created by common belief that all weeds can be controlled manually or mechanically. This action will reduce mischief and waste of national effort by misguided campaigns as the recent one of manual eradication of *Parthenium*.

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HOW TO STRENGTHEN WEED SCIENCE RESEARCH IN INDIA

S. V. RAO[1]

Weeds cause greater loss to crops than do insects and diseases. But there is no concerted move to prevent this loss by the governments, universities, administrators, and planners. When one speaks of pest management or pest control, he invariably refers only to insects and diseases but rarely to weeds. There are very few research institutions or universities in the country which have full-time weed scientists to work in weed science research. This compares very unfavourably with entomology and plant pathology not only in regard to the existence of separate departments but also in regard to the number of scientists engaged in full-time research.

The amount of money allotted and spent for weed research by various research institutions in the country is very meagre and quite inadequate to meet the challenges posed by weeds which are known to cause a Rs.2000 crore crop loss annually. The dogma that human labour is plentiful in this country to afford weed control manually does no longer hold true due to escalating labour costs, implementation of intensive and multiple cropping methods, and changes in the attitude of the farmer to regard farming as a business enterprise. The assumption that herbicides take the place of manual labour is only a myth and is not based on facts aud rationale. The pessimists can only look how the enterprising farmers in the Punjab and Haryana are clamouring for the use of herbicides to save their crops from weed competition and the success of chemical weed control in tea to become a permanent, viable, and profitable agronomic practice without replacing the labour.

Reorganization and strengthening of weed science research which comes under the purview of all institution engaged in research and extension of agricultural science can be done effectively by implementing the following suggestions.

1. Setting up of full-fledged Weed Research Units in all research institutions and universities with adequate staff and research facilities.

2. Appointment of only weed scientists to conduct weed research and extension activities.

3. Providing sufficient funds by the university and the state government to support these research and extension programmes in weed science.

4. Providing liberal financial support by national research bodies like ICAR and CSIR to weed research projects at various research institutions in the country to tackle weed problems.

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1. Weed Agronomist, Tocklai Experimental Station, Jorhat, Assam

5. Providing positions of weed scientist and supporting staff in all of the coordinted research projects of ICAR both at the centre and subcentres.

6. Setting up of a well-organized herbicides testing and certification programme (similar to the one already in existence at Tocklai) to determine herbicide efficacy and toxicity and to safeguard the harvest produce and soil from accumulating herbicide residues. Research institutions can generate part of the funds for research by collecting charges from herbicide industries for testing their products.

7. Setting up of proper coordination of research between weed science and other disciplines particularly soil science, entomology, plant pathology, botany biochemistry, and extension.

8. Directing weed research not only to screen and test herbicides but also to answer several other problems mentioned below :

a. Persistence, metabolism, and residues of herbicides in plant and soil.

b. Absorption and translocation patterns and mode of action of herbicides in plant.

c. Changes in weed spectrum due to continuous herbicide usage.

d. Use of adjuvants and antidotes to increase the efficacy and widen the margin of selectivity of herbicides.

e. Biology and life cycles of weed species.

f. Interaction of herbicides with other pesticides.

g. Determining the effect of weed control on incidence of other pests like insects, diseases, and nematodes.

h. Adoption of integrated approach and systems concept to weed research by taking the entire crop production practice as a unit or system and determining the effect of weed control on various agronomic, insect and disease control, soil and water management practiccs.

i. Integration of mechanical, biological, and chemical methods for effective, economic, and safer weed control.

9. Conducting conferences, seminars, and workshop meetings at national and state level to discuss progress of research, disseminate the recommendations, and coordinate research and extension programmes. Besides scientists, research workers, and administrators, these meetings should also be attended by farmers.

10. Setting up of publicity and publication activitics to advise on weed control practices, to answer weed problems and to disseminate the results of research.

11. Facilitating availability of several new herbicide compounds to :

(a) widen the choice, (b) avoid changes in weed spectrum, (c) lower the cost of chemical control, (d) minimize herbicide residues, (e) increase the efficacy in weed control, and (f) tackle special and persistent weed problems The present policy of central government to restrict the number of herbicides allowed to enter the country through imports needs to be modified to permit greater number of newer and useful chemicals.

12. Encouraging indigenous production of herbicides.

WEED SCIENCE AT THE INDIAN GRASSLAND AND FODDER RESEARCH INSTITUTE

T. R. DUTTA[1]

As a result of recommendtion of various expert committees and the problems that weeds are causing enormous damage in the country, the Government of India desired to set up a Central weed control Laboratory in Lucknow. Later, in view of some other constraints, this laboratory was made an integral part as a Division of weed Ecology and Control of the Indian Grassland and Fodder Research Institute, Jhansi, in December 1967.

The objectives of this Division was to carry out research on all aspects of weeds and their control on a national basis which *interalia* included investigations on the (i) botanical aspects of weeds, (ii) physiology of herbicides, (iii) development of suitable techniques for weed control by chemical and other methods, (iv) assessment of herbicide residues in plants, and (v) training of extension personnel, farmers, etc. on weed control technology.

The Division was organized in four separate disciplines, Viz., weed botany, herbicide and weed Physiology, weed control in agronomy, organic and biochemistry. Research was initiated without adequate laboratory facilities but in the course of time these had been extended and proper laboratory backing had become available since 1973. Briefly, the weed botany section had carried out research on weed ecology, systematic botany, survey and mapping and invasion of weed by competition. The plant physiology section has screened about 150 newly available herbicides in the world market and determined their selectivity. The organic chemistry and biochemistry sections have investigated problems of quality residue and synthesis of new herbicide analogues. The weed agronomy section has developed various methods of weed control and extended their findings to the farmers.

The infestation of weeds accounts for an average loss of about 35% in the fodder crops and the natural grasslands. Unproductive brush species occupy about 30% of the area. These species hove regeneration capacity and it is expensive to remove them by mechanical methods. Manual labour for weed control in the crops as well as in grasslands may become very costly or not available at the time of peak demands. The Division of weed Ecology and Control has been active in bringing in the fruits of current world research and the technology of the modern selective

1. Weed Ecology and Control Division, Indian Grassland and Fodder Rescarch Institute, Jhansi 284001

herbicides to the farmers. Modern herbicides allow us to control weeds without harming the crops and at a much more convenient, safe and very often in a cheaper way than manual methods of weed control. The scientists at this nstitute have developed, standardised, and demonstrated methods of control of weeds in most of the fodder crops and natural grassland currently known in India.

As every one knows, weeds not only reduce the yield of the crop but also compete for soil applied fertilizers and soil moisture. In order to conserve fertilizer and moisture, it is essential that weed control is practiced. In the pasture lands there are also several poisonous weeds which affect cattle. In addition, there are weeds which reduce the quality of animal produce such as milk, meat, and wool. So far scientists at the Institute have developed methods of control of weeds in the following crops : Beet (fodder), berseem, maize, oats, oats+clover (mixed crop), *Pennisetum pedicellatum* (Dinanath grass), sorghum or fodder (cv. M. P. Chari), teosinte, clusterbean (guar), cowpeas, lucerne. soybean, sunflower, turnip ; Brush control, broadleaf weed control, general weed control in reseeded grass lands ; kans *(Saccharum spontaneum)*, nutgrass, *Typha* sp., and waterhyacinth. For example, the methods of brush control in natural grasslands are so convenient now that it is no longer necessary to remove them expensively by repeated axing. Instead, we can use pellets of the herbicide piclorum which is broadcast along with fertilixers before the monsoon. The herbicide granules will selectively act and kill the brushes and weed species without harming the grass. Similarly, for axample, in fodder sorghum, we may simply use 1 kg/ha of atrazine in 700 litres of water sprayed to the soil just after sowing the seed. It will control most of the weeds.

Besides weed control in crops in grasslands, the scientists of the Division have worked out the control of several weeds of national importance. For example, the plant known as Kangres ghas in Maharashtra *(Parthenium hysierophorus)* and *Eupatorium adenophorum* in Nagaland are causing great harm to the national economy. Control methods for these weeds have been devised at this Institute. The weed *Typha*, which is causing immense harm in water-logged soils and invading crop lands, can be controlled by methods developed at this Institute. Another great national problem is the rapid spread in recent years of submerged aquatic weeds in reservoirs of river valley projects and emerged aquatic weeds in fishery lakes. Methods for various weed control tried/developed at the Institute have been demonstrated throughout the country.

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GUIDELINES FOR RESEARCH ON TILLAGE AND SEEDING PRACTICES

R. D. DRYDEN AND CH. KRISHNAMOORTHY[1]

ABSTRACT

Research on tillage practices should have the following objectives :

Control of weeds, seed-bed preparation and conservation of soil moisture in the non-crop season with surface tilloge using the country plough and blade harrow, beginning immediately after harvest and/or as soil moisture permits to prepare the land for early planting of crops.

Minimum or shallow blading following per-monsoon seowers and before and after planting to conserve moisture and control emerging weees.

Row seeding by one of the following local methods :

—plough and hand seeding
—plough and attached seed tube
—local multi-row cone seed-cum-fertilizer drill.

Inter-row blading and weeding in the crop as weeds emerge.

INTRODUCTION

The first concern of scientists should be to develop an economical sequence of field operations which will permit the farmer to seed early in moist soil free of weeds with his own tillage and seeding methods. Therefore, the scientist should emphasize research on what may be termed an appropriate technology, i.e., appropriate to the resources and supply of implements in the village.

To assist the farmer in adopting an improved weed control and early planting program as given in the paper on Year-round Tillage the following objectives are presented for the guidance of research scientists :

RESEARCH GUIDELINES

It is important that the scientist be aware of the following factors when attempting to introduce a new practice or new machine to a large number of farmers, e.g., on a district or state basis.

1. Canadian Adviser and Assistant Director General-cum-Project Director, respectively, All India Coordinated Research Project for Dryland Agriculture, Hyderrbad - 500013, A.P.

The acceptability and suitability of the new practice depends on the following considerations :

—cost of new practice or machine.

—energy requirements. Usually only bullock power is available.

—Supply situation-can the implements be fabricated and repaired in the village ? Supply and repair of machines from sources outside the village are usually unreliable,

—introduction of a new practice or machine may require changes in subsequent tillage, seeding and weeding methods with the result that an increased investment in other implements is required. Examples are : A change of row spacing requires changes in seed-draill and blade harrows for inter-culturing. Mouldboard ploughing requires discing as an additional operation to break the clods. Ridge-furrow planting requires a completely new set of implements.

—significant implements in production are possible without major changes in tillages, seeding and weeding implements.

Scientists should become familiar with the tillage and seeding practices in different regions. For example, in some districts farmers have achieved a relatively high level of soil management, timely seed-bed preparation and seeding with a comparatively low level of energy input, e.g., use of the wide blade harrow and cone seeder in the Deccan rabi region. In contrast, there is the situation of low level management i.e , poor weed control but high energy input in the Bangalore, Hyderabad, Ranchi, and Ludhiana districts. In these areas, farmers do not use the blade harrow and depend only on the country plough for tillage and seeding. The introduction of the blade harrow in these districts would improve crop production significantly.

Some experiments with tillage practices include operations only during a part of the year, e.g., just before planting. Since growth of weeds depends upon soil moisture throughout the year, operations before planting alone are unlikely to be of much benefit. In fact, weed problems may increase under such conditions.

Scientists sometimes claim that tillage may improve soil texture, e.g., deep mouldboard ploughing to mix lower level clay with surface sandy soil. However, since these experiments usually include high weed populations, it becomes very difficult to determine the cause of the improved yields, i.e., soil improvement or weed control. Soil improvement studies should be conducted on weed-free fields.

Some experiments compare deep mouldboard ploughing with medium and shallow discing. Since neither the mouldboard plough nor the disc is available in most villages such studies are of little real value for improved crop production on a large scale. For many years to come the farmer must depend on surface cultivation, i.e., ploughing with the country plough and blading with the blade harrow.

Experiments on tillage practices should monitor soil molsture conservation, erosion control and weed population in the non-crop season as well as in the crop.

CONCLUSION

Scientists must distinguish between what is technically possible with non-village inputs and machines operated by the scientist and what is economically feasible for the farmer. Research should provide low cost answers to what are usually the basic problems. Scientists should determine the value of established practices before discarding them and attempting to introduce new methods.

Emphasis for research should be more on management than on machinery. The concern is how to use existing resources. This approach does not preclude the use of more sophisticated tools and implements as they become extensively available. A farmer readily accepts them as his economic conditions improve.

A. WEED SCIENCE CURRICULUM

Workshop Discussion

In his opening remarks, the Chairman of the Workshop emphasized that there is great need to have weed science curriculum for undergraduate and postgraduate students, and also short-term courses for in-service candidates.

In this Workshop, five papers were submitted but only three were presented and discussed. Dr. Gautam and his colleagues in their paper entitled, "Theoretical and practical instructions in weed science," defined weed science and suggested that emphasis should be given on principles and practices of weed control at undergraduate level. But at postgraduate level, there should be more emphasis on fundamental and applied aspects of weed control. Instructions in theory at the PhD level should relate to concepts in herbicide research, physiology, biochemistry, and lethal and selective mechanisms.

Dr. Sankaran, in his paper entitled, "Syllabus for the weed control courses offered to P. G. students," observed that weed science should be a part of agronomy discipline. He suggested 20 credit courses of weed science. Of these courses, a 3-credit course should be made compulsory for all the postgraduate agronomy students. The same course in weed science may also become a part of integrated pest management course.

Dr. Bhan, in his paper entitled, "Teaching programmes in weed seience," emphasized the inclusion of Weed Science as one of the minors with major in agronomy. He was of the opinion that weed science as a minor course should be equivalent to approximately 15 credits. The course should be so designed that it covers herbicide mode of action and degradation, advances in weed science, and application equipment, etc., in order to meet future job opportunities for such graduates.

GENERAL RECOMMENDATIONS

While discussing these papers, the invitational paper presented by Dr. Krishnamurthy was also taken into consideration and the following recommendations were made :

1. More stress should be given to weed science education and it should form a minor course in agronomy discipline at the postgraduate level in all the Agricultural Universities.

2. In the undergraduate programme a weed control course should be a minor. Credits for this course should be adjusted within the available course credits of Agronomy Department.

3. At PhD level a course of 3 credits on weed control should be made compulsory for all graduate students majoring in agronomy. Even other students in Plant Protection, etc., may be advised to take this course.

4. A short term course should be arrangd for inservice candidates at all the Agricultural Universities to train Government extension and industrial personnel. The course content may be made according to local needs.

5. The Workshop participants decided to have a sub-committe to draft details of curriculum for weed science at undergraduate and postgraduate levels. The recommendations of the Committee follows.

Sub-Committee Recommendations

6. It was recommended that a 3 credit (trimester) course, *Introductory Weed Science*, be made compulsory for all undergraduate students. The credits needed for this course may be obtained by rescheduling the credits available in Agronomy Department/Agriculture Faculty (see courses below).

7. It was recommended to have four courses (of 13 credits) for postgraduate students specialising in Weed Science. Of these, the first course should be made compulsory also for *all* Ph. D. students (see courses below).

8. If there are already Weed Science courses listed for postgraduate or Ph. D. levels in any Agricultural University, then such courses may be revised, keeping in view the present recommended courses and course contents (developed on All India basis). These courses may be offered by the staff competent to do so.

Weed Science Curriculum in the Agricultural Universities : Courses Prepared and Recommended by the Workshop Sub-Committee.

Weed Science Course for Undegraduates :

1. Introductory Weed Science (2 + 1).

Weed definition; weed identification and classification.
Scope of weed control.
Principles of weed control.
Weed control methods - cultural, biological, chemical.
Herbicide classification.
Herbicide mode of action and uses.
Methods and time of herbicide application in field crops.
Herbicide schedule for crops.
Special weed problems in crop and noncrop situations.
Application equipment.

Weed Science Courses for Postgraduates :

1. **Weed Control** (2 + 1), a core course

Concepts of weed -crop associations, magnitude of crop losses.
Weed control methods.
Herbicide selectivity, uses on weeds and in cereals, pulses, vegetables, oil seeds, fibre crops, plantation crops, forests (nurseries), pastures and turfs, and non-agricultural situations.

2. **Herbicides** (2 + 1).

History and development of herbicides; basis of classification.
Absorption, translocation, mechanisms of phytotoxicity of herbicides.
Selectivity behaviour of herbicides in soil, plant, and environment.
Residue problems.
Formulations and compatibility of herbicides.
Use of labelled compounds in herbicide research.

3. **Advances in Weed Science** (2 + 1).

Integrated weed management ; weed management in cropping systems.
Crop sanitation.
Weed shifts; surveillance and forecasting weed problems.
Weeds as detectors of pollution.
Labour utilization and economics of herbicide use.
Developing action plans.
Weed control acts and regulatory laws.

4. **Problem Weeds** (1 + 1).

Important weed problems in crop, noncrop, and aquatic situations.
Weed distribution, weed biology.
Principles and methods of control.

5. **Application Equipment** (1 + 1).

Principles and methods of application.
Equipments needed for different situations.
Common problems experienced in handling equipment.
Hazards and precautions during applications; remedies.
Trends in developing equipment for different sets of situations.

Chairman	:	Dr. V. M. Bhan.
Coordinator	:	Dr. K. Krishnamurthy.
Reporters	:	Dr. K. C. Gautam and Dr. A. S. Indulkar.
Sub-Committee	:	Dr. K. Krishnamurthy (convenor) (UAS).
	:	Dr. U. C. Upadhyay (MAU).
	:	Dr. A. Mishra(OUAT).
	:	Dr. V. M. Bhan (GBPUAT).
	:	Dr. S. Sankaran (TNAU).
	:	Dr. K. C. Gautam (IARI)

B. WEED RESEARCH NEEDS IN INDIA

The workshop recognized the need for improving the coordination of weed research activities in the country based on the following considerations :

1. Identification of weed problems in major cropping systems, acquatic environment, and nonagricultural situations on a techno-economic basis at regional level.
2. Inculcation of multi-disciplinary group approach in the development of integrated weed management practices to solve these weed problems.

For this purpose the Workshop recommended the creation of :

1 A CENTRAL COORDINATION BODY for weed research and extension and

2 REGIONAL COORDINATING CELLS at agricultural universities and cooperative national and international programmes.

Given these facilities, the Workshop identified the following fundamental and applied research needs and corresponding priorities of work.

Fundamental Research

1. **Short term (under 5 years)**

a Identification of the important weeds and weed problems of the main cropping systems covering commercial, food, horticultural, and vegetable crops.

b Herbicide testing programme in relation to the above identified needs for different soils, cropping systems, farming methods, weed situations, and noxious weeds.

2. **Long term (above 5 yeaps).**

a. Weed biology and ecology, including aquatic, parasitic and noxious weeds.

b. The impact of extended chemical weed control on the soil environment (soil fertility, soil structure, and soil microflora, etc.)

c. Herbicide formulation research in relation to the application needs and possible utilization of indigenous raw materials.

d. Development of herbicide "antidotes" to enlarge the spectrum of herbicide selectivity.

e. Studies on the tolerance mechanism in weeds and crops.

f. Identification and forecasting of succession of (or shift in) weed flora due to continuous use of berbicides and changes in cropping systems.

g. Investigations on crop-weed competition and allelopathy as a possible mechanism in mixed weed communities and pasture lands.

Applied Research :

1. Short term (under 5 years).

a. Studies on critical timings of weed control in relaticn to crop and weed growth stages in major crops.

b. Weed control in relation to fertilization schedule for major crops.

c. Weed control in fallow fields, year-round tillage with farmers' implemets and (or) suitable weed control chemicals with low energy requirements.

d. Minimum or zero tillage to enlarge the scope of multiple cropping with special reference to conservation of time and water and to prevent soil erosion.

e. Techno-economic studie on the use of herbicides in conjunction with manual or mechanical operations, and the use of herbicide combinations.

f. Herbicide application research with a view to develop suitable equipment and application techniques.

g. Research on effective control measures for aquatic, nonagricultural, and other noxios weeds.

h. Improvement of extension and communication methods and facilities for effective transfer of technology for the benefit of the farmers-

2. Long term (above 5 years)

a. Studies on the scope of improving herbicide efficiency by the addition of suitable adjuvants and synergists.

b. Development of weed management practices for minor crops in the cropping sequence.

Residue Studies :

There is a need for urgent studies on herbicide residues in crops and soils, to meet the registration reduirements under the Insecticides Act (1968) and to ensure continuity in the supply of herbicides. The Indian Society of Weed Science (ISWS) in cooperation with the Central Insecticides Board should identify laboratories eduiped to undertake residue analysis. The ISWS should also be represented in the Herbicide Panel of the Central Insecticides Board.

Finally, the Workshop urged the Indian Society of Weed Science to ensure that these recommendations are forwarded to appropriate agencies such as ICAR, UGC, CSIR, Agricultural Universities, and State Deprtments of Agriculture and to pursue these suggestions with them towards timely and effective implementation.

Chairman : Dr. V.S. Rao

Coordinator : Prof. V.S. Mani

Reporters : Dr. K.G. Pillai and Dr. D.N. Sen

Principal Contributors :

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Mr. R. Dryden	Dr. D.J. Chandra Singh
Dr. V.S. Rao	Dr. V.S. Sharma
Dr. D.N. Sen	Dr. Nagarajan
Mr. R.K. Pandey	Dr. Samuel
Dr. MG. Srivastava	Dr. Mohammed Ali
Dr. N.S. Negi	Mr. C. Parker

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A. INVITATIONAL PAPERS

Some of the salient points of the paper on "Status of weed science curriculum in India and the need for weed science curriculum in the agricultural universities" by Dr. K. Krishnamurthy :

1. The great damage done by weeds in reducing crop yields makes it necessary to have a stronger insight into the science of weeds and their control.
2. The teaching and research in crop production and crop protection has to be suitably oriented.
3. A separate course on Weed Control should be offered for undergraduate students in agricultural Universities by the Departmenr of Agronomy. Specialised courses should be offered at MSc and PhD levels to improve Weed Science education and research. It would be desirable to have a weed science section in the Agronomy Department to offer Weed Science courses. Specialised staff members should teach Weed Taxonomy, Herbicide, Physiology, Residue chemistry, etc.
4. Some of the points made by the delegates in the discussion that followed are :
   a. Some short term courses of practical nature should be offered for extension workers.
   b. Offer courses on forest weed ecology and orchard weed management.
   c. Students majoring in entomology and plant pathology should have opportunity to take Weed Science as minor course.
   d. Special emphasis on the control of problematic' aquatic, and parasitic weed to be included in the curriculum.
   e. Emphasis on application epuipment.
   f. Inclusion of courses on weed ecology and physiology.

In his concluding remarks the Chairman suggested to have fewer courses with a provision of a number of courses as electives. He also suggested that in the workshop to be held in the afternoon on this subject a separate Sub-Committee be formed to formulate the course details.

Succeeding speakers discussed the research needs in India and in the tropies in general. The afternoon session dealt on weed research needs of the small farmers, prorgress of weed research in tea, and the economics of weed control.

Prof. V.S. Mani (IARI, New Delhi) discussed the weed research needs in India. The following are the major points. Fundamental and applied research on

weed science and weed control should be intensified. Effective, safe, and economical method of weed control should be developed. Weed Research Units should be established at various Agricultural Stations and the ICAR may be requested to initiate the All India Coordinated Project on Weed Management.

During the discussion the participants stressed the need for problem-oriented research leading to economical methods of weed control suitable for adoption by the farmers.

Mr. C. Parker of the weed Research Organization, U.K·, discussed the weed research needs in the tropics. These are his suggestions :

1. Economics, education, and extension should be emphasized as means of solving weed control problems.

2. Research on control of perennial and parasitic weeds should be strengthened in tropical farming.

3. In a country like India handweeding will continue for quite a long time and as such we have to associate or combine cultural and chemical methods of weed control.

4. In planning research work on weed control, shifts in weed species due to continued use of herbicides should be studied in detail.

5. Research on biological control of weeds.

6. Development of more granular herbicides for each crop for easy application. In dryland agriculture weed control is of paramount importance and we should concentrate on this aspect to help the farmers.

7. Research on application techniques involving no risk to the farmers.

8. Many participants took part in the discussion that followed. Some of the Points made are :

a. Study of residual activity of herbicides in vegetable crops.

b. Institution of a control cell to analyze crop residues.

c. Formulation of weed management schedules for cropping systems instead of individual crops.

d. Breeding herbicide tolerant varieties, involving breeders in weed research programmes.

Chairman : Dr. A. Appa Rao

Reporters : Dr. S. Sankaran and Dr. U. C. Upadhyay

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B. TECHNICAL PAPERS (CONSOLIDATED REPORTS)

Session on rice :

The papers dealt with weeds, their competition with rice and their control in rice cultures.

1. The common weeds reported were : *Echinochloa crusgalli, E. colonum, Fimbristylis miliaceae, Ammania baccifera, Panicum* sp., and *Cyperus difformis* in low-land and *Cynodon dactylon* and *Cyperus rotundus* in upland rice crop.

2. Weed-free condition up to 21 days from planting provided the most economical weed control system in transplanted rice.

3. Weed control capacity of rice varieties against *Ammania :* tall rice varieties (more than 100 cm in height) such as Nagina, Dhaneswar, and Saket-1 were capable of suppressing the wced.

4. Chemical weed control in transplanted rice : The promising herbicides were C-288, butachlor, C-19490, USB 3584, bifenox, oxadiazon, penoxalin, 2,4-D IPE, bentazon, benthiocarb, and propanil. The chemicals were effective in controlliog weeds and increased grain yield. USB 3584 and propanil were also effective in controlling weeds in upland rice. A trial report on bifenox tested in different locations in West Bengal showed the following results. Bifenox (2 and 2.5 kg/ha) or bifenox (1 kg/ha) in combination with propanil (0.7 kg/ha) or butachlor (0.85 kg/ha) increased crop yield compared to the handweeded control.

5. Some aquatic weeds such as *Salvinia, Eichhornia,* and *Typha* are also troublesome in rice lands. Control measures of these weeds are necessary for better rice production.

6. Comments of participants : many herbicides tested in the field and found effective and suitable for weed control in rice were not available in the market. This session should note this and request the Government, through the ISWS. to make such effective herbicides available in the market.

Chairman : Dr. Bibhas Ray

Reporters : Dr. M. M. Hosmani and P. A. Sarkar

Session on fruit trees, banana, pineapple, mulberry and tea

1. Work on the use of chemicals which have been proved to be toxic to crops-for example bromacil on banana-should not be carried out any further.

2. Work on the use of herbicides in fruit crops should be intensified.

3. Work carried out already in perennial crops should be given priority in evaluation as the adoption is widespread in these crops more than in any other crops.

4. Intensified work should be carried out on the specific problems as in soil conservation, residue analysis, long term effects of herbicides on crops and soil, and problem of shifts in weed problems due to continued use of herbicides.

Reporter : R. Padmanabhan

Session on fibre and sugar crops :

1. Use of alachlor + one handweeding was found effective for weed control and better yield in jute.

2. Cultural and chemical methods were effective for weed control in cotton, while chemicals were found effective for irrigated cotton.

3. Pyrazon was found promising for weed control in sugarbeet.

4. Sugarcane showed differential tolerance (susceptibility) to triazines and substituted urea herbicibes.

Session on herbicide screening and industry development of herbicides.

1. Herbicide screening : The technique of screening herbicides at ICRISAT was described by Dr. S.V.R. Shetty. Field screening is an important step in evaluating the efficacy, toxicity, and residue of herbicides. The session emphasized the need for standardisation of the technique to enable valid comparisons of the findings of various workers. In this context proper selection of standards, adoption of application techniques in iine with the nature and mode of herbicide action and uniformity in the scales of rating are critical. It was suggested that Dr. Shetty and Mr. P.N. Pande (ACCI) prepare a guideline note for the use of research workers and that the ISWS should ensure its widest possible circulation. In preparing the guidelines, it is important to refer to the criteria adopted by other countries and institutions abroad.

2. New herbicides : The introduction of penoxalin (Cyanamid) and nitrofen (Indofil) was reported. The effectiveness of these herbicides on Indian crops and the areas and scope for further evaluations were reviewed. Another review paper dealt on the current status of the organic arsenical herbicides, including registration position in the USA and in India. It was observed that the fear of harmful arsenic residues seems to have been exaggerated. Arsenical herbicides should not be used at very high rates.

3. Herbicides in subsistence farming : In a conceptual paper, Mr. P.N. Pande critically analyzed the constraints of the farmers in subsistence farming situations. Based on his experience, the author opined that there was a definite scope for herbicidal weed control but for initial introduction simpler, cheaper, and easily available herbicides should be selected. He emphasized the need for stepping up extension and farmer education programmes and advocated greater use of radio and production of suitable films.

4. *Biological control of weeds :* Dr. Meera Gupta reviewed the present status of biological weed control for selected noxious weeds by the use of insect pests and pathogens. Studies on *Eichhornia* and *Lantana* are in progress.

Summing up, the Chairman deprecated the use of brand names and dosage description in terms of formulations. He advised the research workers to use chemical or accepted common names and to state rates in terms of active ingredients (*ai*) or acid equivalent (*ae*) in the future.

Chairman : Dr. M.G. Srivastava

Reporters : Dr. R.K. Pandey and Mr. H.M. Mehta

Sessions on weed problems and control of problem weeds, parasitic and aquatic weeds.

There were many papers under this topic but few comments were raised by the participants. Some of the important weed problems included the following : *Avena fatua*, *Phalaris minor*, *Cyperus rotundus*, *Carthamus oxyacantha*, *Eupatorium adenophrum* (syn. *E. glandulosum*), *Solanum elaeagnifolium*, *Saccharum spontaneum*, *Ageratum conyzoides*, *Cynodon dactylon*, *Hyptis suaveolens*, *Lolium temulentum*, *Abelmoschus ficulneus*, *Bainvillea latifolia*, *Prosopis juliflora*, *Oxalis acetosella*, *Xanthium slrumarium*, and *Parthenium hysterophorus*. The parasitic weeds are : *Orobanche cernua*, *Cuscuta chinensis* and *Striga* sp. The important aquatic weeds are : *Eichhornia crassipes*, *Salvinia molesta* (=*S. auriculata*) and *Typha angustata* and *T. elephaantina*.

Parthenium sp was considered the most important weed problem in India and, consequently, received the most attention of the scientists as evidenced by the number of papers presented on its biology, ecology, and control. *Solanum* was also given prominent consideration.

1. During the discussions on the control of parasitic weeds (Cuscuta, Striga and Orobanche), suggestions were made to explore the possibilities of screening seeds of commercial crops for any contamination so that such seeds could be separated whenever possible. There should also be direct research to arrest the spread of these weeds as it has been done in the U. S. in the case of *Striga*. Comprehensive studies are required for a better understanding of the phenology of these special weed problems so that effective measures could be evolved to control them.

2. Aerial spraying of herbicides for aquatic weed control, now being given a try in the country, should receive more concern and investigations in this direction should be undertaken.

3. The apprehensions about the possible contamination of water sources and toxicity to fish and cattle by the use of chemicals for the control of water weeds were discounted by the experts. At the recommended dosage, herbicides have been found safe to fish and other aquatic life. However, it was necessary to apply herbicides at the proper time to avoid the choking of fish by the sinking weed debris.

Chairmen : Dr. D. N. Sen and Dr. V. S. Sharma.

Reporters : Dr. V. N. Saraswat and Dr. R. K. Maiti.

I S W S OFFICE BEARERS
JANUARY 1977 TO DECEMBER 1978

New office bearers were elected during the Business Meeting on Jan. 18, 1977. The meeting was presided by Prof. V. S. Mani, ISWS Vice President and convened by Dr. S. R. Obian, Chairman of the Programme Committee of the Conference.

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★

THE FOLLOWING STANDING COMMITTEES HAVE BEEN FORMED TO COORDINATE ON VARIOUS MATTERS OF INTEREST TO ISWS (1977-78)

1. Weed Research Task Committee.
   Dr. V. S. Rao, Chairman
   Dr. M. G. Srivastava, Dr. N. S. Negi, Dr. H. S. Gill, Dr. H. G. Singh, Dr. (Mrs.) Githa Kulshrestha.
2. Weed Science Education Task Committee
   Dr. K. Krishnamurthy, Chairman
   Dr. U. C. Upadhyay, Dr. V. T. Rahate, Dr. S. Sankaran, Dr. A. Venkatachari, Dr. A. Misra, Mr. K. C. Gautam.
3. Weed Identification and Terminology Committee
   Dr. D. N. Sen, Chairman
   Dr. V. S. Sharma, Dr. M. M. Hosmani, Dr. T. R. Datta, Mr. M. Lall, Mrs. Kusha Verma.
4. Herbicides Committee
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7. Membership and Liaision Committee
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   Dr. Bibhas Ray, Dr. A. Venkatachari, Dr. J. S. Sawhney, Dr. V. S. Vijay Kuma.
8. Awards Committee
   Dr. V. M. Bhan, Chairman
   Dr. K. G. Pillai, Dr. C. L. Dhawan, Dr. E. Marshall, Dr. D. J. Chandra Singh
9. Finance and Auditing Committee
   Dr. A. Venkatachari, Chairman
   Dr. A. S. Indulkar, Mr. S. V. S. Sastry, Mr. M. Lall, Dr. K. G. Pillai.

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WEED SCIENCE CONFERENCE AND WORKSHOP

Justifications and Objectives

Justification

The Indian Society of Weed Science was organized in 1968 "to advance the development of weed science and weed control in India" by the coordinated efforts of the educational, research, and industrial sectors of the country. At the same time the Indian Journal of Weed Science was also established as the technical publication of the Society to "chronicle the work of the members" so that the new weed control technology could be utilised in agriculture.

India was the first to organise a weed science Society in Continental Asia, yet the progress of weed science in India has not been advancing as rapidly as anticipated or as compared with some of the countries in the region. It is beyond doubt that there are considerable number of weed scientists in the country who are involved in teaching, research, extension, or in herbicide development and marketing. But the absence of frequent interactions among these different "groups" makes it difficult for the technology of weed science to come close to being utilised at the farmer's level or for the farmer's weed problems to be studied thoroughly. The immense diversity of the country's crops, soils, and climate requires cooperation and collaboration among the local scientists in pursuing the task of understanding the complex biology and control of weeds. Therefore, we need more frequent National Conferences for a collective national effort to advance the development of weed science. Work of Indian scientists are now gradually being published in foreign journals which are often beyond the reach of local plant protection specialists and agronomists.

The importance of weeds is well known. During 1973, the crop loss in the country due to pests was estimated to be about Rs. 5,000 crores (18% of the national production). Of these, 33% (R. 1,650 crores) was due to weeds, while diseases constituted 28% (Rs. 1,400 crores) and insects, 20% (Rs. 1,000 crores). The present situation is complex and it may be reflected by the following observations.

The number of weed scientists is very small compared to entomologists and plant pathologists both in the universities and in research institutes. Weed Science is seldom included in the curricula of agricultural colleges and universities. There are well developed departments of entomology and plant pathology but none on weed science in any school in India. The agricultural graduates coming out of the universities have very little background or knowledge regarding weeds and weed control. Thus, while weeds are the major causes of yield reduction of the main food crops in the country, we find that there is very megre attention given to the discipline both at the university and at the ressarch sectors.

Yet it is also true there are important work being done in various organizations which, if communicated, may benefit not only India but also other countries, especially the small scale farmers of the developing world.

Considering the modest progress of weed science research and education in India, it is highly desirable that 9 years after the founding of the Society, the Indian weed scientists meet once again to review the advances in weed science, to reassess the goals of weed science in view of the changing concept of plant protection (pest management) in modern agriculture, and to define future work priorities in order to be able to meet through individual and collective efforts, the new challenge of increasing food production.

Objectives :

1. Provide an opportunity — and a forum — for weed scientists and other plant protection specialists to come together and discuss their ideas and problems of mutual concern and to prepare plans for future activities.
2. Analyze critically the present status of weed science in the country and examine its future role in the changing objectives of modern agriculture in India.
3. Assess the present position of Weed Science in the curricular offerings of the agricultural college and universities and, in a Workshop, discuss the rationale and goals of a Weed Science curriculum and its implementation in India.
4. Through this Conference and with the revitalization of the Indian Society of Weed Science, the following goals could be discussed, promoted, or achieved :
   a. Improve coordination among scientists in the country .. through better communication media, including regular issues of the Society Journal, Society Newsletter, and Society Conferences.
   b. Set research priorities.. so that the weed problems of the country may be solved in an orderly manner through team efforts and collaborative action.
   c. Promote the rapid development of modern cultural, ecological and chemical weed control methods for the major crops in India .. and the extension of this knowledge to farmers and other users of this technology.
   d. Consider ways by which ambitious and enthusiastic students undergraduates and postgraduates to become interested in pursuing careers in weed science, to provide the man-power required by university education, research institutes, and the pesticide industry.
   e. Increase public awareness.. of the harmful effects of various kinds of weeds and of the nature and success of modern weed control methods in combating urgent weed problems that are detrimental to the production of food and fiber, to public health, and to the environment.
5. Evaluate the views of the various sectors of the national and international scientific community as well as of the pesticide industry.. on the appropriate approach to weed research which will help solve the problems of the small scale farmer, the progressive farmer, and other components of the agricultural sector.

1. CEREAL CROPS : RICE

WEED PROBLEMS IN RICE AND POSSIBILITIES OF CHEMICAL WEED CONTROL

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Unlike insect pest and disease outbreaks, crop losses due to weed competition often fail to create a sensation because of the fact that the damage is not clearly of a visual nature, The spread of modern dwarf rice varieties coupled with an increase in fertilizer use and poor land preparation often lead to serious deline in grain yields. Field experiments conducted at the headquarters of the All India Coordinated Rice improvement Project at Hyderabad and at the cooperating centres all over the country have shown that the predominant weed species under lowland rice culture were mostly grasses and sedges like *Echinochloa crusgali' E. colonum Panicum* sp., *Fimbristylis miliacea* and *Cyperus* sp. However, under the upland conditions perennial sedges like *Cyperus rotundus* and grasses like *Cynodon dactylon* were posing major problems. Herbicide screening trials have indicated that butachlor, C 19490 and USB 3584 (dinitramine) alone or in combination with the isopropyl ester of 2, 4-D, and another triazine compound C-288 opplied at 4 to 6 days after planting or sowing under lowland rice culture recorded excellent weed control and superior grain yields of rice comparable to handweed plots. However, in the uplands the choice of herbicides at present is limited only to butachlor, USB 3584, and propanil although none of them are sufficiently effective in controlling all the weed flora under such heavily weed infested conditions. Management of weeds by adopting suitable crop rotations and cropping patterns to bring about possible alterations in the weed community, adoptions of improved culture and water management practices and herbicide application to the extent possible should form the basis of an integrated approach to meet the future challenges in weed control.

STUDIES ON THE CROP-WEED COMPETITION IN TRANSPLANTED RICE

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Tamil Nadu Agricultural University, Coimbatore - 3

A field experiment was couducted in tall indica rice (*Oryza sativa* L. 'Bhavani') during summer 1976 at Tamil Nadu Agricultural University, Coimbatore. The soil was clay loam with shallow depth of water throughout the crop growth. Weed-free

condition up to 7, 14, 21, 28, 35, 42, and 49 days from planting and unweeded control formed the treatments. Weed-free condition was maintained by giving manual weedings. The trial was run in randomized block design with three replications. Following the normal practice, two seedlings were planted in line at the rate of 400 seedlings/sq m, adopting a spacing of 20 cm between lines and 10 cm between plants. The predominant weed species in the field were: *Echinochloa colonum* Beauv., *Echinochloa crusgalli* Beauv., *Cyperus difformis* L., *Fimbristylis miliaceae*, *Marsilea qudrifoliata* L., *Eclipta alba*, and *Ammania baccifera*.

The results indicated that weed-free condition up to 21 days from planting was sufficient for getting economic yield in transplanted rice. Low weed population and dry matter production of weeds and more productive tillers in rice were responsible for increased yield in plots maintaining under weed-free condition up to 21 days from planting. Maintaining weed-free condition beyond three weeks did not enhance the rice yield significantly.

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3. A STUDY ON THE WEED CONTROL CAPACITY OF RICE VARIETIES WITH SPECIAL REFERENCE TO *AMMANIA BACCIFERA* L.

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An investigation was conducted during the wet season of 1975, at Allahabad Agricultural Institute, to study the effect of certain varietal characters of different high yielding rice (*oryza sativa* L.)cultivars on light transmission ratio (LTR), and the resultant effect on population and dry matter production of *Ammania baccibera* L. The *Ammania* weed is commonly associated with lowland rice crop of different rice growing regions of India. At Allahabad, its intensity may be as high as 300 to 400/sq m.

The rice varieties or cultivars under study were Nagina 22, Dhaneswar, Saket-1, Saket-3, Saket-4 Norin8, Bala, Kanchi, Cauvery, Ratna, Jaya, Sona, RP4-14, RP79-13, RP79-14, RP79-22, and RPI89-3.

Varieties that were tall (more than 120 cm in height), like Nagina 22, Dhaneswar and Saket-1, gave low mean values of LTR (23.0). The data on weeds per 0.2 sq m. were : number of weeds, 54 ; fresh weight, 23.7 g ; and dry weight, 3.8 g.

The varieties having medium plant height (between 100 cm to 120 cm), like Saket-3 and Saket-4, showed moderate mean values of LTR (36.2). The data on weeds per 0.2 sq, m. were fresh weight, 25.7 g ; and dry weight, 4.0 g.

The dwarf varieties (less than 100 cm in height), like Bala, Kanchi, Cauvery, Norin 8, RP 79-22,RP79-5, RP 79-13, RP 189-3, RP 79-14, Sona, Jaya, Ratna & RP 4-14,

gave the highest mean values of LTR (46.6). The data on weeds per 0.2 sq. m. were : number of weeds, 71.3 ; fresh weight, 32.3 g ; and dry weight, 5.4 g.

These observations showed that plant height and LTR influence the intensity of *Ammonia* present in transplanted rice.

COMPARATIVE EFFICIENCY OF DIFFERENT HERBICIDES FOR THE CONTROL OF WEEDS IN TRANSPLANTED RICE

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A field experiment was conducted in Tamil Nadu Agricultural University during summer season, 1976 to study the efficiency of different herbicides for the control of weeds in rice (*Oryza sativa* L. 'Co 37'). The experiment was laid out in randomized block design with three replications. Treatments comprised of oxadiazon (1, 1.5, and 2 kg/ha), C-288 (1 kg/ha), penoxalin (1.5 kg/ha), butachlor (2 kg/ha), a hand-weeded (twice) and an unweeded control plots. Herbicides were applied 6 days after transplanting. There was significant reduction in the number and dry matter production of weeds in treated plots compared with the control plots. Among the herbicide treatments, weed control efficiency was in the order of penoxal in, butachlor, and oxadiazon at 1 kg/ha. Maximum yield was obtained in penoxalin (5370 kg/ha), followed by butachlor (5307 kg/ha) and oxadiazon at 1 kg/ha (5203 kg/ha). The grain yield in hand-weeded plot was 4998 kg/ha which was followed by C-288 (4723 kg/ha). All the above treatments were significantly superior to oxadiazon at 1.5 and 2 kg/ha. The unweeded check gave the lowest yield (2210 kg/ha). The study showed that application of penaxalin (1.5 kg/ha), butachlor (2 kg/ha), and oxadiazon (1 kg/ha) were economical.

RELATIVE EFFICIENCY AND METHODS OF APPLICATION OF HERBICIDES IN TRANSPLANTED RICE

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A study was undertaken during 1976 to find out the efficiency of herbicides and their methods of application in transplanted rice (*Oryza sativa* L. 'Bhavani') at Tamil Nadu Agricultural University, Coimbatore. Dinitramine (0.4, 0.6 and 0.8 kg/ha) was applied preplant on the day of planting. Oxadiazon (0.75, 1.25 and 1.75 kg/ha) and butachlor (1.5 kg/ha) were applied at 6 and 10 days after planting respectively. These treatments were compared with conventional hand-weeding. The trial was conducted in randomized block design with three replications. The major weeds in the field

were : *Echinochloa colonum* Beauv., *Echinochloa crusgalli* Beauv., *Cyperus difformis* L., and *Fimbristylis miliaceae* L. Results of the experiment showed that manually weeded plots had the highest yield (5290 kg/ha), followed by oxadiazon (4788 kg/ha) and butachlor (4776 kg/ha). These treatments showed low population and dry matter production of weeds per unit area and, consequently, more productive tillers in rice. Oxadiazon at 0.75 kg/ha gave a yield of 4788 kg/ha whereas the yield at 1.25 kg/ha) was 4581 ka/ha. At the highest dose of oxadiazon (1.75 kg/ha) reduction in yield was noticed due to a reduction in the number of productive tillers. Application of preplant dinitramine was not effective for controlling weeds under lowland condition.

STUDIES ON CHEMICAL WEED CONTROL IN TRANSPLANTED RICE

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The effectiveness of several liquid and granular herbicides in controlling weeds in transplanted rice *(Oryza sativa* L.*)* was evaluated in field trials for four seasons. Hand weeding resulted in an average yield increase of 1540 kg/ha. Of the granular chemicals tested, 2,4-D IPE, butachlor, MON 0358, and EPTC-M have shown good weed control comparable to hand-weeded treatments. Among the liquid formulations, MCPA-K and propanil gave results comparable with the hand-weeded plots.

CHEMICAL CONTROL OF BARNYARDGRASS IN TRANSPLANTED RICE

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Barnyardgrass *(Echinochloa crusgalli)* is the predominant annual grassy weed in transplanted paddy *(Oryza sativa* L. 'Jaya'*)* in the Punjab. In two separate field trials conducted during 1974, different rates of butachlor (granules and EC), propanil (EC), 2,4-D (granules and EC), nitrofen (granules), molinate (EC), dichlormate (granules), and oxadiazon (EC) were evaluated for weed control in transplanted paddy. Their efficacies were compared with the conventional method (two hand weedings). Butachlor (1.5 and 2.5 kg/ha) and molinate (3.75 kg/ha) applied 3 to 4 days after transplanting (pre-emergence) in 3 to 4 cm standing water and propanil (2.6 kg/ha) applied at 3-leaf stage of barnyardgrass (2 weeks after transplanting) gave effective control of barnyard-grass. There was heavy population of barnyardgrass, the dry matter of weeds in unweeded plots being 8330 kg/ha as against 110 to 420 kg/ha in butachlor treatments

and 1980 kg/ha in propanil + 3% urea. Oxadiazon and dichlormate also gave promising results. The performance of granular formulation of the ethyl ester of 2,4-D (0.8 to 1.2 kg/ha, pre-emergence) and nitrofen was rather poor. On an average, butachlor and propanil gave 6.87 t/ha grain yield against 6.81 and 0.32 t/ha for the hand-weeded (twice) and unweeded crops, respectively. In the second trial, butachlor and molinate gave 4.21 and 3.91 t/ha grain yield against 3.57 and 2.13 t/ha for the hand-weeded and unweeded crops, respectively.

RELATIVE EFFICIENCY OF SOME NEW HERBICIDES FOR WEED CONTROL IN TRANSPLANTED RICE

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Weed control experimeuts conducted in transplanted rice *(Oryza sativa* L.*)* at the Central Rice Research Institute, Cuttack, for three seasons (rabi 1975 to kharif 1976) revealed that efficient weed control as well as yield, comparable to hand weeding, could be obtained with several herbicides. The effective herbicides were : MON 0358, C-288 (piperophos+dimethametryn), C-19490/2,4-D IPE, piperophos, 2,4-D EE (0.5 kg/ha), butachlor+2,4-D IPE (0.75+0.5 kg/ha), molinate and EPTC (2 kg/ha), bifenox, butachlor, benthiocarb, dichlormate and bentazon (1.5 kg/ha), RH 2915 and Na salt of 2,4-D (0.6 kg/ha), penoxal in (1 kg/ha), and perfluidone/2,4-D IPE (1.0/0.25 kg/ha).

EVALUATION OF BIFEMOX HERBICIDE FOR WEED CONTROL IN RICE

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Field experiments were carried out during 1974-76 with three formulations of bifenox in " Pusa 2-21 " and " Jaya " varieties of rice *(Oryza sativa* L.*)* at three locations of West Bengal. Emulsifiable concentrate (21%) and wettable powder (80%) formulations of bifenox (1.5, 2, 2.5, and 3 kg/ha) were sprayed in 500 litres of solution 20 days after transplanting rice seedlings whereas granular dust (7%) formulation was applied seven days after transplanting. Combinations of bifenox + propanil (1 kg + 0.70 kg/ha) and bifenox + butachlor (1 kg + 0.85 kg/ha) were also included in the trials.

The various formulations of bifenox controlled 63 to 97% of the weeds in rice while hand weeding gave 71 to 76% weed reduction. Highly effective results were obtained with 3 kg/ha in all the three formulations of bifenox. There was an average yield increase of 1030 kg/ha which was about 12% more over hand-weeded plot and 32% more over the unweeded control. Bifenox (2 and 2.5 kg/ha) or bifenox (1 kg/ha) in combination with propanil (0.70 kg/ha) or butachlor (0.85 kg/ha) also increased the crop yield considerably over the hand-weeded control.

A REVIEW ON VARIETAL TOLERANCE OF RICE TO HERBICIDES

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Herbicide application in rice *(Oryza sativa* L.*)* have become a practice in rice culture. Pre-emergence herbicides butachlor, benthiocarb, C-288, molimate, and oxadiazon applied either alone or in combination with 2,4-D or propanil are widely recommended for rice. Results of experiments conducted in the United States, Japan, the Philippines, India, Germany, Korea and other countries showed that rice varieties significantly differ in their tolerance to herbicides. This phenomenon was exhibited both under transplanted and directseeded conditions, but more often noted in direct seeded crop under lowland condition. Varietal tolerance and susceptibility of rice depend partly on plant morphology and physiology, edaphic and climatic factors, and herbicide dose. Water absorption after sowing, germination, embryo growth, weight of roots and stems, enzyme activity and chemiluminescent response provided criteria in evaluating differential tolerance to herbicides. Correlation existed on varietal tolerance to inter or intra species, stature and stage of the crop duration, resistance to salinity and insect pests. Thus, there is a need for determining the effects of any new herbicide on all popular varieties in particular agro-climatic zone.

CHEMICAL WEED CONTROL IN RICE IN RELATION TO FERTILIZER USE

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Investigation involving two methods of planting (direct seeding on nonpuddled soil and transplanting on puddled soil), four levels of nitrogen (0, 30, 60 and 90 kg/ha), and four weed control treatments (butachlor as Machete granules at 20 kg/ha., propanil as Stam F-34 at 2 L/ha, hand-weeding and a weedy check) were conducted with rice (*Oryza sativa* L. 'Pusa 2-21'). The experiment was laid out in a split plot design with methods of planting and nitrogen levels as the main plots and weed control treatments as the sub-plot treatments. The treatments were replicated three times.

In directseeded rice, butacholr and propanil reduced the dry matter accumulation in weeds from 170 g to 19 g/sq m. The nutrient lost, as 24.0, 5.1, and 48.4 kg/ha of N, P, and K, respectively, in the weedy check, was reduced to 3, 0.6 and 5.6 kg/ha in the treated plots. In transplanted rice, the weed control treatments reduced the dry matter accumulation to 4.6 g as compared to 23.8 g/sq m in the weedy check. The amount of N, P, and K lost (4.2, 0.8, and 6.9 kg/ha, respectively) due to weed growth was reduced to 0.9, 0.2, and 1.6 kg/ha due to weed control treatments. In both directseeded and transplanted paddy, weed control measures improved the Plant nutrition.

The grain and straw yields were increased by 1190 and 1290 kg/ha, respectively, due to weed control measures in the directseeding method; the corresponding increase in the transplanted series was 590 and 1320 kg/ha. The increased grain production in both methods of planting as a result of the weed control treatments was due to improvement in yield attributes such as panicle density, grains/panicle, and weight per 1000 grains.

The increasing levels of nitrogen suppressed weed emergence but the dry matter accumulation in weed growth was enhanced. The response of the crop to 30, 60, and 90 kg N/ha was 17.5, 19.5 and 17.5 kg grain/kg N, respectively.

In both the directseeded and transplanted series. a single application of either butachlor or propanil gave results comparable to manually weeded treatment.

RELATIVE EFFICIENCY OF GRANULAR AND EMULSIFIABLE CONCENTRATE HERBICIDES UNDER GRADED LEVELS OF NITROGEN IN RICE

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Field experiments in rice (*Oryza sativa* L. 'IR20') were conducted during summer and kharif seasons of 1975 at the Agricultural College, farm, Coimbatore, to determine the comparative efficiency of two different herbicide formulations under graded levels of nitrogen.

The experiment was laid out in a split plot design with three replications in both seasons. The main plot consisted of four nitrogen levels (0, 60, 120 and 180 kg N/ha). The sub-plots consisted of eight weed control treatments, namely : granular and liquid formulations of butachlor (2kg/ha), benthiocarb (1.5 kg/ha) and AC 92,553(1.5 kg/ha) compared with hand-weeded and unweeded controls.

The major weed flora were *Echinochloa colonum* Beauve., *Echinochloa crusgalli* Beauv., *Panicum* spp., *Cyperus iria L.*, and *Marsilea quadrifolia* L.

The response to nitrogen application was linear in both the seasons. AC 92,553 gave 75% control of weeds and the highest grain yield of 5703 kg/ha in summer and 5010 kg/ha in kharif. The corresponding yield figures for hand-weeded treatment (done at 21 and 45 days afrer planting) were 5045 kg/ha in summer and 4562 kg/ha in kharif. Emulsiffable concentrate (EC) of all herbidides gave comparatively poorer control of weeds than the granular form. The efficiency of granules over EC in controlling weed growth and for high grain yield was better in summer than in kharif. However, loss in yield due to weeds was more in summer than in kharif.

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COMBINED APPLICATION OF HERBICIDE-INSECTICIDE IN RICE CROP

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Herbicides and insecticides were applied separately and as mixtures at different intervals in transplanted rice *(Oryza sativa L.)* crop during kharif 1975, to find out their compatibility and effect on weeds, insects, and rice plants. Butachlor (G), nitrofen (G), and bentazon (EC) were applied alone and in different combinations with systemic insecticides carbofuran (3G) and phorate (10G). There was no evidence of herbicide-insecticide interaction as revealed by the fact that none of the combinations showed adverse effect on crop stand, growth, and grain yield. The combined herbicide and insecticide treatments resulted in better growth of crop and yield of grain than single application of herbicides. Regarding the effect on weeds, butachlor individually and in combination with either of the insecticides was found to be more efficient in suppressing weed population than nitrofen or bentazon applied alone or in combination with insecticides. With regard to the effect of treatments on insects, combined phorate-herbicide treatments resulted in more effective control of leafhopper than stem borer. But carbofuran-herbibide treatments showed more effectiveness in checking the infestation of stem borer.

STUDIES ON WEED COMPETITION, WEED CONTROL, AND VARIETAL INTERACTION WITH PROPANIL AND PARATHION IN DIRECTSEEDED RICE

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Field experiments on weed competition, weed control, and varietal interaction with propanil in combination with parathion were conducted during rabi and kharif 1972 at the Central Rice Research Institute, Cuttack. Maximum weed competition occurred during the first 3 weeks and the loss was lesser between 3 and 6 weeks and this trend continued till 9 weeks. Thereafter, the reduction in grain yield due to weed competition was negligible. The cost of controlling weeds in direct sown rice through spraying of propanil could be reduced with the use of 2 kg/ha of propanil in 3% solution of urea 2 weeks after rice seeding. Differences in varietal reactions to propanil either alone or in combination with parathion were observed. Varieties Pusa 2-21, Padma, CR 44-35, and BC 6 did not exhibit phytotoxity while varieties Ratna, Cauvery, BC 5. Supriya (CR 36-148), Krishna, Bala, and Kanchi showed phytotoxicity and resulted in an average yield loss of 672 kg/ha, suggesting varietal interaction with the mixed application of propanil + parathion.

INVESTIGATIONS ON CHEMICAL WEED CONTROL IN DIRECTSEEDED AND TRANSPLANTED RICE

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The weed-killing efficiency and selectivity of herbicides (butachlor, MCPB, and propanil)were tested in field trials with rice (*Oryza sativa* L. cv. 'Improved Sabarmati'). The herbicidal efficiency was assessed in terms of population, dry matter accumulation, and nutrient depletion by weed growth. The parameters for selectivity were provided by the effects on crop growth, dry matter production, nutrient removal and yield of straw, grain, and protein content.

Weed competition was found very severe in the directseeded crop. Propanil as Stam F-34 at 2 L/ha reduced the dry matter accumulation of monocot and dicot weeds to an extent of 56 and 48%, respectively, as compared with the unweeded check. The nutrient depletion by weed growth in the unweeded check amounted to 24.7, 5.8, and 63.4 kg/ha of N,P, and K, respectively. This enormous amount of nutrients lost was effectively checked by propanil

Propanil and hand-weeded treatments increased grain, straw, and total dry matter production by 2780, 2290, and 5060 kg/ha, respectively, over the unweeded check. A low dose of MCPB (0.5 kg/ha) combined with 3% urea proved as effective as its higher dose (1 kg/ha) without urea in regard to weed control and crop production.

In the transplanted series, there was practically no weed growth because of the puddling operation on account of which neither the weed nor the crop attributes were influenced by the treatments. As none of the herbicide treatments exerted any adverse effect on crop growth or its development, both propanil and butachlor proved effective and safe herbicides for both directseeded and transplanted .ice.

The protein content (%) in the rice grains was not affected by plantin methods or weed control treatments.

STUDIES ON WEED CONTROL THROUGH HERBICIDES IN DIRECTSEEDED RICE CULTURE

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Weed control in directseeded rice (*Oryza sativa*) culture presents a formidable porblem under mid-hill conditions. By the time the crop is able to stand to any herbicidal treatment, the weed seedlings have become large enough to be killed by

herbicides. Thus, two field experiments were conducted in the wet season kharif of 1974 and 1975 under the mid-hill conditions (1300 mm above mean sea level) to study the effectiveness of herbicides in controlling weeds in rice. The first experiment was on directseeded puddled soil and the second on directseeded unpuddled soil. Both granular and spray herbicide treatments were applied along with hand-weeded and unweeded controls. The treatments were arranged in a randomized complete block design and replicated four times.

In the first experiment, C-288 effectivey controlled the weeds and the grain yield was compaoble with those obtained under hand-weeded check. Other herbicides that performed satisfactorily were benthiocarb/2, 4-D IPE, dichlormat, and C-19490/2, 4-D IPE. Dinitramine was most toxic to the crop throughout and thus resulted in granh yield which was significantly less than under the other treatments mentioned earlier.

In the second experiment, the performance of C-288 was also highly satisfactory and was comparable to hand-weeded check. Preforan also worked effectively. In this experiment again, dinitramine and USB 3153 were phytotoxic to rice seedlings.

Herbicides like C-288, benthiocarb/2, 4-D IPE, dichlormate, C-19490/2,4-D IPE, and preforan seemed to be quite promising for weed control as well as for safe use in directseeded rice under mid-hill conditions of Palampur, H. P.

WEED CONTROL IN DIRECTSEED RICE

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To find out the possibility of chemical weed control in directseeded rice *Oryza Sativa* L. 'Co-39'), an experiment was conducted under puddled condition during summer 1976 at Tamil Nadu Agricultural University, Coimbatore. Co-39, a dwarf indica type, is a short duration variety (95-110 days). Pre-emergence herbicides oxadiazon (0.75, 1. and 1.25 kg/ha) and butachlor (1 kg/ha) were compared with weeded and unweeded controls. The trial was conducted in randomized block design. Pregerminated seeds were broabcast at the rate of 60 kg/ha in previously puddled and levelled field. Herbicides were applied 6 days after sowing. Manual weedings (weeded control) were done at 20 and 35 days after sowing. Weeds present in the field were : *Brachiaria platyphylla*, *Echinochloa colonum* Beauv., *Echinochloa crusgalli* Beuv., *Cyperus difformis* L., *Fimbristylis milaceae*. *Marsilea quaorifoliata* L,, *Eciipta alba*, and *Ammania baccifera*. Results of the experiment showed that oxadiazon and butachlor effectively coutrolled the annual weeds, but they caused about 5% mortality to the rice seedlings. However, tillering in rice was better and the yield was comparable with the weeded control.

EVALUATION OF HERBICIDES FOR DIRECT SOWN RICE

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Evaluation of five herbicides for direct rice (*Oryza sativa* L. 'Cauvery') was conducted in the field in 1972 and 1973 at the Indian Grassland and Fodder Research Institute, Jhansi, The herbicides were : molinate (3 and 6 kg/ha applied preplant), C-6989 or fluorodifen (2 and 4 kg/ha), nitrofen (3 and 6 kg/ha), dichlormate (3 and 6 kg/ha), and CMPT (3 and 6 kg/ha applied pre-emergence) for weed control in broadcast paddy. Dichlormate whose selectivity for rice was determined earlier in this laboratory, was further tried in combination with 120 kg N/ha as urea or ammonium sulphate. Unweeded and manually weeded (three times) plots as control were compared with the performance of the herbicides. The weed flora consisted chiefly of : *Echinochloa colonum*, *Setaria glouca*, *Brachiaria ramosa*, *Ponicum* sp., *Commelina forskeii*, and *Mollugo cerviana*. The best overall weed control and highest grain and dry matter yields were obtained with dichlormate+120 kg N/ha (ammonium sulphate). In general, all herbicides at higher doses were superior to the controls. Dichlormate, fluorodifen, and molinate were superior to nitrofen and CMPT in that order.

EFFECT OF HERBICIDES ON WEED CONTROL AND YIELD OF DIRECTSEEDED RICE UNDER PUDDLED CONDITIONS

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The experiment was conducted during the kharif season of 1973 and 1974 at the Research Farm, Faculty of Agriculture, Banaras Hindu University, Varanasi, to investigate the effect of herbicides on weed control and yield of directseeded rice (*Oryza sativa* L.) under puddled conditions. The herbicide propanil was superior to other herbicides in controlling the weeds. The highest yield was obtained with propanil at 2.4 kg/ha. Largest number of grains per panicle and test weight were also obtained under this treatment. AC 92,553 showed an effective kill of weeds at a dose of 2.4 kg/ha but the yield was considerably less than that obtained with propanil.

CHEMICAL WEED CONTROL IN BROADCAST SEED RICE

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Experiments with different herbicides were conducted on broadcast seeded rice (*Oryza sativa* L.) at the Agricultural Research Institute, Mithapur, Patna. Seeds of

Echinochloa spp. were sown along with rice seeds. The herbicides used were all of liquid formulation mixed with 400 litres of water and sprayed uniformly with high volume sprayer 4 days after sowing. In the four years of experimentation, hand-weeded and unweeded controls were also maintained. The highest yield was obtained in hand-weeded plots and lowest in unweeded control. Among the herbicides the most promising which gave yield comparable to that of hand-weeded plots were propanil (3 kg/ha), butachlor (1.5 kg/ha), and C-288 (1 kg/ha).

EFFECT OF NEWER HERBICIDES ON WEEDS IN DRY AND WETLAND RICE IN FIJI

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Due to high cost of manual labour in Fiji, the traditional method of mechanical weeding has been replaced by the use of herbicides which have proved comparatively more efficient and economic in controlling weeds in rice (*Oryza sativa* L.).

In dryland drilled rice, pre-emergence application of butachlor at 3.6 kg/ha controlled all annual grasses, sedges and broadleaf weeds throughout the crop period. In upland rice dominated by sensitive weed, *Mimosa pudica*, postemergence application of a combination of propanil at 4 kg/ha + oxadiazon at 3 kg/ha controlled all weeds including *Mimosa*.

In case of broadcast and transplanted wetland rice, a selective herbicide, benthiocarb granules (1 kg/ha) was found to be very effective for the control of all common weeds e. g. barnyardgrass, pickral, sedges, except *Salvinia;* where as a newer chemical, C-288 (0.75 kg/ha) as postemergence application controlled all weeds including *Salvinia*.

WEED CONTROL IN DIRECT SOWN UPLAND RICE UNDER RAINFED CONDITION

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Weeds are serious problems for the direct sown short duration high yielding rice (*Oryza sativa* L.) cultivars such as Bala, IET 849, and Cauvery. These varieties fail to exhibit their yield potential in the absence of suitable weed control measures. Hence, field experiments were condncted at Ranchi Agricultural College Farm during the kharif seasons of 1975 and 1976 to study the effect of butachlor liquid as preplant incorporation and pre-emergence alone and in combination with postemergence application of propanil on the performance of upland rice variety Bala. Butachlor

(0.5 kg/ha) applied preplant + propanil (2 kg/ha) applied postemergence gave consistently the best control of weeds and the maximum yield (3 t/ha) of rice over the control (2 t/ha) which was given one hand weeding.

PROBABILITY OF THE EXISTENCE OF PREMERGENCE HERBICIDE MOISTURE VARIETY INTERACTION ADVERSE TO DIRECTSEEDED RICE ON UPLANDS

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In the *kharif* (wet) season of 1975 eight pre-emergence herbicides were tested at two dosages for weed constol in upland directseeded rice (*Oriza sativa* L.). Severe toxicity to rice seedlings was observed with some of the herbicide treatments 14 days after application. The extent of toxicity to rice (complete death of seedlings) was 86 to 90% with dinitramine, 87 to 88% with butachlor, 79 to 91% with C-288, 66 to 89% with benthiocarb, 43 to 52% with nitrofen and 38 to 62% with fluchloralin. The weed control efficiencies with the above herbicides (calculated on the basis of dry weed weight of the handweeded plots) were 74 to 76%, 83 to 89%, 81 to 93%, 69 to 78%, 85 to 86%, and 74 to 84%, respectively. A rainfall of 136 mm received between 2 to 5 days after spraying of the herbicides was suspected to be the cause of the severe toxicity to rice. In earlier years when no such high toxicity was noticed, there was much less rainfall during a week after herbicide spray. The study was repeated in kharif 1976 with five of the above herbicides under flooded conditions using two rice varieties, CR 125-12-8 (which was used in 1975) and Annapurna. The results again showed severe toxicity in the case of dinitramine, C-288, and butachlor; moderate toxicity with nitrofen, and low toxicity with Benthiocarb. Weeds were controlled efficiently in all the herbicide treatments. Further, the extent of toxicity to a particular herbicide varied with varieties.

The above studies indicate the probable existence of adverse herbicide-moisture-variety interactions which need more extensive studies for confirmation of the above results. The high intensity of weed infestation (3470 kg/ha) in upland directseeded rice pointed to the need for herbicides that are efficient, cheap, and nonphytotoxic to rice.

EFFECTIVENESS OF PREEMERGENCE HERBICIDES IN UPLAND RICE

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Eight new herbicides were tested in upland rice (*Oryza sativa* L.) at the Rice Research Farm, Agricultural Research Institute, Kanke, Ranchi. Among the annual

weeds, *Digitaria longiflora* and *Echinochloa crusgalli* accounted for 48 and 36 percent of the total weed population, respectively, as observed in the butachlor-treated plot (Control). Among the herbicides, C-288, USB 3584, and oxadiazon were significantly more effective than others in controlling the weeds. However, none of these herbicides could control *Cyprus rotundus* effectively. Effectiveness of herbicides in terms of grain yield were comparable with hand weeding where by 2554 to 3020 kg/ha were recorded as against 620 kg/ha in the unweeded control. Lowest dry matter of weeds (50 kg/ha) were recorded in plots treated with C-288 but this did not enhance the production of effective tillers, apparently due to some toxic effect of the weedicide.

THE RELATIVE EFFICENCY OF HERBICIDES ON WEEDS AND THE RICE CROP GROWN UNDER UPLAND CONDITION

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A weed control trial was conducted at the Agronomy Research Block (upland crops) of Orissa University of Agriculture and Technology, Bhubaneswar, during kharif season of 1976 to study the performance of butachlor, propanil, and benthiocarb for the control of weeds in high yielding rice (*Oryza sativa* L. 'Annapurna') under direct seeding condition.

In upland direct sown rice (HYV) yield reduction due to weed competition was about 69%. Among the various herbicides tested, propanil was the best, followed by benthiocarb. Propanil at 2.24 kg/ha in 4% urea solution applied 15 days after rice emergence gave the least weed growth, while split application of propanil at 1.5 kg/ha each at 15 and 30 days after rice emergence recorded higher grain yield over other herbicidal treatments. Butachlor applied 8 days after sowing showed phytotoxic effect to rice resulting in mortality of some seedlings. However, the cultural treatment of hoeing once at 15 days after sowing followed by hand weeding at 25, 40, and 55 days gave satisfactory control of weeds and recorded maximum grain yield.

EFFECT OF LEVELS AND TIME OF APPLICATION OF HERBICIDES ON GROWTH AND YIELD OF UPLAND RICE

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Field experiments were conducted on upland rice (*Oryza sativa* L.) at the Researsch Farm, Department of Agronomy, Banaras Hindu University, Varanasi, during kharif seasons of 1967 and 1968 to study the effect of herbicides, propanil, nitrofen (granular), MCPA, and 2,4-D at three levels (1,2,3 kg/ha). They were

applied preemergence (pre), postemergence (post), and pre + post. Propanil was the most effective herbicide closely followed by nitrofen with respect to all the yield and yield attributes of the crop. 2,4-D was also superior to MCPA. The medium dose of 2 kg/ha gave the best control of weeds. With regard to the time of application, postemergence was, in general, superior to preemergence as well as pre+post.

WEED MANAGEMENT IN UPLAND PADDY

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Field study to determine the possibility of chemical weed control in upland paddy (*Oryza staiva* L.) was conducted at the Central Soil and Water Conservation Research and Training Institute farm, Selakui (Dehra Dun) in 1975 and 1976. It was found that weeds could be effectively controlled in upland paddy with the application of butachlor granules at 2 kg/ha+one hand weeding (yield 3155 kg/ha), and propanil at 1.4 kg/ha+one hand weeding (yield 2852 kg/ha) as compared to control (yield 1041 kg/ha). Net returns obtained with the use of chemicals were comparable with hand weeding. The study has helped in removing a major production constraint in direct sown upland paddy.

CONTROL OF RICE WEEDS WITH BUTACHLOR

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Trials on farmers' fields were conducted in Nellore (A.P.) with 1.25, 1.5, and 1.87 kg/ha of butachlor applied at 0,4, and 6 days after planting (DAP). Dat. were recorded for weed control, weed weight, weeding time, and yield.

All treatments gave 90 to 95% control up to 3 weeks after planting. The weed control in 1.25 kg rate was slightly less (2 to 3%) than that obtained with 1.87 kg rate, and treatments applied at 6 DAP have lower weed control compared to those applied at 0 and 4 DAP. In the next 3 to 4 weeks weed control decreased, the maximum decrease was under treatments applied at 6 DAP. Over-all best weed control was with 4 DAP application.

Weed weight and weeding time data showed that there was no difference among the three rates with regard to time taken for weeding or the fresh weight of weeds removed under 0 and 4 DAP applications but the 1.87 kg plots under 6 DAP required slightly less time (about 6%) and weed weight was 25% less compared to 1.25 and

1.5 kg/ha. Average of all three rates for different days of application showed that the time required for weeding was less (35% of handweeded) with 0 DAP application compared to about 50% of handweeded required for 4 and 6 DAP plots. Similarly, the average weed weight in 0 DAP plots was 19% of handweeded whereas in 4 and 6 DAP plots was 25 and 41%, respectively.

Overall yield was higher in treated plots, the highest increase being 10% with 1.25 kg/ha rate over 2336 kg/ha in handweeded plots. Also, applications at 0 and 4 DAP gave 7 to 8% more yield than those applied at 6 DAP.

2. CEREAL CROPS : WHEAT, MAIZE, SORGHUM AND PEARLMILLET

WEED CONTROL IN WINTER IRRIGATED WHEAT IN TAMIL NADU

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An experiment was conducted in the Tamil Nadu Agricultural University, Coimbatore, during November 1975 to compare the different weed control methods in the winter irrigated wheat *(Triticum aestivum* L. 'Kalyansona'). Preemergence herbicides like dinitramine (0.5 kg/ha), nitrofen (2 kg/ha), RH 2512 (1.2 kg/ha), and alachlor (1.5 kg/ha) were compared with normal hand-weeded (twice) method. The common weed flora comprised of : *Trianthema portulacastrum, Tridax procumbens, Digera arvensis Amaranthus* sp., *Flaveria australacica, Datura* sp., *Cyperus* sp., and *Cynodon dactylon* of which *Trianthema portulacastrum* was the major weed. The weed control efficiency was high in dinitramine, followed by alachlor and nitrofen. Alachlor caused initial stunting of wheat but the plants gradually recovered. The different treatments had no effect on plant height and population of the crop. Longer panicles and higher number of grains were noticed in dinitramine treatment which also gave the maximum yield of 1835 kg/ha, followed by nitrofen (1758 kg/ha) and alachlor (1614 kg/ha). The yield under hand-weeded control was 1504 kg/ha. The cost of chemical weed control was less in the herbicide treatments as compared to the hand-weeded control.

VARIETAL REACTION OF WHEAT TO HERBICIDES

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Experiments have been in progress at the Indian Agricultural Research Institute, New Delhi for studying the reaction of wheat *Triticum aestivum* L.) cultivars to herbicides. A field trial in a splitplot design was carried out during rabi 1975-76 with two cultivars of wheat (Arjun and Sonalika) raised under three levels of nitrogen (40, 80, and 120 kg N/ha) in the main plots. The sub-plot treatments were : control, hand-weeded, methabenzthiazuron (2 kg/ha) and terbutryne (1 kg/ha) applied preemergence and a post emergence spray (5 weeks after sowing) with 2,4-D amine (0.5 kg/ha).

The grain yield differences between the varieties were not significant. Application of 120 kg N/ha produced the maximum grain yield in both the cultivars. All the weed control treatments increased grain production significantly over the control in both the varieties.

In Sonalika, the grain yield from methabenzthiazuron treatment was superior to hand-weeded and 2,4-D treatments, while in Arjun, the grain yield from 2,4-D was significantly more as compared to hand-weeded control and methabenzthiazuron but was comparable with terbutryne. It is interesting to note that even though Arjun was affected by 2,4-D as manifested by severe ear deformities, the grain yield did not suffer. The postemergence spray of 2,4-D proved lethal to the natural infestations of annual dicot weeds. The data in this study provided clear evidence on the selectivity of terbutryne and methabenzthiazuron to the two wheat cultivars.

OBSERVATIONS ON WEED KILLING AND SELECTIVE EFFECTS OF HERBICIDES IN WHEAT

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High yielding dwarf varieties of wheat (*Triticum aestivum* L) pose interesting and challenging problems in respect of chemical weed control. A presowing irrigation, heavy doses of fertilizer, and frequent irrigations promote rapid growth of weeds in dwarf statured wheat cultivars. A great necessity exists for evolving a safe and effective herbicide or methods of application, to tackle the weed problems under the agronomic conditions these cultivars of wheat are raised.

A replicated field trial carried out in 1975-76 with cultivar Arjun involved early postemergence soil application of fluchloralin (0.25 and 0.50 kg/ha), methabenzthiazuron (1.40 kg/ha), and terbutryne (0.80 kg/ha), followed by irrigation immediately in one set and at a later stage in another; and a late postemergence spray with benzoylprop ethyl (1 and 2 kg/ha) and 2,4-D (0.42 kg/ha combined with 3% urea and 0.84 kg/ha). An unweeded control and a handweeded (twice) treatments were included in the trial.

The soil-applied chemicals (fluchloralin at 0.25 kg/ha, methabenz-thiazuron at 1.40 kg/ha, and terbutryne at 0.80 kg/ha) immediately followed by an irrigation gave grain yields comparable with the handweeded control.

The post-emergence spray with benzoylprop ethyl at 1 kg/ha and a combination of 2,4-D (0.42 kg/ha) + 3% urea also resulted in high grain production. In the case of 2,4-D + urea, the combination spray proved more beneficial to grain production than when the compounds were applied separately.

Another interesting observation noted in the trial was the complete absence of ear deformities in Arjun from 2, 4-D which was perhaps due to the late application of the chemical.

CONTROL OF PHALARIS MINOR L. IN WHEAT WITH POSTEMERGENCE APPLICATION OF NITROFEN, METOXURON, AND METHABENZTHIAZURON

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Phalaris minor L. is a serious annual grassy weed in wheat (*Triticum sativum* 'Kalyan Sona') in Punjab, particularly in fields under paddy (*Oryza sativa* L.) and wheat rotation. The physical condition of paddy soils and the presence of crop stubbles do not permit a fine seed bed preparation which lowers the efficiency of preemergence herbicide, particularly of nitrofen. Thus, postemergence herbicides hold better promise for the control of *Phalaris* in such soils.

Field experiments conducted in Punjab Agricultural University, Ludhiana, during 1971-72, 1973-74, 1974-75, and 1975-76 showed promising control of *Phalaris* with postemergence application of nitrofen. Even 3 kg/ha of nitrofen applied after first irrigation (25 days after sowing) was well tolerated by wheat. It induced a severe burning effect on the leaves but the crop recovered within 2 weeks of treatment. *Phalaris* seedlings at the coleoptile stage were quite susceptible to postemergence nitrofen at 1.25 kg/ha. Nitrofen-treated crop, on an average, gave 300 to 800 kg/ha more grain yield than the unweeded crop. During 1975-76 crop season, postemergence application of methabenzthiazuron at 0.7 kg/ha and metoxuron applied 16 days after sowing gave an effective control of *Phalaris* and resulted in significantly higher grain yield than nitrofen applied postemergence.

EFFICACY OF HERBICIDES ON THE CONTROL OF WILD CANARYGRASS IN DWARF WHEAT

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Field experiments were conducted at Central Jail Farm, Ambala City and Kurukshetra University Farm, Kurukshetra, during rabi 1974-75, to determine the performance of methabenzthiazuron and nitrofen and some combinations of these herbicides for the effective control of canarygrass (*Phalaris minor*) and broadleaf weeds in wheat (*Triticum aestivum* L.), In Ambala, the preemergence application of metha-

benzthiazaron (2 kg/ha) resulted in 92% control of *Phalaris* and 56% of broadleaf weeds; whereas nitrofen (1.25 kg/ha) gave 84% control of *Phalaris* and 9.5% of broadleaf weeds. In Kurukshetra, methabenzthiazuron controlled 89% of *Phalaris* and 89% of broadleaf weeds; whereas nitrofen controlled 76% of *Phalaris* and 12% of broadleaf weeds, Both herbicides were as effective as methabenthiazuron+one hand weeding or nitrofen+one hand weeding. To control wild canarygrass and broadleaf weeds, preemergence application of methabenzthiazuron followed by postemergence application of 2, 4-D at 5 weeks after sowing was found promising for higher grain production.

EFFECT OF METOXURON ON THE CONTROL OF PHALARIS MINOR RETZ. IN WHEAT AND ITS RESIDUAL EFFCT ON SUBSEQUENT CROPS

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Metoxuron was tested under different levels and time of application for the control of *Phalaris minor* Retz. in wheat (*Triticum aestivum* L.) and also to find out residual effect on the germination and growth of maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), paddy (*Oryza sativa* L.), sunflower (*Helianthus annuus*), moong or green gram (*Phaseolus aureus Roxb.*), urd or black gram (*Phaseolus mungo* L.), soybean (*Glycine max* L.) Merr.), and groundnut (*Arachis hypoqaea* L.).

Application of metoxuron at 2 and 3 kg/ha sprayed any time between 25 and 40 days after sowing reduced significantly the population of *Phalaris* and the dry matter produced by the weeds over weedy check. Reduced competition from weeds under these treatments resulted in increased grain yield which was significantly over weedy check.

No phytotoxicity was observed on maize, sorghum, paddy, soybean, moong, urd, sunflower and groundnut when planted immediately after the harvest of wheat.

RESPONSE OF HYBRID MAIZE TO CULTURAL AND CHEMICAL METHODS OF WEED CONTROL

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An experiment was conducted to study the response of hybrid maize (*Zea mays* L. 'Ganga 5') to hand weeding, simazine, and atrazine during kharif 1975. The experiment was laid out in randomized block design with four replications. Hand weeding

was done to keep plots weed-free. Four rates of herbicides (0.50, 0.75, and 1.25 kg/ha) were applied as preemergence sprays immediately after sowing. Higher grain yield was obtained through the application of simazine and atrazine at 1 kg/ha, followed by 0.75 kg/ha and hand weeding which were all significantly superior than the remaining methods. Herbicide treatments and hand weeding methods gave significantly higher grain yields than the unweeded control.

CHEMICAL WEED CONTROL STUDIES IN HYBRID MAIZE CROP

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In the kharif (warm wet) season most effective control of total weed population in hybrid maize (*Zea mays* L.) crop was obtained with simazine at 1 kg/ha. Simazine or atrazine (0.5 kg/ha) either followed by hoeing or by postemergence 2,4-D (0.75 kg/ha) were next in order of efficiency in killing weeds. In the rabi (dry winter) season simazine (0.5 kg/ha) followed by 2,4-D (0.75 kg/ha) showed maximum control of weeds followed closely by atrazine (1 kg/ha), simazine (1 kg/ha), or triazine herbicides followed by hoeing. The experimental herbicides BAS 2901 H and BAS 2691 H, linuron, propachlor, and butylate were less effect than simazine, atrazine, and their combinations with hoe or 2,4-D.

The grain yield in kharif maize was highest under preemergence simazine (1 kg/ha). In rabi maize, however, 0.5 kg/ha of simazine followed by 0.75 kg/ha of 2,4-D produced the higest grain yield. Addition of hoeing to the lower dose of simazine or atrazine (0.5 kg/ha) was not as effective as simazine or atrazine at higher dose (1 kg/ha) in kharif maize. BAS 2901 H, BAS 2691 H, propachlor and butylale were less effective in increasing the grain yield as compared to simazine or atrazine or their combinations with 2, 4-D or hoe. Among these herbicides butylate was the least effective and BAS 2691 H and BAS 2901 H, linuron, and propachlor did not differ much among themselves in increasing the yield.

CROP WEED COMPETITION FOR NITROGEN IN MAIZE

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A study was conducted on sandy-loam soil at Hissar to investigate the competition of the maize (*Zea mays* L.) crop with the associated weeds for nitrogen under varying weed control practices, nitrogen fertilization, and soil moisture levels. Increasing levels of nitrogen gave progressive increase in the nitrogen uptake by the maize crop, whereas it was not true in the case of weeds which removed 24, 24, 27, and 24 kg N/ha from the crop plots fertilized at the rate of 0, 60, 120, and 130 kg N/ha respec-

tively. The N removed (45.1 kg/ha) by weeds from the unfertilized and unweeded plots (weedy check) exceeded the amount removed (40.5 kg N/ha) by the crop which indicated the existence of strong competition for this nutrient in the fertilized crop conditions. Handweeded and simazine-treated crops showed an increase of 50 and 25% in nitrogen uptake, respectively, over that of the unweeded crop. Increase in the number of irrigations showed a tendency for increased N uptake by the crop, whereas weeds followed an opposite trend, indicating higher ability of the maize crop to compete for this essential nutrient under more than one irrigation. Of the total nitrogen accumulated, percentage N removed by the crop up to knee high stage was higher under the weedy check treatment than in those of simazine and handweeded treatments.

EFFECT OF SIMAZINE IN MAIZE RAISED UNDER VARYING LEVELS OF NITROJEN AND SOIL MOISTURE

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The study conducted in maize (*Zea mays* L.) on sandy loam soil at Hissar in 1968 and 1969 revealed that simazine significantly suppressed weed growth. Its effect was not changed by the variable levels of nitrogen or soil moisture. An increase of 51 and 67% in grain yield was observed due to simazine and hand-weeding, respectively, over that of the unweeded crop. The yield increased with the increase of nitrogen up to 180 kg N/ha under hand-weeded and weedy check treatments but with simazine, there was no yield increase beyond 60 kg N/ha. The highest stover yield was obtained from the hand-weeded plots, followed by those of simazine and weedy check treatment. Increase in stover yield of hand-weeded over simazine was more under frequent irrigations than under one irrigation. None of the treatments / interactions affected significantly the protein content of the maize grains.

INFLUENCE OF TILLAGE AND HERBICIDES ON WEED GROWTH, LOSS OF NUTRIENTS AND YIELD OF RAINFED MAIZE

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An experiment was carried out for two years (1975-76) at the Research farm of the Central Soil and Water Conservation Research and Training Institute, Dehra Dun, on silty loam soil to investigate the efficiency of deep tillage, simazine application, and hand-weeding in controlling weed growth, losses of plant nutrients through weeds, and to boost yield of rainfed maize (*Zea mays* L.). Under shallow tillage weed growth was as high as 6500 kg/ha which could be brought down to 3500 kg/ha by the combined

effect of deep tillage and simazine application. Similarly, losses of plant nutrients (N, P, K) could be brought down from 48, 36, and 21 kg/ha to 25, 19, and 10 kg/ha by the same treatment. As a result yield of maize under deep tillage + simazine was more than doubled. The experiment, therefore, indicated that about 20 kg N, 20 kg P_2O_5, and 10 kg K_2O/ha could be saved and 3400 kg/ha yield of maize obtained with efficient weed control measures adopted in the cultivation of maize.

EFFECT OF WEED CONTROL ON YIELD COMPONENTS OF MAIZE

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A weed control experiment on maize (*Zea mays* L.) was undertaken with atrazine (0.5, 1, 1.5, and 2 kg/ha) and dicamba (2, 3, 4, and 5 L/ha) as preemergence with repeated hand-weeding and unweeded controls on two maizes (Deccan hybrid and Amber composite) for two seasons, on a red sandy loam soil of Bangalore. It was observed that Deccan hybrid yielded 11% more than Amber composite (3300 kg/ha). The performance of Deccan was better than Amber under unweeded condition. Herbicidal doses did not cause significant differences in grain yield, while the effect due to different herbicides was significant. Repeated handweeding and atrazine gave 19 and 13% more yield, respectively, than unweeded control (3300 kg/ha). However, dicamba gave the lowest yield (3200 kg/ha) due to crop injury. In addition, weed control efficiency of dicamba was also lower than atrazine. Dicamba controlled the monocots relatively better than atrazine, while atrazine controlled the dicots better than dicamba. Grain yield decreased because of reducttion in mean grain weight per cob due to the competition of weeds. Competition due to weeds curtailed the sink capacity (grain number) considerably as compared to individual grain size which was slightly affected. In addition competition increased the barrenness owing to increased time lag between silking and tasseling, which was perhaps a result of lower availability of nutrients, specially N. In addition, it decreased the dry weight of the plant, besides lowering the dry matter distribution to the economic part.

CONTROL OF TRAINTHEMA MONOGYNA AND OTHER WEEDS IN MAIZE FODDER

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Trianihema monogyna is a big problem in maize (*Zea mays* L.) fodder because it reduces the quality and quantity of fodder yield. In field experiments conducted in Punjab Agricultural University, Ludhiana, during 1975 and 1976, preemergence appli-

cation of atrazine (1 kg/ha), simazine (1 kg/ha), atrazine+alachlor (0.375+1.25 kg/ha), atrazine+nitrofen (0.375+1.25 kg/ha), atrazine+prometryne (0.5+0.8 kg/ha), prometryne (0.75 kg/ha), and linuron (0.5 kg/ha) gave an effective control of *Trianthema* and *Eleusine* sp. Amiben, fluchloralin, alachlor, and nitrofen were not effective against *Trianthema*. Simazine as hexazine formulation (primarily due to low dose of application) and Terbutrex gave partial control of *Trianthema*.

Differences in green fodder yield among different treatments were significant during both the years. Maximum green fodder yield of 4377 and 4181 kg/ha were recorded under tank mix applications of alachlor+atrazine during 1975 and 1976, respectively, and it was higher by 26 to 28% than the yield of the weedy check. Tank mix application of atrazine+nitrofen had a depressing effect on the fodder yield during both the years. Prometryne showed some initial growth reduction from which the crop plants recovered subsequently.

STUDIES ON WEED CONTROL IN SORGHUM

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A field trial to study the efficiency of various herbicides in comparison to the normal practice of two weedings and two hoeings in sorghum (*Sorghum bicolor* L. 'CSH-4') hybrid was conducted in the monsoon season of 1975-76, at the Agronomy farm of Marathwada Agricultural University, Parbhani. Treatments tried were: atrazine, simazine, and Na salt of 2, 4-D at 1 kg/ha applied preemergence and postemergence ; fluchloralin at 1 kg/ha applied preemergence ; normal practice of two weedings and two hoeings; weed-free condition, and an unweeded check.

Results indicated that yield of sorghum grain in weed-free and atrazine (pre+post) were 7486 and 6333 kg/ha, respectively, which were significantly superior to 5955 kg/ha obtained with the normal practice of cultural operations. Minimum yield occurred in the unweeded control plot. Maintenance of weed-free condition is not practically feasible in monsoon season especially in clayey soil having highly cohesive nature dominated by montmorillonitic type of clay mineral. This proved the significant superiority of atrazine (pre+post) in controlling the weeds and ultimately increasing the sorghum production. Minimum weed index was 2.4 in atrazine (pre+post) plots, whereas maximum weed index of 28.0 was recorded in control plots and 27.0 in 2,4-D preemergence sprayed plots. Economics computation revealed that an expense of Rs. 32/ha in atrazine (pre+post) over normal practice resulted in an additional increase of 378 kg/ha of sorghum grain valued at about Rs, 378/ha,

It was interesting to note thet *Striga densiflora* infestation was maximum in 2,4-D preemergence plots. *Striga* plants were 7/sq m in the above treatment, which was even more than the population in the control plots.

RELATIVE EFFICIENCY OF HERBICIDES ON WEED CONTROL IN SORGHUM UNDER DRYLAND CONDITIONS

MASOOD ALI

Indian Grassland and Fodder Research Institute, Jhansi

A field experiment was conducted during kharif 1976 on red soils of the Central Research Farm, Indian Grass land and Fodder Research Institute, Jhansi, to study the relative effects of herbicides on sorghum (*Sorghum bicolor* L. '604') production under dryland conditions of Bundelkhand region. Atrazine (0.5, 0.75, and 1 kg/ha) 2,4-D(0.5 kg/ha) and their combinations were compared with one and two hand weedings, weed-free, and unweeded controls. The treatments were arranged in randomized block design and replicated three times.

Applications of atrazine and 2,4-D significantly increased grain yield of sorghum and supressed weed population as compared with the weedy check. However, the herbicide treatments remained inferior to weed-free plots. Atrazine was highly effective as compared with 2,4-D. Among different doses of atrazine, 1 kg/ha was significantly superior to the lower rates. Two hand weedings was superior to 2,4-D, comparable with 0.5 and 0.75 kg/ha of atrazine, and inferior to 1 kg/ha of atrazine.

The beneficial effect of 2,4-D in combination with atrazine was observed at 0.5 kg/ha level of the latter only. Highest yield was recorded with weed-free plots (1555 kg/ha) and lowest with weedy check (362 kg/ha).

It may be summarized that effective weed control in sorghum can be obtained through preemergence application of atrazine at 1 kg/ha.

WEED MANAGEMENT IN RAINFED SORGHUM

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The effect of year-round tillage on the yield of sorghum (*Sorghum bicolor* L.) with and without the use of herbicides and normal inter-culture operations have been evaluated over normal tilling practices in the semi-arid red soil region of Hyderabad (India). The results indicated that year-round tillage lead to increased sorghum production. There was no yield difference between atrazine and isoproturon applied either alone or in combination. However, atrazine or isoproturon applied in combination with interculture (two blade harrowings) led to increased production.

In another experiment, band placement of atrazine (graded levels) was compared with whole plot application. The result indicated that band placement of 0.5 kg/ha of atrazine + two blade harrowings at 3 and 7 weeks after planting was as good as 1 kg/ha of atrazine applied on the whole plot + one interculture.

CHEMICAL CONTROL OF WEEDS IN PEARL MILLET UNDER RAINFED CONDITIONS

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An experiment was conducted for four years (1973 to 76) at the Dry Farming Research Sub-centre, R.B.S. College, Bichpuri (Agra) to find out the most effective herbicide and its rate of application to control the weeds in rainfed pearl millet (*Pennisetum typhoides* L.). The predominant weed species were : *Trianthema monongyna*, *Echinochloa crusgalli*, *Commelina benghalensis*, *Cyperus rotundus*, *Cynodon dactylon*, and *Phylanthus niruri*. Control of weeds either mechanically or chemically resulted in an increase in the yield of pearl millet ranging from 3 to 103% over un-weeded control. Atrazine at the rate of 1 kg/ha (preemergence) proved most effective in controlling the weeds. This treatment resulted in the drastic reduction in the dry weight of weeds at harvest (67%) and subsequently increased the grain yield by 103%. Hand weeded plot and atrazine at the rate of 0.5 kg/ha were the next best treatments. giving an increase in yield by 95 to 91%, respectively.

WEED CONTROL STUDIES IN PEARL MILLET

H. P. TRIPATHI and P. S. TOMER

Haryana Agricultural University, Hissar

Effect of propazine, atrazine, combined application of both propazine and atrazine and norea as preemergence herbicides were studied and compared with mechanical weeding and unweeded control in pearl millet (*Pennisetum americanum* (L.) K. Schum). Propazine (1 or 0.5 kg/ha) and atrazine (0.5 kg/ha) yielded about as much as that with mechanical weeding. Single application of atrazine and propazine each at 0.5 kg/ha gave yields as high as that obtained when they were combined and applied at the same rate. Atrazine at 1 kg/ha was toxic to the crop. Norea did not show promising effect.

NITROGEN FERTILIZATION IN RELATION TO DIFFERENT WEED CONTROL METHODS IN PEARL MILLET

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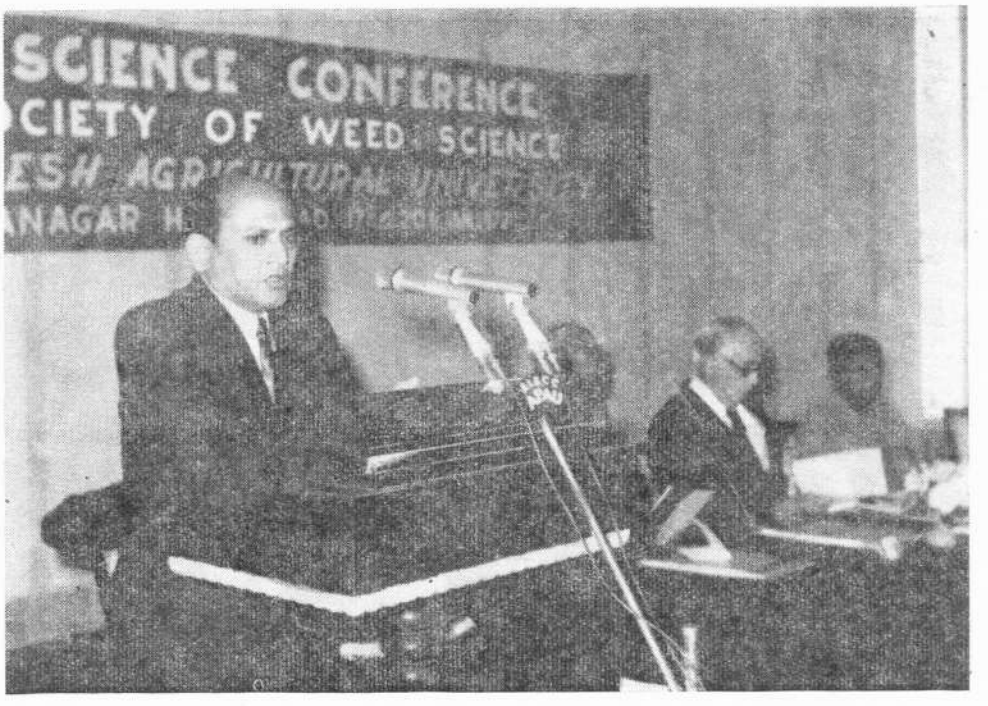
Haryana Agricultural University, Hissar, Haryana

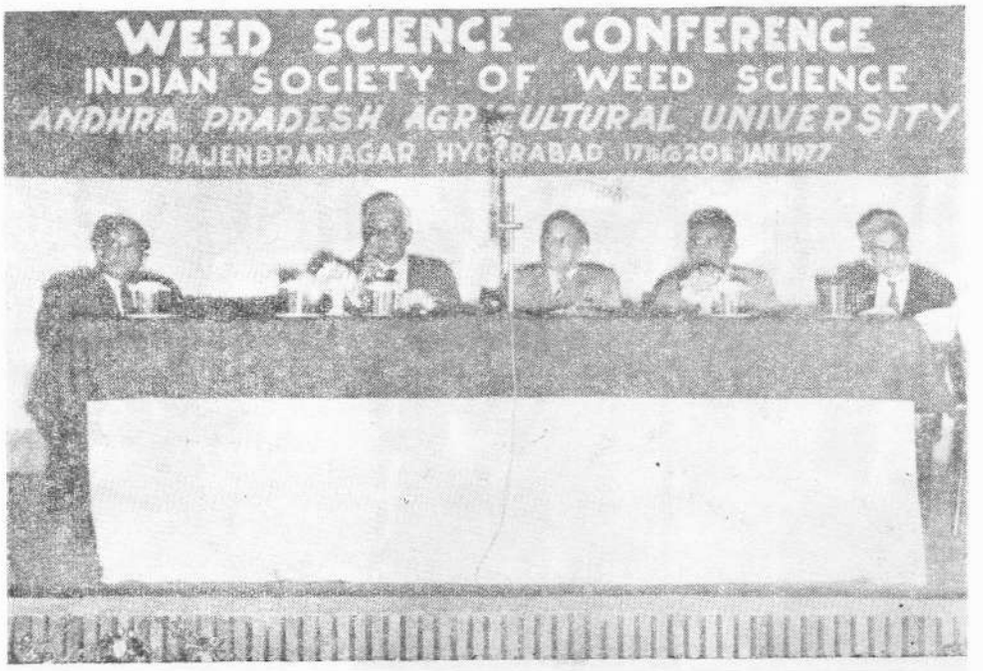
The results pertaining to the studies on pearl millet (*Pennisetum americanum* (L.) K. Schum) in relation to nitrogen levels and weed control methods are reported.



1. Inauguration Function.

2. Visitors going round the exhibition.

3. *Catering arrangements.*



4. *Valedictory function.*

Plots fertilized with 120 kg N/ha and treated with atrazine at 0.5 kg/ha or weeded by khurpi or kasola were equally good in pearl millet production and yield under these plots was maximum. Further, comparable yields were obtained under the plots fertilized with either 120 kg N/ha and weeded by mechanical means or 60 kg N/ha and treated with atrazine. It appears from these results that, from nitrogen economy point of view, it is better to control the weeds with atrazine at 0.5 kg/ha and fertilize the crop with 60 kg N/ha instead of using 120 kg N/ha and controlling the weeds with mechanical means.

The highest nitrogen use efficiency was recorded in the plots treated with atrazine and fertilized with 60 kg N/ha. The next best treatment combination in this regard was weeding and with the application of 60 kg N/ha.

Alachlor applied preemergence was phytotoxic to pearl millet.

EFFECT OF DIFFERENT PRIMARY TILLAGE TREATMENTS ON WEED INFESTATION IN PEARL MILLET

H. S. DAULAY

Central Arid Zone Research Institute, Jodhpur.

Studies on the effect of different primary tillage treatments such as desi plough, sweep cultivator, tyne tiller, disc harrowing, deep discing, deep ploughing, and no tillage on the crop stand establishment and infestation of weeds in pearl millet (*Pennisetum typoides* L. 'HB3) were carried out during kharif 1975 and 1976. Data on weeds before the first weeding indicated that there were practically no weeds in deep tillage while maximum weed species were recorded in no tillage, followed by tillage with desi plough, tyne tiller, deep discing, disc harrowing, and sweep cultivator. The predominant weed species were *Cyperus rotundus* and *Cenchrus biflorus*. Other associated weeds were *Tribulus terristris*, *Pulicaria wightiana*, *Tephrosia purpurea*, *Ipomoea pestagridis*, *Euphorbia hirta*, *Phyllanthus niruri*, *Crotalaria burhia*, and *Heliotropium subulatum*. Statistical analysis of the number of *Cyperus* plants revealed significantly higher number of plants per unit area in no tillage, desi plough, disc harrowing, and tyne tiller than in deep discing and sweep cultivator. One year data on dry matter production of other weeds showed similar trend as that of *Cyperus*.

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3. FIBER CROPS : JUTE AND COTTON

WEED CONTROL STUDIES ON JUTE THROUGH CULTURAL AND CHEMICAL METHODS.

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Studies on lowland jute (*Corchorus* sp.) were conducted to assess the relative efficiency of dalapon, propachlor, and alachlor for weed control. These herbicides were tried at 2 kg/ha (presowing) individually and in combination with one hand weeding. They were compared with the conventional method of two hand weedings. Propachlor gave the best effect against the weeds, followed by alachlor. Propachlor and alachlor supplemented with one hand weeding at 25 days gave higher yields and higher net profits over their corresponding single applications and the conventional method.

PROGRESS OF CHEMICAL WEED CONTROL IN COTTON

Makhtehism-Agan

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During the last few years cotton (*Gossypium* spp.) growers in Israel have come up against a problem of increasing infestation by deeprooted weeds such as *Solanum* spp. and *Amaranthus* spp. This problem has arisen following repeated annual treatment with trifluralin as preemergence application. In our efforts to solve the problem we have during the years 1972 to 1975 tested tank mixtures of trifluralin with the residual herbicides diuron, prometryne, and terbutryn. All mixtures were applied preemergence to cotton followed by mechanical soil incorporation. They were compared with the standard trifluralin treatments. In these trials we investigated the effects of the various mixtures and rates of application in four aspects :

(1) Effectiveness of weed control, i.e., range of weeds controlled and lasting effect ;

(2) Effect of herbicide mixtures on the crop ;

(3) Optimal depth of incorporation according to types of soil and agro-technical practices, and

(4) Optimal time of application according to climatic conditions.

As a result of 3 years trials, we have succeeded in selecting mixtures which control the complete range of weeds infesting cotton fields in the various soils and cotton areas of the country. The most efficient mixtures were:

(1) trifluralin 1 kg/ha + diuron 1.2 kg/ha, and

(2) trifluralin 1 kg/ha + prometryne 1 kg/ha.

WEED CONTROL IN COTTON THROUGH HERBICIDES

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Field study on weed control through herbicides was made with cotton (*Gossypium* spp. 'Hompi') for two seasons during 1973 and 1974, on medium black soils at the Agricultural Research Station, Siruguppa, under irrigated cropping. Eleven herbicides, viz., difenoxuron, fluometuron, dichlormate, finchloralin, paraquat, nitrofen, alachlor, butralin, dimitramine, MSMA, and fluchloralin were tried Preemergence herbicides were applied a day after sowing and post-emergence spray at six weeks after sowing. The volume of spray was 900 L/ha.

The major weed flora identified were: *Brachiaria rumosa*, *Brachiaria cruciformis*, *Chloris barbata*, *Panicum isachne*, *Isachne dispar*, *Euphorbia geniculata*, *Chrozophora rotteleri*, *Phyllanthus maderas patanisis*, *Commelina benghalensis*, *Cynotis axillaris*, *Lagascea mollis*, *Tridux procumbens*, *Flaveria australasica*, *Abutilon indicum*, *Corchorus trilocularis*, *Convolvulus arvensis*, *Alysicarpus rugosus*, *Desmodium diffusum*, *Cyperus rotundus*, and *Calotropis gigantea*.

In the first trial, diuron at 1 kg/ha (1529 kg/ha yield of seed cotton) and fluometuron at 2.5 kg/ha (1412 kg/ha) gave better yields than other herbicides. In the second trial, hand weeding three times gave 2257 kg/ha of seed cotton and 488 kg/ha in the non-weeded treatment. A yield of 2374 kg/ha was obtained from diuron (1 kg/ha) as preemergence coupled with MSMA at 2.5 kg/ha. Diuron at 0.75 kg/ha gave 2136 kg/ha of seed cotton.

CHEMICAL AND CULTURAL METHODS OF WEED CONTROL IN COTTON

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Field investigations on the comparative performance of chemical and cultural methods of weed control in cotton (*Gossypium hirsutum* var. 'P.S. 9') were carrid out for two consecutive seasons (1973 and 1974) at two different locations. The herbicides

used were trifluralin, diuron, fluometuron, and alachlor as soil application (preplant and pre-emergence) and MSMA and dalapon as postemergence subsequent to manual weeding operation three weeks after planting. A weedy check and a weed-free check (manual weeding repeated thrice) were included in the experiment for assessing the efficiency and selectivity of the herbicides.

Both the chemical and cultural methods reduced weed competition and enhanced the seed cotton yield. Among the herbicides, diuron applied either as preplant (1.5 kg/ha) or as preemergence (1.2 kg/ha) was the most effective in checking the weed growth thereby leading to increased seed cotton yield. Between fluometuron (1.2 and 2.4 kg/ha) and alachlor (1 and 2 kg/ha), the former maintained the seed cotton yield in level with the weed-free check in both the seasons. A postemergence spray with either MSMA or dalapon (1 kg/ha) after a manual weeding operation also gave results comparable with the weed-free check.

STUDIES ON THE SELECTIVITY OF ALACHLOR FORMULATIONS IN COTTON UNDER TWO SYSTEMS OF PLANTING AND ADSORBENT SEED TREATMENT

P. Rethinam and S. Sankaran

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Field investigations were conducted on the comparative performance of cotton (*Gossypium hirsutum* L.) crop the treated with preemergence application of emulsifiable concentrate (EC) and granular (G) formulations of alachlor at two seeding methods (bed and ridge systems) and two seed treatments (with and without coatings with activated charcoal).

The results revealed that EC formulation of alachlor was better than the granular formulation, and bed system of planting was superior to ridge system with regard to selectivity of alachlor to cotton. Alachlor at 1.5 kg/ha gave sufficient weed control and yielded 2065 kg/ha of seed cotton (132 kg more than the yield with alachlor at 1.75 kg/ha). Seeds coated with activated charcoal at 1:5 ratio of charcoal to seed gave early crop vigour and better seed cotton yield of 398 kg/ha over the untreated seeds.

EFFICIENCY OF ADSORBENTS IN REDUCING THE PHYTOTOXICITY OF ALACHLOR ON COTTON

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A field experiment was conducted to study the efficiency of adsorbents in reducing the phytotoxicity of alachlor on cotton (*Gossypium hirsutum* L. 'MCU5') under

field conditions. Adsorbents like activated charcoal, compost, and powdered domestic charcoal were used. The treatments comprised of seed treatment with activated charcoal at 1:5 ratio on weight basis, band application of activated charcoal at 25 kg/ha, seed coating and band application of powdered domestic charcoal at 375 kg/ha, and band application of compost at 1 t/ha. Alachlor (2.5 and 10 kg/ha) was sprayed preemergence after sowing the seeds and adsorbents were applied on the soil as per schedule,

The results revealed that under activated charcoal treatment germination was increased by 28 to 36% at 2.5 and 10.0 kg/ha of alachlor, respectively, over untreated control. Plant height, number of bolls, and seed cotton yield were more in the adsorbent-treated plots than in the herbicide-treated plots without adsorbents. Powdered charcoal was effective at the lower dose of alachlor but at higher rate the phytotoxicity to crop was reduced only to a small extent. Compost as an adsorbent behave moderately at both the doses of alachlor. A seed cotton yield of 2183 kg/ha was obtained under the band-applied activated charcoal, followed by hand-weeded (1962 kg/ha) and seed treatment with activated charcoal (1943 kg/ha). The present study revealed that coating seeds with activated charcoal was an efficient method of minimizing herbicide phyto toxicity on cotton.

STUDIES ON CHEMICAL WEED CONTROL IN IRRIGATED COTTON

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Weed control field trials were conducted in heavy soils of the Cotton Research Station, Amaravati during the Kharif seasons of 1972-1974 with cotton (*Gossypium hirsutam* 'MCU-5'), In 1972-73 season, MSMA alone at 3.4 kg/ha applied postmer gence twice during the crop period was the best herbicide treatment which was compaable with hand-weeded, followed by alachlor applied preemergence and a combination of MSMA and diuron. In 1973-74, flumeturon at 1 kg/ha applied preemergence followed by MSMA at 3.4 kg/ha gave the most effective weed control and highest yield of kapas. But this treatment will cost more than MSMA alone ; therefore, MSMA at 3.4 kg/ha alone is recommended.

STUDIES ON CHEMICAL WEED CONTROL IN COTTON

D.J. Chandra Singh and K. Narayana Rao

Weed Control Division, A.P. Agricultural University, Agricultural College. Bapatla, A.P.

Cotton (*Gossypium hirsutum*) is an important commercial crop providing cloth for the masses. The recent introduction of high yielding and hybrid cottons attracted

the attention of farmers as a remunerative income crop. Since cotton is prone to attacks by insect pests and diseases a regular plant protection schedule is being followed by farmers for prevention and control of pests. Thus, spraying operations have become a normal routine and weed control by the use of chemicals as one of the practices is now adopted by farmers. Systematic field trials were conducted and the results showed that of the available herbicides, alachlor and nitrofen are the best preemergence and paraquat as the postemergence herbicide. Alachlor and nitrofen can be sprayed preemergence at 3.75 kg/ha and 2.5 kg/ha, respectively, immediately or within three days after sowing. Paraquat at 0.5 kg/ha can be spraped postemergence 25 days after sowing, provided that the spray droplets do not fall on the crop plants.

EFFECT OF CERTAIN AERBICIDES ON WEED CONTROL AND YIELD OF COTTON

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(No abstract of paper submitted at the time of printing.)

4. OIL CROPS : GROUNDNUT, SESAMUM SAFFLOWER AND SUNFLOWER

CROP-WEED COMPETITION STUDIES IN RAINFED GROUNDNUT

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A field experiment was conducted in kharif 1975 at the Tirupati Campus of the Andhra Pradesh Agricultural University, to study the crop-weed competion in a rainfed bunchy variety of groundnut (*Arachis hypogaea* L. 'TMV 2'). There were 14 treatments with hand weeding spaced at 15 days intervals all through the crop period and no weeding. The studies revealed that weed competition was critical up to 45 days from sowing of groundnut. Weed-free environment maintained up to 45 days resulted in highest pod yield. The yield components such as number of filled pods and weight were also high in this treatment. There was reduction in the number of filled pods, weight and, consequently, in pod yield where hand weeding was done 45 days after sowing. The dry matter of weeds at 45 and 75 days after sowing indicated that the least dry matter of weeds was recorded in the weed-free treatment. Keeping land weed-free only from sowing to 30 days (and no weeding later) or no weeding from sowing to 30 days but weeded later lowered the pod yield compared to the crop kept weed-free from sowing to 45 days. In this treatment where no weeds were allowed to grow for 45 days, there was suppression of even later growth of weeds. Highest net return was also obtained in this treatment.

WEED CONTROL IN RAINFED GROUNDNUT WITH THE USE OF HERBICIDES

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Department of Agronomy, S.V. Agricultural College, Tirupati, A.P.

A field experiment was conducted in the kharif seasons of 1972 and 1973, at the Tirupati campus of the Andhra Pradesh Agricultural University, on sandy loam soil of low fertility, for the control of weeds in rainfed groundnut (*Arachis hypogaea* L. 'TMV 2') bunch variety. The treatments were; unweeded check, hand-weeded (at 15 and 30 days after sowing), ethyl ester of 2,4-D (0.5 and 1 kg/ha), alachlor (0.5 and 1 kg/ha), 2,4-D (0.5 kg/ha)+one hand weeding at 30 days, and alachlor (1 kg/ha)+one hand weeding at 30 days. All the herbicides were applied preemergence in 500

L/ha of spray solution. The results indicated that alachlor at 2 kg/ha or alachlor at 1 kg/ha+one hand weeding at 30 days after sowing effectively controlled the weeds and gave higher net return than the other treatments.

STUDIES ON CHEMICAL WEED CONTROL IN GROUNDNUT

D. J. CHANDRA SING and K. MAHADEVA GUPTA

Weed Control Division, A.P. Agricultural University, Agricultural College, Bapatla, A.P.

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop and a good foreign exchange earner. Among short term crops, the first 30 days is usually the critical period of weed competition. Cansequently, weed-free condition during this early stage of crop growth results in maximum production. Hence, the efficacy of different preemergence herbicides such as fluorodifen, dichlormate, I. C. 21 and perfluidone were studied at different doses. Fluorodifen sprayed preemergence at 3.36 kg/ha was found to be the best, followed by I. C. 21 and perfluidone. Satisfactory control of nutgrass was obtained in plots sprayed preemergence with perfluidone.

EVALUATION OF HERBICIDES FOR WEED CONTROL IN GROUNDNUT

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Four herbicides, prometryne as preemergence at 1 and 2 kg/ha, pebulate as preplant at 4 and 6 kg/ha, C-6989 (or fluorodifen) as preemergence at 2 and 4 kg/ha and EPTC+isooctyl ester of 2,4-D as preemergence at 0.9 and 1.8 kg/ha, were evaluated in groundnut under field conditions during kharif 1969. Pebulate, fluorodifen, and prometryne at all doses gave promising control of *Euphorbia thymofolia*, *Celosia argentea*, *Amaranthus Viridis*, *Cynodon dactylon*, *Tribulus terrestris*, *Trianthema monogyna*, and *Convolvulus arvensis* associated with the crop. EPTC caused severe injury to groundnut seedlings. Pebulate and, Prometryne at both doses and fluorodifen at the lower dose gave 50% increase in yield of grounut pods over control. Among these three herbicides, pebulate at 2 kg/ha increased the net weight of kernels.

EFFICIENCY OF HERBICIDES FOR WEED CONTROL IN IRRIGATED GROUNDNUT

R. KULANDAIVELU and S. SANKARAN

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An experiment was conducted at the Agricultural Research Station, Bhavanisagar, during summer 1974 in irrigated groundnut (*Arachis hypogaea* L.) with preemergence

herbicides. The treatments were : alachlor, prometryne, diuron, amiben, alachlor+nirofen, alachlor+amiben, alachlor+prometryne, alachlor+diuron, prometryne+amiben, and nitrofen+diuron. They were compared with hand-weeded (twice) and unweeded controls. The treatments were replicated thrice and laid out in a randomized block design. There were more grasses than broadleaf weeds. The important weeds in the order of abundance were : *Digitaria marginata* L., *Chloris gayana* L., *Cyperus rotundus* L., *Portulaca oleracea* L., *Acanthospermum hispidum* DC., *Flavaria australasica* Hook., and *Amaranthus viridis* L.

The results of the experiment indicated that application of alachlor at 1.5 kg/ha as preemergence spray reduced the weed population and dry matter of weeds. Maximum number of pods per plant and yield of pods (3514 kg/ha) were obtained in plots treated with alachlor (1.5 kg/ha) and followed by amiben (3 kg/ha). Diuron affected the crop, reducing the population by 60% in the initial stage but there was no more crop after 30 days. Among the herbicide mixtures, alachlor+nitrofen recorded maximum pod yield of 3453 kg/ha, followed by alachlor+amiben and alachlor+prometryne. Comparing the cost of herbicides with manual weeding, the yield optained under alachlor (1.5 kg/ha) was found to be economical.

EFFECT OF WEED-FREE ENVIRONMENT DURING SPECIFIC GROWTH PERIODS IN GROUNDNUT

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An investigation on the effect of Weed-free environment in ground-nut (*Arachis hypogaea* L.) under irrigated cropping was carried out during kharif 1976 at the Agronomy Field unit, University of Agricultural Sciences, Bangalore. Highest pod yield (2690 kg/ha) was obtained when weed-free environment was maintained from sowing to harvest. The yields decreased as the weed-free period was also reduced : 75 days weed-free period, 2560 kg/ha ; 60 days, 2540 kg/ha ; 45 days, 2290 kg/ha ; 30 days, 1750 kg/ha ; and 15 days, 1650 kg/ha. The pod yield was lowest in unweeded control (1220 kg/ha). Weed weight increased with the decrease in weed-free condition from sowing.

ECONOMISING FERTILIZERS IN GROUNDNUT THROUGH WEED CONTROL

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The investigation on economising the fertilizer application in groundnut (*Arachis hypogaea* L.) by effective weed control through chemical and cultural methods was made during kharif 1976 at the Agronomy field unit, University of Agricultural Sciences, Bangalore, on red sandy loam soil under irrigated condition. The results

revealed that spraying of nitrofen at 2.5 kg/ha as preemergence with or without intercultivation by hoe reduced by 40% the recommended fertilizer dose without significant reduction in yield (2549 to 3097 kg/ha). Results also revealed that the recommended dose of fertilizer with one intercultivation by hoe one hand weeding recorded the highest pod yield of 3104 kg/ha. On the other hand, the trea ment with recommended dose of fertilizer alone (without nitrofen, intercultivation by hoe and hand weeding) recorded 42% decrease in yield over the treatments with recommened dose of fertillzer but with one intercultivation and one hand weeding or nitrofen spray and one intercultivation.

STUDIES ON THE RELATIVE EFFICIENCY OF PREEMERGENCE HERBICIDES IN SESAMUM UNDER GRADED LEVELS OF NITROGEN

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Field experiments were carried out during summer and kharif 1975 to study the efficiency of alachlor, fluometuron, and dichlormate in sesamum (*Sesamum indicum* L.) under graded levels of nitrogen. The design adopted was split-plot with three replications. There were four nitrogen levels (0,15,30, and 45 kg N/ha) in the main plot in both the seasons. Fluometuron (0.25, 0.50, and 0.75 kg/ha), alachlor (1.25, 1.50, and 1.75 kg/ha), hand hoeing and weeding twice, and an unweeded control formed the sub-plot treatments in summer 1975. In kharif 1975 there were only two levels of alachlor (1.50 and 1.75 kg/ha) and two levels of dichlormate (1.25 and 1.50 kg/ha) plus the controls mentioned above.

Significant increase in sesamum seed yield (537 kg/ha) was obtained with 30 kg N/ha in the summer crop. In the kharif crop, the maximum yield of 375 kg/ha was obtained at 45 kg N/ha which was comparable with 370 kg/ha from 30 kg N/ha. In summer 1975, alachlor at 1.50 kg/ha gave significantly superior yield (613 kg/ha) to the rest of the treatments, except alachlor at 1.25 kg/ha which yielded 588 kg/ha.

Fluometuron at 0.25 and 0.5 kg/ha did not control weeds effectively, whereas 0.75 kg/ha caused phytotoxicity to sesamum which resulted to yields lower than those of alachlor or hand hoeing and weeding. During kharif 1975, alachlor at 1.75 kg/ha was significantly better (473 kg/ha) than the rest of the treatments. Alachlor at 1.75 kg/ha in combination with the 30 kg N/ha gave the maximum net income and also the highest return per rupee invested on weed control.

CHEMICAL WEED CONTROL IN SAFFLOWER

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In a field experiment with safflower (*Carthamus tinctorius*) under irrigated conditions, seven herbicides, chlormben (both granules and emulsion types), alachlor,

nitrofen, BV 201, EPTC, and trifluralin at two concentrations each were tried for the control of weeds as compared to hand weeding, hoeing twice, and an unweeded check. Data showed that preemergence application of trifluralin (1 kg/ha) yielded 1833 kg/ha with an insignificant weed weight (dry) of 45 kg/ha. Similarly, BV 201 (1 kg/ha) gave a safflower yield of 1690 kg/ha with a weed weight of 73 kg/ha ; alachlor (1 kg/ha), 1308 kg/ha with a weed weight of 23.5 kg/ha ; nitrofen (1 kg/ha), 1354 kg/ha with a weed weight of 67.5 kg/ha hand weeded, 1283 kg/ah with a weed weight of 21 kg/ha, and unweeded check, 753 kg/ha with a weed weight of 273 kg/ha.

It may be concluded that trifluralin (1 kg/ha), BV 201 (1 kg/ha), alachlor (1 kg/ha), and nitrofen (1 kg/ha) applied preemergence in safflower field reduced the weed population and helped increase crop yield. Similar trend was noticed in the subsequent trial during 1975-1976.

POSSIBILITIES OF SUNFLOWER PRODUCTION BY USING HERBICIDES BLACK COTTON SOILS

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Weeds represent a major challange to optimum efficiency in farming operations throughout the country. But weeds become still more a serious problem in areas where frequent rains occur on medium to heavy black soils, such as in Bhopal, Hoshangabad, and Sagar divisions of Madhya Pradesh, where a large area has to be left fallow during kharif and only a rabi crop is taken because of weeds.

Investigations were carried out in the Tawa Pilot Research Project (JNKVV), Powerkheda, during the kharif season of 1974 to explore the Possibility of sunflower (*Helianthus annuus* L.) production by controlling weeds with the help of herbicides. The following herbicides were tested: fluchloralin, alachlor, nitrofen, chloramben, dichlormate, EPTC, chlorbromuron, prometryne, and dalapon.

Fluchloralin (1.5 kg/ha) gave sunflower yield of 1082 kg/ha which compared favourably with the plots hand-weeded four times (799 kg/ha) and the unweeded control (532 kg/ha). A combination of nitrofen and prometryne was found to be the next best treatment with a yield of 999 kg/ha.

The results revealed that sunflower production in kharif season was possible with the use of herbicides even under the adverse conditions which favour weed growth.

WEED CONTROL BY HERBICIDES IN SUNFLOWER UNDER RAINFED CONDITIONS

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Investigation on weed control in sunflower (*Helianthus annuus* L.) under dry land conditions was carried out during the monsoon seasons of 1974 and 1975 under the All India Coordinated Research Project on Oilseeds at the University of Agricultural Sciences, Bangalore. The highest seed yield (459 kg/ha) was obtained in plots free of weeds, followed by prometryne (0.75 kg/ha applied preemergence) with a yield of 414 kg/ha Prometryne was also effective in checking weed growth'

CHEMICAL WEED CONTROL IN SUNFLOWER

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In order to find out effective herbicides and their optimum concentrations for the control of weeds in sunflower *(Helianthus annuus* L.*)*, three herbicides, alachlor, nitrofen and chloramben at three concentrations each were tried during kharif 1976, at the College Farm, Dharwar. Soil type of the experimental field was black clay loam.

Experimental data indicated that nitrofen at 1 kg/ha gave 2554 kg/ha of seeds and a weed weight of 542 kg/ha. This was closely followed by alachlor at 1.5 kg/ha which gave 1784 kg/ha of seeds and a weed weight of 266 kg/ha as against 1616 kg/ha seeds and a weed weight of 2530 kg/ha by the unweeded control treatment. On the other hand, hand-weeded treatment recorded 1850 kg/ha of seeds and 373 kg/ha of weed.

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5. SUGAR CROPS : SUGARBEET AND SUGARCANE

THE INFLUENCE OF WEEDS ON SUGARBEET YIELD AND THEIR CONTROL USING HERBICIDES

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Sugarbeet (*Beta vulgaris*) yields remain unaffected even when grow in association with weeds for the initial 60 days of crop growth. Maintaining the land weedfree for the first 30 days of planting gave root yield significantly superior over weedy check. Further increase in the period of weedfree condition increased root yield but the differences were not significant.

Application of pyrazon+phenmedipham (3+2 kg/ha) gave maximum root yield among the various herbicide combinations under test.

STUDIES ON CHEMICAL WEED CONTROL IN SPRING PLANTED SUGARCANE

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Herbicide field trials were conducted in spring planted sugarcane (*Saccharum officinarum* 'Co. J. 64') in the Punjab Agricultural University, Ludhiana, during 1972-73 and 1973-74 on light textured soils (organic matter, <0.3 percent). Tank mix of simazine+diuron (0.5+0.5 kg/ha) applied preemergence gave promising weed control and resulted in maximum cane yield of 69 t/ha as against 63.4 and 51.9 t/ha with two hoeings and unweeded control, respectively. Preemergence application of simazine+diuron (1+0.25 kg/ha) and simazine (1.5 kg/ha), each followed by post-emergence 2,4-D (0.5 kg/ha), were the next promising treatments. The above herbicide treatments gave, respectively, 33, 28, and 25% higher cane yield than the unweeded control. EPTC was not effective against most of the broadleaf weed species, the dry matter of weeds being nearly of the same level as in the unweeded plots. None of the treatments showed any phytotoxic effect on the crop.

DIFFERENTIAL TOLERANCE OF SUGARCANE VARIETIES TO HERBICIDES

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An experiment was conducted to find out the differential tolerance of sugarcane (*Saccharum officinarum* L.) varieties to preemergence application of atrazine and diuron at 2.4 and 9.6 kg/ha. A weedfree check was taken as standard for the comparison. Sugarcane varieties screened were: Co. 1158, Co. 281, Co. 449, Co. 527, Co. 658, Co. 1163, Co. 1340, Co. 62174, Co. 997, and B. O. 17. The soil of the experimental field was sandy clay loam and of medium fertility. The soil pH was 7.5.

Observations were recorded on the effect of herbicides on germination, cane height, cane thickness, millable cane at harvest, cane yield, and juice quality. There were highly significant differences in cane yield among the sugarcane varieties under different treatments. Both the low and high doses of diuron reduced the cane yield significantly of varieties Co. 281, Co. 1340, Co. 62174, Co. 997, and B. O. 17, while the higher dose reduced the yield of Co. 1158 and Co. 449. Likewise, the low and high doses of atrazine significantly reduced yield of varieties Co. 658, Co. 1340, Co. 62174, and Co. 997, while the yield of variety Co. 1158 was affected only under high dose. Varieties Co. 527 and Co. 1163 were found tolerant to both atrazine and diuron, while varitey Co. 281 was tolerant only to atrazine.

RELATIONSHIP BETWEEN THE POPULATION AND DRY MATTER OF WEEDS WITH THE YIELD AND QUALITY OF SUGARCANE UNDER DIFFERENT WEED CONTROL METHODS.

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A field experiment was laid out at the Sugarcane Breeding Institute, Coimbatore, during 1973-74 with different preemergence soil applied herbicides, ametryne, atrazine, and diuron, coupled with preemergence and postemergence applied 2, 4-D at two concentrations and further associated with and without intercultivation treatments. Unweeded control and pre and post-monsoon weeding treatments were also included for comparison on the variety Co. 6304. The data on the weed population and dry matter were correlated with the number of millable canes, cane yield, sucrose percent in juice and sugar yield (C. C. S., t/ha). Negative correlation was obtained with weed population, millable cane, cane yield, and sucrose percent in juice. The C. C S. (t/ha) did not correlate with that of weed population. With the dry matter of weeds, negative correlations of high significance were noticed in all the factors studied, indicating that weed dry matter component interfered with yield of cane, number of millable cane, sucrose content, and C. C. S. The results have shown

that the suppression of the sprouting and subsequent growth of the weeds using herbicides were more efficient than allowing the weeds to grow and their removal later by hand-weeding.

PRESENT POSITION OF CHEMICAL WEED CONTROL IN SUGARCANE

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Sugarcane (*Saccharum officinarum* L.) is a tropical crop and is the chief source of sugar. This crop is in the field from 12 to 18 months and one of the major operations is weeding. The weeding in the early stages is very important, since heavy weed infestation prevents proper bud germination and may cause death of the crop. The smothering effect of crop by weeds is observed only for about 4 to 5 months; therefore, the weeds must be kept under control for four months.

The use of herbicides has become very common in Hawaii, Australia, Jamaica, and the West Indies whereas it is just gaining momentum in India. Of several compounds screened for use in sugarcane, preemergence application of either atrazine at 2.8 kg/ha or alachlor at 3 kg/ha satisfactorily controlled weeds, resulting in increased tonnage and improved juice quality. Post-emergence application of the Na salt of 2,4-D (3 kg/ha) paraquat (0.5 kg/ha) at 15 to 20 days after planting also gave acceptable weed control.

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6. PULSE CROPS : CHICKPEA, BLACKGRAM, GREENGRAM AND SOYBEANS

EFFECT OF HERBICIDES ON GROWTH AND YIELD OF GRAM

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Grain or chickpea (*Cicer arietinum* L. cv. 'C-130') was sown in the field in rabi season of 1975-76 and treated one day after sowing with alachlor and nitrofen at 0.75, 1.0, and 1.25 kg/ha and chloroxuron at 0.25, 0.50, 0.75, and 1 kg/ha. Controls were hand weeding and no weeding. *Chenopodium album* L. and *Convolvulus arvensis* L. were the dominant weeds in the field. All the herbicides caused better growth of gram seedlings in comparison to controls. Chloroxuron at 0.50 kg/ha and nitrofen at 1.25 kg/ha were the best regarding the growth of gram seedings. The dry matter production followed the same trend. Herbicides, in general, increased the nitrogen and phosphorus contents of treated plants. All herbicides in their higher doses have shown better weed control over lower doses. Nitrofen at 1.25 kg/ha, chloroxuron at 1 kg/ha, alachlor and nitrofen at 1 kg/ha, and chloroxuron at 0.75 and 1 kg/ha gave better yields over both types of controls.

THE INFLUENCE OF VARIOUS DENSITIES OF ASPHODELUS TENUIFOLIUS CAV. AND CHENOPODIUM ALBUM L. ON GRAM CROP

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Competitive losses in gram (Cicer arietinum L.) due to manipulated varying density levels of two major weeds, Asphodelus tenuifolius Cav. and Chenopodium album L., were compared with yield and growth performance of crop in naturally occurring weed and weed-free situations. Results indicated that Asphodelus was more deleterious in curtailing the growth and yield of crop than Chenopodium or the natural weedy conditions.

CHEMICAL WEED CONTROL IN BLACK GRAM

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Three herbicides, alachlor, nitrofen and chloramben at three concentrations each were used as preemergence in black gram *(Phaseolus mungo* L.*)* crop during kharif 1976. The experintal site consisted of clay loam soil type.

Results indicated that hand-weeded treatment gave 1265 kg/ha of seeds and a total dry weed weight of 449 kg/ha. On the other hand, black gram treated with alachlor (1 kg/ha) yielded 1184 kg/ha of seeds and 234 kg/ha of weed and nitrofen (1.5 kg/ha) gave 1032 kg/ha of seed and 170 kg/ha of weeds. Chloramben was not as effective as other herbicides in controlling the weeds. Unweeded check gave 734 kg/ha of seeds and 649 kg/ha of weeds.

CRITICAL PERIOD OF CROP WEED COMPETITION IN MUNG BEANS

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Field studies were conducted on mung beans (*Phaseolus aureus* L.) at the Punjab Agricultural University, Ludhiana, during 1973 and 1974 to find out the critical period of mung-weed competition so that the crop may be saved from the damaging effect of weeds by giving hoeing or through the application of chemicals.

For determining the critical period of crop-weed competition (i) the weeds were removed from the crop at 2,4, and 6 weeks after sowing and (ii) keeping the plots weed-free after 2,4, and 6 weeks. In addition, a conventional method of weeding (at 30 and 50 days after sowing), weed-free throughout the season, and unweeded treatments were kept for comparison.

Weeds offered great competition to mung crop and thus reduced yield by 50%. The conventional method and one weeding at 4 weeks after sowing were quite effective in controlling weeds thus produced good grain yields. Weed-free condition after 2 or 4 weeks and weed-free throughout the crop season gave statistically comparable results. One weeding at 2 or 6 weeks after sowing could not help in improving the yield.

From these studies, it appeared that the critical period of crop weed competition in this crop was at 4 to 6 weeks after sowing.

CHEMICAL WEED CONTROL IN MUNG BEANS

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Field studies on chemical weed control in mung beans (*Phaseolus aureus* L.) were conducted at the Punjab Agricultural University, Ludhiana, during 1973 and 1974. The trials were conducted under irrigated condition, on loamy sand soil of low available N and medium P. The herbicides tested were: alachlor (1.5, 2.5, and 3.5 kg/ha), nitrofen (1.25, 1.50, and 2 kg/ha), and three combinations of alachlor+nitrofen (0.75+0.625, 1.25+0.75, and 1.75+1 kg/ha). They were compared with the conventional method for their efficacy to control the weeds in mung crop.

The highest grain yield (1530 kg/ha) was obtained from weed-free plots in the year 1973, which was 44% more than the yield of the unweeded plots. Combination of alachlor+nitrofen (0.750+0.625 kg/ha) and nitrofen (1.25 kg/ha) gave comparable yield with the weed-free plots and were statistically better than the unweeded control. However, in the year 1974 the highest grain yield was obtained under a combination of alachlor+nitrofen (1.750+1 kg/ha). The difference in the two years' yields and the effects of different doses and chemicals may be attributed to the differential rainfall in both the years. In 1973 the rainfall was received within 24 hours after preemergence spray of the herbicides. However, in 1974, no immediate rains were received and, moreover, drought prevailed during the later half of the crop season. This condition produced profound influence on the growth of the crop and weeds and on the herbicidal activity.

In general, plant population was adversely affected be alachlor and nitrofen and the magnitude increased with the increase in dose in the year 1973. The magnitude of toxic effect of nitrofen on plant population was comparatively lower than that of alachlor.

Nitrofen showed comparatively better control of broadleaf weeds than alachlor. However, combination treatments were more effective as they controlled both the dicot and monocot weeds effectively and the weed population and dry matter accumulated by weeds were relatively low.

It may be suggested that in areas of high rainfall low doses of these herbicides may be used. Application of mixture of alachlor+nitrofen at 0.750+0.625 kg/ha, respectively, may be safe both under high and low rainfall conditions.

EFFICACY OF MECHANICAL AND CHEMICAL WEED CONTROL METHODS IN GREEN GRAM

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Weed control is a serious problem for green gram (*Phaseolus aureus* L.) which is usually sown in the rainy season without much preparatory cultivation. A field trial

with green gram (Type 44) consisting of mechanical weeding and preemergence spray of alachlor (1,2 and 3 kg/ha) and nitrofen (1 and 2 kg/ha) was conducted at the Research Farm of C.S. Azad University of Agriculture and Technology, Kanpur, U.P., during kharif 1973-74 and 1974-75.

One weeding after 20 days of sowing was quite effective in controlling the weeds and thus doubling the yield as compared to unweeded plots. Nitrofen at 1 kg/ha was most economical and increased crop yield by 136% over the control.

INVESTIGATIONS ON CHEMICAL WEED CONTROL IN SOYBEAN

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Field experiments were carried out to study the comparative efficiency of various herbicides, their mixtures and combination with cultural methods in terms of weed control and grain production, mineral nutrition, and quality in soybean (*Glycine* max cv. 'Bragg'). The effect of herbicides on microflora and nodulation of soybean was studied in pot culture experiment.

The critical period of weed competition was up to six weeks after planting. Two weeding operations, one at three weeks and other at six weeks, proved beneficial to grain production.

Trifluralin at 2 kg/ha or its combination with vernolate and EPTC each at 1 kg/ha applied preplant reduced the dry matter accumulation in weeds to as low a level as that resulting from the hand-weeded (twice) control. The combination treatment of trifluralin+vernolate also effected a substantial improvement in the dry matter production of soybean. Unchecked weed growth depleted the soil nutrients to as high as 35.9, 10.6, 56.1, and 54.1 kg/ha of N,P,K, and Ca, respectively. On the other hand, plots treated with trifluralin+vernolate los only 9, 2.3, 12.1, and 13.1 kg/ha of these nutrients, respectively. This combination treatment improved the crop nutrition, seed, and protein yield,

The protein content of the grain was improved due to nitrofen (2 kg/ha) applied preemergence and trifluralin +- vernolate. These treatments compared favourably with other treatments including repeated weeding in respect of P, K, Ca, S, and methionine content in soybean grain. Nitrofen favourably influenced the bacterial and fungal population in rhizoplane and rhizosphere of soybean. It stimulated the nodulation of soybean and increased its nitrogen uptake.

A postemergence soil application of either trifluralin or nitrofen immediately after a manual weeding operation at 3 weeks did not appear to have additional adv n-tage over those applied preplant or preemergence in respect of weed control and crop yield. On the other hand, EPTC applied postemergence on the soil immediately after a weeding operation appeared beneficial.

7. VEGETABLES AND SPICES : OKRA, POTATO, ONION AND TURMERIC

COMPARATIVE EFFICIENCY AND SELECTIVITY OF HERBICIDES IN OKRA

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Field experiments were conducted for two seasons (spring and kharif, 1973) with okra *Abelmoschus esculentus* Moench. 'Pusa Sawani') at the Agricultural Research Institute, Sabour (Bihar), to evaluate the selectivity and efficiency of preemergence application of alachlor (1 kg/ha), nitrofen (0.5 kg/ha), and their combinations with one hand-weeding or postemergence application of MSMA (0.8 kg/ha). Repeated weeding and an unweeded check were also included for comparisons.

The herbicidal efficiency was assessed in terms of population and fresh weight of weeds, weed control efficiency and weed index, and selectivity in terms of the effect on fruit number and yield.

The most critical period for weed competition was recorded at 30 to 60 days after sowing. Alachlor controlled most of the weeds, particularly the annual grass weeds which dominated in both the seasons, and checked the fresh weight accumulation in weeds. However, one hand-weeding combined with nitrofen or alachlor were found more effective in controlling the annual grasses, giving higher weed control efficiency for longer duration and lower weed index.

Alachlor was as effective as repeated weeding in increasing the fruit-yield in spring season, whereas in kharif season addition of one hand-weeding with alachlor or nitrofen applied as preemergence was found essential for getting the higher yield.

CHEMICAL WEED CONTROL IN OKRA

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An experiment was conducted on okra (*Abelmoschus esculentus* L. 'Pusa Sawani') during summer 1976 under the All India Coordinated Vegetable Improvement Project of the Department of Horticulture, Tamil Nadu Agricultural University. The treatments were ; different levels of alachlor (1.5, 2, and 2.5 kg/ha), nitrofen (2 and

3 kg/ha), prometryne (0.5 and 1 kg/ha), alachlor 1.5 kg/ha + one hand weeding. nitrofen 2 kg/ha + one hand weeding, prometryne 0.5 kg/ha + one hand weeding, farmers' method (2 to 3 hoeings and a third light weeding), and unweeded control. The spacing for okra was 45 by 20 cm with two plants per hill. All the three herbicides showed selectivity for the crop. The main weed species found was *Trianthema portulacastrum*. Other weed species were *Gynandropsis pentaphylla*, *Echinchloa* sp., *Cyperus rotundus*, and *Cynodon dactylon*. The herbicide persistence was in the order of nitrofen <alachlor <prometryne. The treatment receiving prometryne (0.5 kg) + one hand weeding recorded a fruit yield of 16900 kg/ha, followed by prometryne (1 kg), 16792 kg ; farmers' method, 16240 kg ; nitrofen (2 kg) + one hand weeding. 16355 kg ; and prometryne (0.5 kg), 15947 kg. Economics of weed control showed that prometryne (1 kg) gave a gross income of Rs. 6581; prometryne (0.5 kg) + one hand weeding, Rs. 65250 ; farmers' method, Rs. 6090. and nitrofen (2 kg) + on hand weeding, Rs. 6062. It was concluded that application of prometryne (0.5 kg/ha) as preemergenee + a hand weeding at 30 days was economical. Since this chemical is not yet available in the market the farmers' method of two to three hoeings and a light fluid weeding is recommended for okra for the present.

EVALUATION OF EARLY PERIOD WEED CONTROL IN POTATO THROUGH HERBICIDES

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Field experiments were conducted on potato (*Solanum tuberosum* L.) from 1972 to 1974 to evaluate the possible benefits of pre-earthing period weed control with EPTC, paraquat, and metobromuron. It was found that on the heavy latisol of Udaipur, irrigated crop of potato responded well to early period weed control even though the weeds accumulated dry matter of no more than about 400 kg/ha up to the time of first earthing when all weeds were removed. Nutrient competition was thus not considered an important factor in weed-crop interference in these experiments. Early shading of crop plants by weeds and (or) allelopathy were speculated as dominant effects of early weed growth in potato. Further, the weeds in potato did not adversely affect tuber number per plant (tuberisation) but reduced the tuber yield per plant (tuber development).

Preplant incorporation of EPTC at 1.5 kg/ha along with last seed bet tillage operation was found to be a very selective and most economic treatment for weed control in potato with a benefit cost ratio of approximately 10.

COMPARATIVE EFFICACY OF SOME HERBICIDES FOR WEED CONTROL IN POTATO

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Field experiments were conducted in the Punjab Agricultural University, Ludhiana, during 1975 and 1976 to study the comparative efficacy of simazine, methabensthiazuron, metoxuron, linuron, fluchloralin, and paraquat for weed control in autumn sown potato (*Solanum tuberosum* L. 'Kufri-chandermukhi'). Differences in tuber yield under different treatments were significant during both the years. Linuron at 0.8 kg/ha gave maximum tuber yield of 20.7 and 22.4 t/ha during 1975 and 1976, respectively. This was followed by linuron at 0.4 kg/ha preemergence and paraquat 0.5 kg/ha applied at 5 to 10% emergence of crop (about 15 days after sowing). The unweeded crop gave 11.4 and 13.7 t/ha tuber yield during 1975 and 1976, respectively. Promising results were also obtained with preemergence application of simazine (0.25 kg/ha), methabenzthiazuron (0.70 kg/ha) and metoxuron (0.4 and 0.8 kg/ha). There was no difference in the tuber yield when simazine at 0.25 kg/ha was applied preemergence either before or after the first irrigation but before weed emergence. Split application of paraquat at 0.5 kg/ha as blanket spray (one-half at 5 to 10% emergence and one-half at 30% emergence of the crop) showed a depressing effect on tuber yield. Data also indicated that the primary result of earthing up the crop about 4 to 5 weeks after planting was to control weeds and prevent the greening of tubers by strengthening the ridges. If hand pulling of weeds is done on plots with well-prepared ridges at sowing, there is no need for subsequent earthing up. None of the herbicides showed any residual phytotoxic effect on wheat (*Trtricum sativum* L. 'S-308') and harley (*Hordeum vulgare* 'C-164' and 'DL-70') crops sown after potato harvest.

COMPARATIVE EFFICIENCY OF SEVEN DIFFERENT HERBICIDES FOR THE CONTROL OF WEEDS IN POTATO

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Field trials were conducted for two seasons of 1973 and 1974 with potato (*Solanum tuberosum* L. 'Kufri Jyoti') for the evaluation of the efficiency and selectivity of preemergence herbicides nitrofen (2 kg/ha), simazine (0.5 kg/ha), Na salt of 2,4-D (1 kg/ha), alachlor (2 kg/ha), and dichlormate (5 kg/ha), and postemergence herbicides propanil (2 kg/ha) and paraquat (2.5 kg/ha). The other treatments were weedy check and handweeded check (weeded on three different occasions during the season).

Results of the trials showed that preemergence herbicides simazine, alachlor, and dichlormate were as good as handweeded check in controlling the weeds. The other herbicides in this trial could not control the dominant weeds. The tuber yield in 1973 season under simazine (4426 kg/ha) and dichlormate (4255 kg/ha) was comparable

with the yield of handweeded check (4383 kg/ha). Thus, it appeared that a preemergence application of simazine (0.5 kg/ha) and dichlormate (5 kg/ha) gave satisfactory weed control and increased tuber production. However, the yield data for the 1974 season did not differ significantly among the treatments.

SELECTIVITY AND EFFICACY OF SOME NEW HERBICIDES FOR WEED CONTROL IN ONION

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Studies were conducted in the Department of Vegetable Crops, Landscaping and Floriculture, Punjab Agricultural University, Ludhiana to ascertain the selectivity and efficacy of some new herbicides for weed control in onion *(Allium cepa* L.*)*. Oxadiazon (1 and 1.5 kg/ha) applied as preemergence and fluchloralin (2 kg/ha) as preplant spray gave excellent weed control. Fluchloral in significantly increased the bulb yield followed by oxadiazon, although there was no significant difference between oxadiazon (1.5 kg) and two hand weedings. Metoxuron (1 and 1.5 kg/ha) applied preemergence had some phytotoxicity to the onion crop resulting in significantly lower yields over the weeded control plots.

CHEMICAL WEED CONTROL IN ONION

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Alachlor at 2 kg/ha and a combination of nitrofen and chloroxuron at 1 kg/ha. sprayed preemergence to weeds, 20 and 10 days before transplanting of onions (*Allium cepa* L.), respectively, were found to be the effective herbicides giving yield increases of 26 and 23%. Highest total sugar (%) was obtained in the combination of nitrofen and chloroxuron. The herbicide treatments did not have any adverse effect on the storage capaity of onions.

CHEMICAL WEED CONTROL IN TURMERIC

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An experiment was conducted in the Tamil Nadu Agricultural University, Coimbatore from July 1975 to April 1976, to study the comparative efficiency of different chemical weed control methods in turmeric (*Curcudma longa* L.). Three

preemergence herbicides, alachlor, diachlormate, and nitrofen at 1.5 and 2 kg/ha each were individually compared with that of hand-weeded and unweeded controls. The experiment was laid out in a clay loam soil. The common weeds were : *Trianthema portulacastrumt*, *Eclipta alba*, *Euphorbia hirta*, *phyllanthus niruri*, *Cyperus sp.*, *Echinochloa Colonum*, and *E. crusgalli*. The weed control efficiency was more in a alachlor at 2 kg/ha, which had the least dry matter of weeds. The effect of herbicides lasted up to 35 days in alachlor and 25 days in nitrofen and dichlormate. Earthing up was done at 45,90, and 135 days as general practice. The application of the preemergence herbicides reduced the early crop-weed competition which resulted in the early vigorous growth of turmeric under weed-free environment. The rhizome weight of plant was more in alachlor followed by diahlormate at 2 kg/ha. Alachlor (2 kg/ha) gave the highest yield, 16.83 t/ha> dichlormate (2kg/ha), 15.12 t/ha> hand-weeded control, 13.52 t/ha> unweeded control, 5.34 t/ha. The cost of chemical weed control was found to be economical compared to that of hand-weeding.

8. FRUIT TREES, BANANA, PINEAPPLE, MULBERRY AND TEA

HERBICIDAL CONTROL OF WEEDS IN APRICOT

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A preemergence trial was conducted in 1975 at S.N. Stokes Horticultural Complex, Solan, to test the efficacy of various concentrations of simazine, diuron and terbacil for the control of weeds in apricot (*prunus armeniaca* L.) orchard. The study revealed that simazine or diuron at the rate of 2,4 and 6 kg/ha checked the emergence of monocot and dicot weeds effectively for 90 days. Terbacil applied at the rate of 1 kg/ha did not control the monocot weeds effectively whereas the higher rates of 2 and 3 kg/ha checked the emergence of weeds. In general there was no statistical difference in the relative responses to the varying levels of simazine and diuron. The best control of weeds were recorded with 4 and 6 kg/ha simazine and diuron. There were no phytotoxicity effects of the herbicides on the trees. The yield and other quality parameters of the fruits were not affected significantly.

EFFICACY OF VARIOUS HERBICIDES ON THE CONTROL OF WEEDS IN PLUM ORCHARDS

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A trial in plum (*Prunus domestica* L.) orchards was initiated in 1975 to study the efficacy of different herbicides at the S. N. Stokes Horticultural Complex, Solan. The study revealed that application of various concentrations of simazine, diuron, atrazine, and terbacil along with paraquat (0.4 kg/ha) checked the emergence of monocot and dicot weeds. However, MSMA (0.88 kg/ha) along with paraquat was not effective against the monocot weeds. The higher dosage of MSMA controlled to a considerable extent the emergence of monocot and dicot weeds. The best control was obtained with 4 and 6 kg/ha of simazine, diuron or atrazine. There were no phytotoxic effects of herbicides on the trees. The yield and other quality parameters of the fruits were not affected significantly.

EFFECT OF HERBICIDES ON GROWTH, YIELD, AND QUALITY OF BANANA

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A weed control study was conducted on banana (*Musa paradisiaca* 'Dwarf Cavendish') in 1975-76 at the Assam Agricultural University farm, Jorhat (26.47° N, 94.12 E). Three herbicides were applied, namely : diuron and simazine at the rate of 2,4, and 6 kg/ha as preemergence and paraquat at the rate of 1,2, and 3 kg/ha as postemergence.

Diuron at higher doses was found effective in controlling *Elusine indica*, *Imperate cylindrica*, *Setaria glauca*, *Axonopus compressus*, and *Borreria hispida*. Next to diuron was simazine which was also effective in arresting the growth of weeds. Simazine at 6 kg/ha significantly increased the bunch weight (10.4 kg), number of hands per bunch (7.6), and length of the fruit (11.2 cm), pulp weight, and pulp-peel ratio. Application of herbicides significantly increased banana yield. The highest yield (35.53 t/ha) was obtained under simazine at 6 kg/ha, followed by 4 kg/ha (29.70 ton) which was significantly better than other treatments. The herbicides did not affect the acidity, total soluble salts, and the reducing and total sugars.

PRELIMINARY STUDY ON CONTROL OF WEEDS IN PINEAPPLE-BANANA PLANTATION WITH TWO SOIL APPLIED HERBICIDES

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An exploratory study was undertaken with two soil applied herbicides, simazine and bromacil, for the control of weeds in plantation of banana (*Musa paradisiaca* L.) and pineapple (*Ananas comosus* (L.) Merr,). The herbicides were applied at 3 kg/ha as preemergence directed spray (15 days after planting) to weed-free soil in newly planted pineapple banana and in established crops (6 months after planting).

Both herbicides were equally effective in controlling weeds for about one month after planting. But bromacil was found better and more effective than simazine for the control of weeds for about 90 days after planting.

Bromacil application showed phytotoxic effect on both the newly planted and the established banana plants, resulting in die-back symptoms and poor plant growth. Simazine application did not show any phytotoxic effect to pineapple and to banana under both the conditions of treatment.

CHEMICAL CONTROL OF WEEDS IN MULBERRY

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With a view to find effective and economic control schedule for the varied spectrum of weed flora in mulberry (*Morus alba* 'Dudhiamona') field trials were conducted with MSMA alone and in combinations with 2,4-D, diuron, and dalapon.

Postemergence application of MSMA (1.7+2.6 kg/ha), MSMA+Na salt of 2,4-D (1.2+0.8 kg/ha), MSMA+diuron (1.0+0.48 kg/ha), and MSMA+Na salt of 2,4-D+dalapon (1.0+0.56+1.2 kg/ha) resulted in 82 to 94% control of weeds in mulberry. Increase in yield of 220 to 740 kg/ha were obtained from the treatments over the cultivated control crop. Among the treatments, performance of the combination of MSMA+2,4-D+dalapon was the best. Cost of chemical weeding was Rs. 385/ha against Rs. 750/ha for hadweeding, giving a net profit from chemical weed control of about Rs. 470/ha.

WEED MANAGEMENT IN TEA FIELDS IN SOUTH INDIA

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In South India, tea (*Camellia sinensis* (L.) O. Kuntze) is grown at altitudes ranging from 100 to 2200 m, most of which less between 10 to 16% slopes, though some tea area is situated on even up to 33% slopes. Tea estates are located in widely varying climatic zones with rainfall varying from 120 to 600 cm, spread over seven to nine months in a year. Situated as they are, the tea fields in South India have specific weed problems peculiar to their situation and the prevailing climatic conditions.

Weeds are particularly a problem in young tea clearings and pruned fields and the need for their control persists till the bushes cover over the rows, thus screening off light and reducing weed growth by shading. Though weed control in tea fields is as old a practice as tea itself, a real breakthrough was achieved only with the introduction of herbicides in the mid-sixties. Dalapon, 2,4-D, paraquat, MSMA, duiron, and simazine are the herbicides recommended and used at different rates and in different combinations in tea fields in South India, for over a decade now. But the prolonged and continuous use of some of the above herbicides led to a situation now where tolerant/resistant weed species and their populations are increasing. Measures are needed to counter this problem and the introduction of new herbicides like glyphosate is important in this context and in the eradication of recalcitrant grass species.

There is a definite advantage in integrating the herbicides into a system of weed control, rather than using them as the only tools, particularly with reference to the problems encountered in tea fields in South India.

ADVANCES IN WEED RESEARCH IN TEA OF NORTH EAST INDIA

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Approximately 55% of the area under tea *(Camellia sp.)* in Northest India is under herbicides and this accounts for about 70% of the herbicides marketed in India. This achievement is mostly due to the poineering research done by Tocklai Experimental Station on chemical weed control in the past 25 years. During this time, a number of new chemicals have been tested, and effective herbicides and herbicide combinations selected and recommended for nursery, young tea, and mature tea areas. Efficacy of herbicides, persistence of toxicity to tea plant, and effect of herbicides on quality of cup tea were the main criteria used in developing these recommendations. This was made possible by a well organized herbicide testing and certification programme.

Research has also been conducted on : (a) biology and control of individual weed species predominant in tea growing area; (b) changes in weed spectrum due to continuous use of herbicides on the same soil ; (c) enhancement of herbicide activity by wetting agents, surfactants, and fertilizers, and (d) prevention of rain wash of postemergence spray off weed foliage. Significant amount of work has also been done to standardize spraying techniques and spraying equipment. The possible use of sub-standard and adulterated herbicides by tea estates is discouraged and prevented with the help of a quality testing programme.

EFFECTIVE WEED CONTROL IN TEA BY GLYPHOSATE

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Glyphosate is a new postemergence herbicide proven effective for control of perennial grassy weeds. Several field and potculture experiments were conducted to determine the effects of glyphosate on a wide range of weed species, the influence of surfactant and fertilizer materials on glyphosate activity, and synergism between glyphosate and 2,4-D.

Glyphosate (1.5 to 6 kg/ha.) effectively controlled perennial grassy weeds such as *Imperata cylindrica* (L.) Beauv., *Paspalum conjugatum* Berg., *Paspalum scrobi-*

culatum L., *Arundinella benghalensis* (Spreng) Druce., and *Setaria palmifolia* (Koen.) Stapf. Glyphosate was also found effective on broadleaf weeds like *Borreria hispida* (L.) K. Schum., *Polygonum chinensis* L., *Commelina benghalensis* (L.,) and *Scoparia dulcis* L.

Addition of Triton AE, a wetting and sticking agent, had no influence on glyphosate activity. However, it reduced rainwash of glyphosate off weed foliage occuring 1 or 2 hr. after herbicide application. Triton AE had no effect if the rainfall was delayed by 4 hr. or more after glyphosate application. Addition of urea or ammonium sulphate upto 8 kg/ha. enhanced the rate of glyphosate activity.

Application of 2,4-D as a tank mix with glyphosate enhanced the rate of activity of the latter. This synergistic effect substantially reduced the rate of application of glyphosate for effective weed control. The combination of glyphosate and 2,4-D was found very promising for two reasons: (a) activity of glyphosate was enhanced and (b) in a mixed weed population, 2,4-D can control most broadleaf weeds, and glyphosate can elimate persistent grassy weeds as well as some broadleaf weeds.

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CONTROL OF IMPERATA CYLINDRICA IN YOUNG TEA BY GLYPHOSATE

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Five trials were conducted in Assam in April/May 1976 with the following treatments:

Control (repeated sickling only).

Glyphosate (0.75, 1.5, 2.0, and 2.5 kg ae/ha) followed by sickling as and when required (Series-I)

Glyphosate 1% solution as and when required (Series-II *

Glyphosate 2% solution as and when required (Series-III)

Repeated sickling alone averaged only 9% control of *Imperata cylindrica*. A 90% control of *Imperata* was achieved by a treatment of 2.5 kg/ha glyphosate followed by repeated sickling or by 0.75 kg glyphosate followed by 1% glyphosate.

Over 90% control of *Imperata* was obtained by an initial application of 1.5 kg followed by 1% glyphosate 2 months later. There was no appreeiable advantage in using rates higher than 1.5 kg/ha as initial treatment or 2% glyohosate was follow-up application.

Borreria was the major weed replacing *Imperata* following its control but *Borreria* and other weeds were controlld by follow-up glyphosate application, the total infestation being 75 and 50% less in land 2% glhphosate follw-up plots, respectively, compared to plots which were sickled only after the first application.

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9. WEED BIOLOGY AND COMPETITION

STUDIES ON GERMINATION OF WEED SEEDS IN SOIL

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The soil is a rich reservoir of weed seeds. The weed seeds in the soil are replenished continuously through many natural agencies. Dormancy and longevity of weed seeds are natural mechanisms for the perpetuation of different weed species on account of which it is virtually impossible to deplete the soil of weed seeds. Other attributes like periodicity and peak period of germination of seeds of different weed species make these weeds appear in crop fields in regular successions season after season. The periodicity and peak period of germination of weed seeds in the soil was studied through an experiment conducted in shallow earthen pans.

Soil to a depth of 10 cm was collected form two different fields, one cropped to vegetables for many years (MB 6) and another, cropped to cotton (*Gossypium* sp.) in kharif and left fallow in the rabi (MB 11). The soil from each of these blocks was put in earthen pans 40 cm in dia. The experiment was started in February 1975 and is still being continued. The pans received tap water as and when necessary. After germination, the seedlings were identified, counted, and removed. After this the soil was thoroughly stirred and watering continued for another flush of germination. The cycle of operations was repeated after every flush of germination, identification, and removal of seedlings. As of June 1976, 13 cycles have been completed.

There were 25 different weed species identified during the 13-cycle period. Of these, 16 were dicot species and 9 monocot species. These different species exhibited definte periodicity in germination in that they germinated in a particular season and also attained maximum population at a particular point in time. The field cropped to vegetables (MB 6) had more weeds than the soil where cotton was grown (MB 11). A large number of dicot species germinated and attained the peak during the winter months while the germination and peak for the monocot species occurred during the summer and rainy months.

PERIODICITY IN GERMINATION OF WEED SEEDS

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Periodicity in germination of ten rabi and eight kharif weed species were studied in July 1972 to June 1973. It was observed that rabi and kharif weeds germi-

nated better during the months and temperatures which corresponded to their period of development. Alternating rather than constant temperatures favoured seed germination. The alternating temperatures of 15 to 30° C for 7 to 17 hours enhanced germination of kharif weeds during summer and rabi weeds in winter months, indicating that inherent season bound, internal self-controlled triggering mechanism operates and mainly stimulates germination. The periodicity of germination is attributable to such temperature responses of weed seeds. These studies might be helpful in planning a more effective use of preemergence herbicides.

GERMINATION, GROWTH AND REPRODUCTIVE BEHAVIOUR OF PHALARIS MINOR RETZ. AS AFFECTED BY DATE OF PLANTING

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An exotic weed *(Phalaris minor* Retz*).* is becoming increasingly menacing in wheat *(Triticum aestivum* L.*)* crop in India. The plant has morphological similarity with wheat until flowering.

Phalaris germinates well between 10 and 20° C. Late December planting produced considerably more tillers per meter row length than normal November planting. Plantings in November resulted in higher dry matter accumulation over later dates of planting. The average number of grains per panicle were significantly more in November planted plots and this resulted in higher seed production as compared to late plantings. The average thousand grain weight of *Phalaris* was 2 g.

PHENOLOGICAL STUDIES OF CERTAIN WEEDS

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The losses caused by weeds depend upon their density, duration and species. The knowledge about their distribution, time required for germination, flowering and seed setting is essential to take the control measures at appropriate time. Two experiments conducted at Hyderabad with eight common weed species, Viz : *Lagasca mollis : Tricahodesma indicum ; Celosia argensia ; Tridax procumbens ; Lachenera pusilla ; Euphorbia hirta ;* and *Achanthospermum hispidum*, of this region revealed that all the weeds germinated within a week and most of them flowered from 4th to 6th week and completed their life cycle in about 10-12 weeks. This indicated that mechanical or cultural method of weed control should be adopted before sixth week otherwise

seeds would sett in and will be difficult to eradicate in next season as their number will increase. All the weed species, studied had no dormancy except *Trichodesma indicum.*

CROP WEED COMPETITION STUDIES IN MAIZE (ZEA MAYS L.)

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Crop weed competition studies in maize were conducted in *Kharif* and *Rabi* season at Hyderabad in sandy loam soil under irrigated condition to investigate the critical stages of the crop when weeds cause maximum damage to the crop growth and yield. The results indicated that *Cynoden dactylon* and *Lagasca mollis* constituted the major weed population in both seasons. Weed population was maximum at earlier stages upto 15th day in *Kharif* and 30th day in *Rabi* of crop growth and their number decreased gradually with the increase in the age of the crop. The delay in weeding from 15 to 30 days age of the crop resulted in maximum (33.6%) reduction of grain yield in *Kharif* season which was found to be the critical stage of the crop. During *Rabi* the weed infestation was less and erratie hence there was no significant differences in the yield.

STUDIES ON SOME ASPECTS OF WEED ECOLOGY AND BIOLOGY IN DIFFERET CROPPING SYSTEMS

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Studies have been made to understand the crop-weed competition, weed ecology and weed biology which include survey, morphology, anatomy, agronomy characters, growth behaviour, blooming period, life cycle, weed shifts, and rooting pattern of weeds under different cropping systems.

Study on rice field indicated that from the 3rd week of September, weeds in paddy fields began to thrive profusly when the vegetative growth of rice plants and weeds was vigorous. Growth of the flowering species reached maximum by 15th October. From the middle of November, there were abrupt decreases of weed species. The optimum period of flowering of weed species seemed to be correlated with temperature and humidity. The time when both temperature and humidity began to fall after reaching their peak seemed to be the most favourable period. Further, weeds have been grouped on the basis of weak, intermediate, and strong stereome system (sclerenchyma band) in the stem.

Weed shifts and characteristic dominant weeds in different jute-based cropping systems like jute—paddy—wheat, jute — paddy — potato, jute—paddy—pulse, and jute — paddy — mustered. Most of the weeds that grow in particular crop field generally complete their life cycle along with the life cycle of respective crop. Lastly, weeds have broadly been grouped on the basis of agronomic characters, blooming periods, life cycles, and root types. Shallow-rooted types with profuse amount of fibrous roots are characteristics of advanced family of dicotyledons where as deep-rooted types are found in less advanced family.

PRELIMINARY OBSERVATIONS ON THE ROOT SYSTEMS OF SOME SEMI-ARID TROPICAL DICOTYLEDONOUS WEEDS

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Studies were conducted to understand the rooting patterns of some major dicotyledonous weeds, which play an important part in the competition for nutrients, moisture, and space with the crops. Observations indicated that the weeds had wide range of variations in their rooting patterns like depth of tap root, frequency, distribution, and angular diversions of lateral roots at different zones of the tap root. On the basis of the distribution of the lateral roots, the dicotyledonous weeds were grouped under seven major categories. The distribution of lateral roots at different zones indicated their efficiency in competition with the associated crops. It is suggested that the efficacy of a weed control method on a particular weed depends considerably on the pattern and distribution of its root system.

The results are interpreted as supporting evidences that the study of root systems of weeds and the associated crops can be an important field of Research in weed ecology and crop-weed association.

WEED COMMUNITIES IN NATURAL GRASSLAND AND CULTIVATED FIELDS OF JHANSI

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The results of ecological survey and study of the dominant weed associations and floristic components in natural grasslands and cultivated fields of 475 ha. in both kharif and rabi seasons for the years 1970 and 1971 are reported in this paper. Depending upon phytosociological parameters, there were 5 weed communities in natural grasslands during kharif; whereas there were 10 in kharif and 7 in rabi in cultivated fields.

ECOLOGICAL LIFE HISTORY OF SACCHARUM SPONTANEUM L. WITH REFERENCE TO ENVIRONMENTAL PLANT ASSOCIATION PREFERENCES

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The study dealt with the phytosocialogical aspects of *Saccharum spontaneum* L. infested natural grass covers of Jhansi and environs as well as its competitive and reciprocal growth responses in habitats dominated by *Dasmostachya bipinnata* and *Dichanthium annulatum*. Two ecologically different forms (ecads) were observed differing in floral morphology and habitat. Variations existed on relative growth rates, distribution pattern, and frequency of occurrence of root buds. There were types of buds—senescent, juvenile, and intermediate types--which were physiologically distinct in sprouting and dormancy.

SOME CHARACTERISTICS OF AN INHIBITORY FACTOR IN POLYGONUM ORIENTALE L.

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Aqueous extract of leaves of *Polyquonum orientale* L., an annual weed, retarded the germination of test species more than the extracts of its stem, root, and flower. In all cases, the leaf extract adversely affected the seedling growth of mustard (*Brassica* sp.) and the inhibition was discernible more on the hypocotyl than on the root. Increasing the amount of leaf tissues augmented the inhibitory action and washing removed much of the activity. Phytotoxicity was conspicuous in the extract rather than in the leachate, with the 5-day soaked leachate being more potent than the 3-day one. Successive extractions of the same leaf material showed that the first extract contained most of the active principle. Very old leaves seemed to produce more inhibitor (s) than young and mature leaves. Activity was higher when the bioassay was conducted at 30°C than at either 25°C or 20°C. Toxic effect appeared greater in the light than in the dark and more during the period ranging from the pre-monsoon to post-monsoon than during the winter. Extract of dried foliage was less inhibitory than that of fresh foliage, but ash from dry leaves lacked activity. Treatment of aqueous solution of leaves with Norit eliminated much of the inhibitory factor (s) from the solution. The repressing power of the leaf extract was lost after auto-claving or even after inoculation with a soil microorganism. Two compounds isolated and identified from the leaves of *Polygonum* included luteolin and apigenin glycosides.

INVESTIGATION ON THE AUTECOLOGY OF SOME OBNOXIOUS WEEDS OF JUTE FIELDS

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Fifteen major weeds, eight belonging to Gramineae, four to Cyperaceae, two to Euphorbiaceae, and one to Compositae were chosen for studies on the relationship of their life span, physiological behaviour, and nutrient absorption to jute (*Corchorus* sp.) grown for fibre and seed. The frequency of weeds, dry matter accumulation, and nutrient uptake were also estimated to understand the gravity of the problem of these weeds in jute fields at the Jute Agricultural Research Institute, Barrackpore, West Bengal, during the years 1971-72 and 1972-73.

The studies revealed that time of seed germination, growth period, flowering, and seed setting were very much affected by climatic changes. However, most of the weeds germinated with jute and completed their life cycles before the harvest of jute crop either for fibre or seed production. The major weeds of upland jute were grouped on the basis of their vegetative growth period as short, medium, and long vegetative growth period weeds. The studies further showed that the severity of graminaceous and cypraceous weeds were maximum in regard to frequency, dry matter accumulation, nutrient uptake, and seed production by individual plants in competition with the crop, though great variations existed in different weed species. Weed seeds tested for germination showed that after one and two years not more than 30 to 35% of the seeds germinated in any species.

STUDIES ON THE AUTECOLOGY OF UTRICULARIA STELLARIES L.

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The study dealt with general account of habit, morphology, reproduction, and growth of *Utricularia steellaris* L. in relation to the prevailing physico-chemical conditions of water.

Utricularia is a submerged rootless weed very often found checking the water body in association with other plants. The density of infestation during the study was found to vary from 0.6 to 2.2 kg/sq m. Flowering started from October and continued till February. The plant produced both by vegetative and sexual means.

The ponds where *Utricularia* thrived had soil pH 6.6 to 7.6, water pH 6.2 to 8.5 dissolved oxygen 3.2 to 10.2 ppm, nitrates 0.05 to 1.09 ppm, and phosphates from trace to 3 ppm.

Post-monsoon months were observed to be the period of active vegetative growth.

EVAPOTRANSPIRATION LOSSES IN SORGHUM AND MAIZE INFESTED BY WEEDS

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Studies were conducted to assess the loss of soil moisture in plots of sorghum (*Sorghum vulgare* Pers, 'CSH-1') and maize (*Zea maize* L. 'Deccan') hybrids and infested by weeds of varying intensity. Measurements were taken during drying cycle from 60 days after sowing for a fortnight of the kharif season of 1972 at the College of Agriculture, Dharwar. The loss of soil moisture from 0-45 cm. soil layer was 30 mm in fallow plots and 48 mm in maize plots free of weeds. On the other hand, the loss of soil moisture was about 80 mm in maize plots infested by weeds. In the case of sorghum the loss of soil moisture from 0-45 cm soil layer was 53 mm from plots free of weeds and 80 mm from those infested by weeds. The data showed that plots infested by weeds lost moisture to a greater extent than those without weeds and made the crop suffer from soil moisture stress.

CROP PRODUCTION IN RELATION TO CRITICAL PERIOD OF WEED COMPETITION

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Field experiments were conducted at the Indian Agricultural Research Institute, New Delhi, to assess the magnitude of weed competition in various crops such as sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetum typhoides*), soybean (*Glycine max*), and lentil (*Lens esculenta*) in relation to critical periods of crop growth. The idea behind these investigations was to determine the time of application of weeding treatment, so that crop plants can grow in a comparatively weed-free environment, thereby leading to enhanced grain yields and improvement in nutrient uptake by the crop plants. It was observed in all these crops that one weeding given during 2 to 4 weeks after sowing effected adequate weed control and pushed up the grain production. Thus, it was concluded that the cost involved in one weeding operation given at the most critical period will be nominal and the expenditure involved in weeding operation was profitably spent.

ECOLOGY OF WEEDS IN INDIAN ARID ZONE

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(No abstract submitted at the time of printing)

10. WEED MANAGEMENT IN CROPPING SYSTEMS

SOME BIOLOGICAL ASPECTS OF INTERCROPPING SYSTEMS ON CROP-WEED BALANCE

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Many physical, biological, and cultural management factors determine the crop-weed balance which in turn influence the crop and weed reproductive yields. Intercropping of pigeonpea (*Cajanus cajan*) with sorghum (*Sorghum bicolor*) reduced weed growth to an extent of 50 to 75%. The competitive ability of crops in the intercropping system was enhanced by high plant population pressure provided together by the component species. Within an intercrop system row arrangement patterns did not significantly influence the weed infestation. However, with the increase in the population pressure there was considerable decrease in weed dry matter weights. Weed growth in compact type genotypes of pigeonpea (HY3A) was 37% higher than that observed in spreading type (STI). Pearlmillet (*Pennisetum typhoides*) and maize (*Zea mays* L.) showed high initial smothering ability followed by cowpea (Vigna spp.) and groundnut (*Arachis hypogaea* L.). Sorghum progressively increased its competitive ability with time. Hardy and tall weeds like *Celosia*, *Acanthospermum*, and *Digitaria* were predominant in groundnut system. Pigeonpea and castor were poor competitors with weeds. A quantitative description of the effects of some biological factors like crop species, crop veriety, plant population, crop geometry, relative proportion of the crops in the mixture, cropping pattern, etc., on the crop-weed balance indicated that these factors should be taken into account while evolving integrated weed management systems.

INTEGRATED WEED CONTROL OF MULTIPLE CROPPING SEQUENCES IN IRRIGATED UPLAND

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A study was under taken for three years (1969-70 to 71-72) at the Central Research Farm of the Orissa University of Agriculture and Technology, Bhubaneswar,

to evaluate the comparative efficien of herbicids and cultural methods in overall control of weed under four different coopping patterns with three crops per year in irrigated upland. The crops used were : maize (*Zea mays* L.), groundnut (*Arachis hypogaea* L.), jute (*Corchorus* sp.), cauliflower (*Brassica oleracea* L.), and lady's finger or okra (*Abelmoschos esculentus* Moench.).

The data revealed that the overall weed incidence was the least with the maize-cauliflower-groundnut sequence, followed by the jute-maize-lady's finger. The use of of herbicides was found to be significantly superior over the cultural methods, The total production per year showed that the maize-cauliflower-groundnut combination was significantly superior over the rest of the patterns tried. Herbicidal method recorded higher net profit over traditional cultural methods.

COMPARATIVE EFFICIENCY OF CHEMICALS AND CONVENTIONAL METHODS OF WEED CONTROL IN MULTIPLE CROPPING WITH JUTE

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Five most common crop rotations were chosen to compare the efficacy of herbicides with manual weeding. The study was conducted on sandy loam soils under irrigated conditions during 1972-73 and 1973-74 at the Jute Agricultural Research Institute, Barrackpore, West Bengal. The recommended doses of herbicides were applied preplant or preemergence in different crops while the manually weeded plots were hand-weeded twice. The effects of the treatments were evaluated on weeds and crop yields. The comparative economics of the treatments were also calculated for each rotation.

In the first crop of jute (*Corchorus* sp.) the weed intensity was high in all treatments, but it was more intense in the manually weeded plots. The nutsedge (*Cyperus rotundus* L.) population was reduced by 50% and grasses by 70 to 90% in treated with tetrapion. However, in the second year complete control was obtained on all types of weeds. In the succeeding 'aman' paddy crop, butachlor gave complete controll of all types of grasses and sedges with the exception of nutsedge. The intensity of weeds in the third crop was much less specially in the chemically treated plots. The first crop of 'aus' paddy in the paddy-paddy-wheat rotation was badly infested with grasses and sedges. The chemical method did not give satisfactory control of weeds ; however, the weed density was comparatively less in the second year. The grain yield was also reduced in both years ; the reduction was more in the first than in the second year. The crop yields in other rotations were comparable with the manually weeded plots. Slight phytotoxic effects were seen on jute following maize (*Zea mays* L.) in which simazine was used for the control of weeds. No phytotoxic effects of the herbicide residues were observed in any of the succeeding crops of the other rotations.

The comparative economic figures showed that, in general, the cost of manual weeding was more than herbicidal treatments in all crops, except in 'aman' paddy where the cost of manual weeding was slightly less than the herbicide treatments due to reduced man power for weeding in puddled fields.

WEED MANAGEMENT IN JUTE AND SUCCEEDING CROP IN MULTIPLE CROPPING THROUGH HERBICIDES

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Weeds are of special significance in jute (*Corchorus* sp.) cultivation because yields are adversely affected if weedings are not done timely or properly. High rainfull, humidity, and hot climate favour profuse growth of weeds but these factors also make the use of herbicides less effective. Proper techniques in the use of chemicals for weed control in jute are necessary specially when herbicides applied postmergence. Since high doses of chemicals may result in phytotoxicity to the crop and less doses may not give the desired effects, it is necessary to make the users understand all the factors governing the efficiency of selective herbicides in jute. Preplant application of tetrapion was safe on jute. In moist but not wet soils the chemical can control almost all types of weeds if used in jute consecutively for two or three years. But at present this herbicide is not available in India. Therefore, it should be manufactured in India or imported and sold at a reduced price for the benefit of farmers with small holdings.

Weed intensity in crops following jute was not as intense as in the plant crop of jute. Current studies on the residual toxicity of herbicides to crops following jute should be continued and expanded. Reduction in price of herbicides specially for rice (*Oryza sativa* L.) and potato (*Solanum tuberosum* L.) in succession to jute crop is necessary to make the use of herbicides feasible, profitable, and popular to farmers. The methods developed should be passed on to the farmers in the form of "package of practices" for chemical weed control in multiple cropping based on jute.

WEED CONTROL IN PURE VS. PARALLEL CROPPING OF GREEN GRAM AND BLACK GRAM WITH EARLY MATURING PIGEONPEA

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Early canopy producing and close growing pulses like green gram (*Phaseolus aureus* L.) and black gram (*Phaseolus mungo* L.) may suppress weed growth when intercropped with tall growing crops like pigeonpea (*Caianus caian*), which develops

canopy at a later stage. This situation may reduce the cost of weeding to a considerable extent. With this objective, a field trial was conducted during kharif 1974-75 and 1975-76 at the Research Farm, Kalyanpur of C. S. Azad University of Agriculture and Technology, Kanpur, U. P. Different weed control treatments (weedy check, one weeding, two weedings, and nitrofen at 1 kg/ha) in the pure and parallel cropping of green gram (T44) and black gram (T9) with pigeonpea (T21) were tested in a replicated trial.

In the unweeded plots the yield of pigeonpea was increased by parallel cropping of black gram and green gram. Two weedings in pure pigeonpea and one weeding in pure green gram and black gram gave optimum results. One weeding in pigeonpea could be economical in parallel cropping, which was more remunerative than pure cropping. Maximum yield and profit were obtained when one weeding after 20 days of sowing was done in the parallel cropping of black gram with pigeonpea.

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DIRECT AND RESIDUAL EFFECTS OF HERBICIDES IN POTATO-WHEAT RELAY

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Field trials were carried out for two seasons (rabi 1974-75 and 1975-76) to evaluate the direct effects of preplant, preemergence, and postemergence applications of herbicides to potato (*Solanum tuberosum* L. cv. 'Chandramukhi') and on the residual effects on wheat (*Triticum aestivum* L. cv. 'Sonalika') planted as a relay crop before the potato tuber was harvested.

Fluchloralin (0.50 kg/ha) was applied as a preplant treatment a day prior to planting of potato. Nitrofen (1 kg/ha), alachlor (1 kg/ha), linuron (0.25 kg/ha), metobromuron (0·5 kg/ha), and metribuzin (0.5 kg/ha) were applied preemergence two days after planting. An unweeded check and hand-weeded (twice) treatments were included in the trial for gauging the herbicidal and selective effects on the crops.

All the herbicides reduced the weed population significantly over the unweeded check. The tuber production was substantially enhanced under all the weed control treatments with the exception of the postemergence application of metribuzin which had the tuber production significantly lower than the one applied preemergence. This result indicated that the herbicide was phytotoxic to potato when applied postemergence.

None of the six herbicides left residues in the soil to affect the growth, development, and grain production of wheat which was raised in the first fortnight of January as a relay in the standing crop of potato.

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CHEMICAL WEED CONTROL IN CABBAGE-ONION RELAY

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The herbicidal and selective effects of a preplant application of trifluralin (0.5 kg/ha) and fluchloralin (0.5 kg/ha) and preemergence soil application of desmetryne (0.25 kg/ha), nitrofen (1 kg/ha), butachlor (1kg/ha), and alachlor (1 kg/ha) ou transplanted cabbage (*Brassica oleracea* L. 'Golden Acre') and the residual effects of these compounds on onion (*Allium cepa* L. 'Pusa Red') grown as a relay in the standing cabbage were studied in field trials for two seasons (rabi 1974-75 and 1975-76). Inclusion of a weedy check and a repeated manually weeded treatment provided the basis for assessing the herbicidal and selective effects.

A preplant application of either trifluralin or fluchloralin or a preemergence application of desmetryne gave excellent control of both monocot and dicot weeds in cabbage and enhanced the cabbage yield.

These chemicals persisted in the soil and prevented any weed growth even in the relay onion crop till almost its maturity. The substantial improvement in onion bulb production appeared to have resulted from the long duration weed control with trifluralin, flchloralin, and desmetryne in cabbage. All these three chemicals were selective on cabbage and onion.

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EFFECT OF IRRIGATION ON WEED INFESTATION AND EFFICIENCY OF SOIL APPLIED HERBICIDES IN THE CROPPING SYSTEM OF WHEAT-GUAR

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An experiment was conducted on sandy loam soil during 1972-73 and 1973-74 at the Indian Grassland and Fodder Research Institute, Jhansi. Chlorbromuron and linuron at 0.5 and 1 kg/ha were applied preemergence in combination with first flow irrigation treatments at 2 and 3-week crop stages, with and without water sprinkling 5 days after sowing of wheat (*Triticum aestivum* L. 'Sarvati Sonora'). Evaluation was carried out in split-plot design with three replicates with weed control treatments as sub-plots (3 by 2 m).

Irrigation treatments did not have much influence on the infestation of broadleaf weeds and weed controlling efficiency of herbicides, although plots with irrigation given at 2-week crop stage had less weed intensity. Chlorbromuron and linuron were safer to the crop when irrigation was given at the 3-weeks crop stage than at the 2-week stage. These herbicides gave better control of broadleaf weeds at 1 kg/ha than at 0.5 kg/ha but the rate of crop mortality increased when irrigation was given earlier than at 3-weeks after sowing. Linuron appeared more phytotoxic than

chlorbromuron and damaged crop stand severely at 1 kg/ha when irrigation was applied at 2 weeks, resulting in substantial reduction in crop production as compared to weedy check. The severity of this treatment was further enhanced in association with water sprinhling treatment. Chlorbromuron at 1 kg and linuron at 0.5 kg/ha showed better and comparable performances when the crop was given a first flow irrigation 3 weeks after sowing. These treatments suppressed infestation of broadleaf weeds considerably and raised what yield over weedy checks. Higher yield of wheat was recorded with the first flow irrigation at 3-week crop stage in comparison to the 2-week flow irrigation. Herbicide treatments did not adversely affect subsequent crop of fodder guar or cluster beans (*Cyamopsis tetraqonoloba*).

CUMULATIVE EFFECTS OF HERBICIDES IN RELATION TO PHOSPHATE APPLICATION IN THE CROPPING SYSTEM OF GROUNDNUT AND FODDER OAT

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Experiments with groundnut *(Arachis hypogaea* L.*)* and fodder oat *(Avena sativa* L.*)* were conducted on sandy loam soil during 1973-75 at the Indian Grassland and Fodder Research Institute, Jhansi. Preplant applied nitralin (0.75 and 1.5 kg/ha), preemergence applied alachlor (1.5 and 3 kg/ha), and dichloromate (2.5 and 5 kg/ha), manual weeding, and a weedy check were the main treatments (main plots). These treatments were combined with 50 and 100 kg P_2O_5/ha (sub-plots) which were applied repeatedly in two consecutive seasons. The experimental design was split-plot with 3 replicates. In each following rabi, oat crop was grown with and without postemergence MCPA amine at 0.75 kg/ha in sub-sub-plot (3 by 2 m). In addition, 20 and 50 kg N/ha was applied in legume and nonlegume crops, respectively, but no phosphate was added to the oat crop.

In both the years. all the herbicides treatments appeared selective and effective for ihe groundnut crop grown with either of the phosphate levels. But in the second year, yield increase due to herbicide treatments was less than in the first year which might be because of the less weed infestation. The weed control efficiency of the treatments was reflected by the average number of broadleaf + grassy weeds per sq m of both years ; alachlor, 0,8 ; nitralin, 1.2 ; and dichlormate, 1.3, while the control was 76.2. Consequently, the yield of dry pods of groundnut was much higher among herbicide treated than the control. A yield of 1619 kg/ha was obtained from alachlor, 1561 kg/ha from nitralin, 1545 kg/ha from dichlormate, and 801 kg/ha from the control. In the first year, 100 kg P_2O_5/ha showed higher groundnut yield over that of 60 kg P_2O_5/ha. In the second year similar trend was observed but the difference was minimized considerably. This result might be due to the carry over effect of residual phosphate from the first year application. None of the herbicide combinations

adversely affected the following crop of oats. The high rate of phosphate increased the dry matter yield of oats by 7.7 to 9% over the low phosphate application. MCPA was effective against broadleaf weeds but the increase in the yield of oats over the control was not significant.

CHEMICAL WEED CONTROL IN DRYLAND CROPS OF THE SEMI-ARID RED SOIL REGION (HYDERABAD)

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Several experiments were conducted on chemical control of weeds in the important crops of the semi-arid red soils region (Hyderabad), including sorghum (*Sorghum bicolor* (L.) Moech.) and castor (*Ricinus communis* L.). Experiments were also laid out on the introduced crops such as pearl millet (*Pennisetum typhoides* L.) and sunflower (*Helianthus annuus* L.). Trials were also conducted on the control of nutsedge (*Cyperus rotundus*). These experiments were conducted on farmers' fields. The effective herbicides are given below :

Crop/weed	Effective herbicide	Dose (kg/ha)	Method of application
Sorghum	Atrazine	1.0	Pre
	bromoxymil+MCPA	1.0	Post
	dicamba+2,4-D (Amine)	0.5	Post
	Dalapon	2.0	ppi
Pearl millet	dicamba+2,4-D (Amine)	0.5+ 0.5	Post
	bromoxymil+MCPA	1.0	Post
Castor	trifluralin	1.0	ppi
Sunflower	EPTC	3.0	ppi
	fluchloralin	1.0	ppi
Nutsedge	Glyphosate	5.0	Post
	MSMA	3.0	Post

YEAR-ROUND TILLAGE FOR WEED MANAGEMENT

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From an assessment of crop and weed conditions in different regions of India, it appears that improved tillage practices using the farmers' country plough and blade

harrow (3-ft straight blade) for better weed control and early planting are pre-requisites for increased production. Weed Control in kharif lands is unsatisfactory because inadequate attention to tillage in the non-crop season leads to a losing battle with weeds in the crop season. To assist the farmer in combating weeds and to enable him to plant early under improved seed-bed conditions with his bullock power, tillage and seeding equipment, a year-round tillage practice was developed and recommended by the Dryland Project.

HERBICIDAL AND SELECTIVE EFFECT OF ALACHLOR AND ATRAZINE IN MAIZEPULSE ROTATION

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Field experiments have been in progress at the Indian Agricultural Research Institute, New Delhi, for evolving effective and safe techniques of chemical weed control in crop rotations. A replicated field trial carried out with maize (*Zea mays* L. 'Hybrid Ganga 5') in kharif 1975 involved a study on the efficiency and selectivity of a preemergence application of atrazine (1, 2, and 4 kg/ha) and alachlor (1, 2, and 4 kg/ha). Observations were also carried out on the residual effects of these treatments to the succeeding pulses such as gram (*Cicer arietinum* L.), peas (*Pisum sativum* L.), and lentil (*Lens esculenta* Moench.) in the rabi. A weedy check and a manually weeded (twice) treatments were included in the trial.

The herbicidal efficiency was assessed in terms of the dry matter accumulation in weeds at periodic intervals. The basis for selectivity was provided by the effect on grain yield. The residual effect was determined by a field bioassay with peas (T 163), gram (C 235), and lentil (L 9-12) which were raised after maize harvest.

All the weed control treatments improved the grain yield of maize significantly over the weedy check. The two higher levels of atrazine (2 and 4 kg/ha) and all the three levels of alachlor (1, 2, and 4 kg/ha) gave grain yields comparable with the handweeded plots.

All the weed control treatments reduced significantly the dry matter accumulation in weeds over the control for 2 months. The two higher levels of atrazine (2 and 4 kg/ha) and the highest level of alachlor (4 kg/ha) reduced the dry matter accumulation as efficiently as that resulting from the hand-weeded treatment. The grain production of the legumes was not affected by the two herbicides, except by the highest level of atrazine, thereby indicating the short persistence of residues in the soil that can affect growth, development and grain production of the three pulses. The highest level of atrazine, (4 kg/ha) applied to maize checked the dry matter accumulation in weeds during the rabi season. Inspite of this effect on weeds, the grain production in pulse crops did not go up thereby indicating some adverse carry over effect of atrazine at 4 kg/ha.

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11. HERBICIDE SCREENING AND INDUSTRY DEVELOPMENT OF NEW HERBICIDES

MULTICROP HERBICIDE SCREENING - PRELIMINARY EVALUATION ON MAJOR SEMI - ARID TROPICAL CROPS

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The note contains the data on two preliminary herbicide Screening trials on the major semi-arid tropical crops established during kharif and rabi of 1975-76. The objective of the trials was to determine the crop tolerance and weed control activity of several herbicides on sorghum *(Sorghum bicolor)*, pearlmillet *(Pennisetum typhoides)*, groundnut *Arachis hypogaea)*, pigeonpea *(Cajanus cajan)*, chickpea (*Cicer arietinum*), and maize (*Zea mays*). These tests were also intended to establish guidelines for more detailed herbicide-based weed research on these crops and on cropping systems involving these major crops.

Visual evaluation on crop injury and weed control indicated that the following herbicides are very promising on sorghum : dinitramine, perfluidone, fluchloralin, methabenzthiazuron, napropamide, terbutryn and ametryn proved promising. Maize was quite resistant to most of the herbicides tested, except naptalam+dinoseb,MSMA+ diuron, MSMA, MBR 12325, and RH coded compounds. However, many herbicides caused phytotoxicity on pearlmillet and only a few were sufficiently safe like dinitramine, bensulide, fluchloralin, terbutryn, and methabenzthiazuron.

Prometryn, ametryn, alachlor, dinitramine, nitrofen, and trifluralin, were the promising pre-emergence herbicides for pigeonpea. Most of the post-emergence herbicides were phytotoxic to pigeonpea. Groundnut was fairly resistant to many herbicides tested, including nitrofen, alachlor, dinitramine, prometryn, terbutryn, and trifluralin. The herbicides which may prove quite effective on chickpea are napropamide, terbutryn, ametryn, perfluidon, fluchloralin, dinitramine, and RH coded chemicals. Further testing of these and other newer herbicides on the crops, cropping systems, and weeds are in progress.

SELECTIVITY OF NEW HERBICIDES FOR RABI CROPS

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New herbicides received in sample quantity from the herbicide industries were evaluated for their selectivity on wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and oats (*Avena sativa* L.). The experiment was conducted in rabi 1975-76 on a medium soil. The herbicides used as pre-emergence (dose t.p. kg/ha.) were: bromoxynil (1,2,3), dichloprop (2,3,4), mecoprop (2,3,4), metribuzin (0.25, 0.5. 0.75), TRICORNOX - a mixture of benazolin+dicamba+MCPA (2,3,4), and a post-emergence of metribuzin (0.25, 0.5, 0.75). Weed flora consisted of: *Chenopodium album*, *Asphodelus tenuifolius*, *Modicago denticulata* and M. *sativa*, *Vicia hirsuta*, *Convolvulus arvensis*, *Spergula arvensis*, and *Anagellis arvensis*.

Tricornox, dichlorprop, and mecoprop gave the most effective weed control with zero weed population at all doses and with no visible injury to any crop. Metribuzin (pre-emergence) gave selectivity in barley with complete control of weeds at all doses; however, oat and wheat were severally injured. Metribuzin (postemergene) gave excellent weed control but was apparently injurious to oats at 0.5 and 0.75 kg/ha. However, the crop recovered from this apparent injury at 0.25 and 0.5 kg/ha. and yielded more fodder than the control. Therefore metribuzin is a good candidate herbicide for further agronomic evaluation at 0.25, 0.5 kg/ha. for fodder oats. Since the rate required of metribuzin for effective weed control is very low, it would be interesting to study its economic feasibility for wider adoption.

WEED PROBLEMS AND EFFICACY OF SOME HERBICIDES

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More than half a dozen herbicides were tested either as pre-emergence or post-emergence for weed control in paddy (*Oryza sativa L.*), sugarcane (*Saccharum officinarum* L.), cotton (*Cossipium* sp.), maize (*Zea mays* L.), and sorghum (*Sorghum bicolor* L.). The results revealed that some herbicides were effective against the vegetative growth of monocot or dicot plants or both for very short period. They were ineffective in bringing about complete weed control in many crop fields and other places. On the other hand, MSMA gave complete control of *Parthenium hysterophorus*.

STATUS OF ORGANIC ARSENICAL HERBICIDES

BIBHAS RAY

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Organic arsenical herbicides are being extensively used for the last two decades. The most commonly used compounds are MSMA, DSMA, and cacodylic acid.

In the U.S., MSMA and DSMA are cleared for cotton, citrus and non-bearing fruit (other than citrus), nut orchards and non-crop weed control. Label applications are pending with the Environmental Protection Agency (EPA) for wheat, surgarcane, and bearing nut trees. Organic arsenical are in use in Japan, Greece, Malayasia, Indonesia, Egypt, Israel, Brazil, and other countries besides the United States. Recently, MSMA/DSMA have been identified by the EPA as registered substitute chemicals for certain cancelled and suspended uses of 2, 4, 5-T.

In India, MSMA and DSMA have been used for weed control in cotton, surgarcane, tea, coffee, rubber, oil palm, jute, sisal, mulberry, coconut, etc., and in lawns and turfs. Recently, MSMA has been found to control *Parthenium* effectively. Besides cotton and te', registration applications are pending with the Central Insecticides Board for clearance of MSMA in the above mentioned crops.

Methanearsonates are used most extensively for postemergence control of annual grassy weeds in cotton. Effective control of nutsedge and johnsongrass is obtained from applications of methanearsonates. Methanearsonates are reported to be very effective for controlling *Paspalum conjugatum*, *Panicum* sp., *Pennisetum clandestinum*, *Axonopus compressus*. *Sorghum halepense*, *Cyperus rotundus*, *Avena fatua*, *Setaria glauca*, *Brassica kaber*, *Sida spinosa*, *Rumex acetosella* *Polygonum* sp., *Richardia scabra*, etc.

The acute oral LD-50 of MSMA (35.21%) is 1800 mg/kg a value considered to be slighly toxic. In tests on acute inhalation and eye irrigation no adverse effects were reported. No significant adverse effects were found in cattle grazing on pasture treated with 4 times the recommended rate. In cows, pentavalent compound was excreted rapidly in the urine and arsenic was not found in the milk. In chicken, arisenic was not found to be accumulated in eggs on in tissues. Results indicated that food chain magnification of arensicals does not occur.

No adverse effects are reported from teratogenic and Mutagenic studies. No reports are available on the oncogenic effect of MSMA and DSMA on animals. Arsenic poisoning was not encountered in studies concerning occupational hazards. Parameters studied at pollution concentration showed that high rates of applications may have limited short-term effects only.

Herbicidally effective concentrations of MSMA and DSMA disappear rather rapidly from field soil after application. Microbial activity appears to contribute to the degradation to some extent. Sustained use of methanearsonate at rates recom-

mended for weed control does not appear to result in hazardous accumulation of arsenic in harvested crops. Methanearsonates are extensively adsorbed in soil and subject to little movement in leaching. Organic arsenicals are oxidised in soil microbiologically to form arsenate.

Volatalisation of methylated arsensicals appears to be significant loss process that limits arsensic accumulation in soils. Methyl arsines are very unstable in air and are rapidly oxidised to less reduced forms of arensic. While arsensate is subject to methylation and volatile loss much of the residual arsenic in soil reverts progressively to less soluble form with aluminium and iron compounds.

More research are in progress in India on the effective utilisation of MSMA in resistant crops, in non-crop weed control, and also on build-up in soils due to continued use in croplands.

A REVIEW OF TRIALS WITH DINITRAMINE HERBICIDE

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Dinitramine (USB 3584)* and its analogue USB 3153 (proposed name Rydex) have proved very effective in controlling annual weeds in upland paddy when applied 3 days after showing at dosages ranging from 1 to 2 kg/ha. in the Phillippines and in trials conducted by the All India Coordinated Rice Improvement Project in India. Dinitramine has proved useful in controlling weeds upto 6 weeks in cotton, groundnut, soybean and chillies at rates ranging from 0.4 to 0.8 kg/ha. Preliminary indications are that this herbicide will be effective also in wheat and tobacco. The herbicide is effective against *Portulaca oleracea, Trianthema portulacastrum, Amaranthus* sp., *Commelina benghalensis, Gynadropsis pentaphylla, Phyllanthus niruri, Portulaca quadrifida, Acalypha indica, Euphorbia prostrata, Mullugo pentaphylla, Amaranthus blitoides, Dinebra retroflexa, Echinochloa colonum, Eragrostis pilosa, Tetrapogan tenellus, Bergia capensis, Dopatrium lobelioides, Marsellia quadrifido, Ecliptb prostrata, Sphearanthus indicus, Dentella repens,* and *Glinus oppositifolius.*

NITROFEN – A VERSATILE HERBICIDE FOR MANY CROPS

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Nitrofen has shown considerable activity as a preemergence herbicide and has proved useful for weed control in many crops. Nitrofen is a contact herbicide with

residual activity, effective on actively growing weed seedlings, particularly at the first true leaf stage,

Nitrofen is effective in the control of weeds such as *Phalaris minor* in wheat, *Echinocloa* in paddy, *Plantago* in cumin, *Celosia* in peanuts, and *Trianthema* sp. and *Digera* sp. in cotton. Nitrofen has also shown good weed control activity in soybeans, and in vegetables such as cabbage, turnips, carrots, cauliflower and rape.

The granular formulation containing8% nitrofen is particularly suited for weed control in paddy fields where water management is efficient. It acts mostly as a preemergence herbicide and has very limited postemergence activity.

The granular formulation is easy to apply and has good activity against monocot and dicot weeds in paddy fields, effecting significant reduction in dry matter accumulation of weeds, resulting in improved nitrogen uptake and grain yield.

PENOXALIN – A NEW SELECTIVE HERBICIDE

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(No abstract submitted at the time of printing.)

INTRODUCTION OF HERBICIDES IN SUBSISTENCE FARMING IN INDIA

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The use of herbicides should be popularised in India. A breakthrough in herbicide usage in the country in the country can be made through improvement and modification in research and extension activities by Central and State Governments and agricultural Universities, teaching of herbicide course for Botany students at undergraduate level in all the colleges, one year apprenticeship at a model farm for B. Sc. Ag- students, incentives to farmers using herbicides through offer of better prices in procurement schemes and by sugar mills, indigenous screening and development of newer products in collaboration with international companies, reducing marketing costs, liberal import of newer herbicides, formation of an All India Herbicide Coordination Unit and Liasion with international organisations involved in herbicide research. Problem of weed control in crops like sorghum, pearl millet, groundnut, and upland rice was dealt with and a suggestion made to give priority to introducing a suitable herbicide for preemergence or early postemergence weed control in these crops commonly grown by small farmers all over the country.

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12. HERBICIDE PHYSIOLOGY, SOIL ASPECTS AND HERBICIDE PERSISTENCE, AND HERBICIDE FORMULATIONS

BIOCHEMICAL MECHANISMS OF ACTION OF ACETANILIDE HERBICIDES

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The biochemical and physiological mechanisms of action of three preemergence acetanilide herbicides, alachlor (2-chloro-2', 6'-diethyl-N-(methoxymethyl) (acetanilide), propachlor (2-chloro-N-isopropylacetanilide), and prynachlor (2-chloro-N-(1-methyl-2-propynyl) acetanilide) in barley (*Hordeum vulgare* L.) the susceptible species, and corn (*Zea mays* L.) the resistant species, were investigated. All three herbicides inhibited production of hydrolytic enzymes, α-amylase and protease, in the germinating bareley seeds, but not in corn seeds. However, these herbicides did not inhibit mitochondrial activities like oxidative phosphorylation (ATP formation) and respiration.

Molecular level investigations showed that these acetanilide herbicides inhibit ribosome and polyribosome synthesis in barley root growth. Time course studied with alachlor revealed that the inhibition was occuring during the first 12 hr of seed imbibition. Leucine-C^{14} incorporation studies indicated that all herbicides severely reduced nascent peptide synthesis in barley, with alachlor being more inhibitory than propachlor and prynachlor. Although these herbicides did not inhibit any of these processess in corn, the standard protein and RNA synthesis inhibitors (cycloheximide and actinomycin D) did, indicating that corn was resistant to these herbicides. Further studies showed that corn was able to metabolize alachlor faster than barely.

These studies revealed that in susceptible species. Inhibition of protein synthesis and related processes like formation of ribosome MRNA complex, amino acid activation, ribosome synthesis, etc, is the primary mechanism of action of acetanilide herbicides. The other effects are only secondary.

ANTIDOTAL ACTION OF R-25788 ON EPTC AND ALACHLOR INJURY TO CORN AND BARLEY

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Greenhouse studies were conducted to determine the effect of the new herbicide antidote, R-25788 (N,N-diallyl-2, 2-dichlornacetamide), in reducing EPTC (S-ethyl diprophylthiocarbamate) and alachlor (2-chloro-2', 6'-diethyl-N - (methoxymethyl) (acetanilide) toxicites to corn *(Zea mays* L.) and barley *(Hordeum vulgare* L.), respectively. EPTC was applied pre-emergence to corn at 0,3.4, 6.8, and 10.2 kg/ha. alone and in combination with 0, 0.28 and 0.84 kg/ha. of R-25788. Seedling growth of Cornell M-3 variety of corn was significantly inhibited (26 to 29%) at 6.8 and 10.2 kg/ha. rates of EPTC but this inhibitition was completely nullified when R-25788 was applied at 0.84 kg/ha. as a tank mix with the herbicide.

In a highly sensitive Himalaya variety of barley, application of R-25788 at at 0.84 kg/ha. along with 1.12 kg/ha. of alachlor brought herbicide injury from 53% down to 28%. In the moderately sensitive Schuyler variety, alachlor inhibition was almost complete. This antidotal action was not apparent in both varieties at 2.24 kg/ha. rate of alachlor application. Similar protective action by R-25788 against herbicide injury was not evident in barnyardgrass *(Echinochloa crussgalli* L. Beauv.), a predominant annual grass.

Molecular level investigations conducted in the laboratory showed that alachlor severally inhibited polyribosome formation in barley roots and this inhibition was almost completely reversed by R-25788. This suggested that the antidote and alachlor compete for the same active site(s).

PHYSIOLOGICAL EFFECTS OF HERBICIDES ON GROUNDNUT

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Physiological studies on the effects of the 4 herbicides, pebulate (100, 50, 25, and 12 ppm), prometryne (25, 12, 6 and 3 ppm), C-6989 and EPTC+isooctyl ester of 2,4-D (50, 25, 12 and 6 ppm), on groundnut (*Arachis hypogaea* L.) were conducted under laboratory conditions during 1969-'70. All the herbicides at the higher doses initially blocked the utilization of reserve carbohydrates in seeds during germination. But later on except EPTC+2,4-D the herbicides increased the height, dry matter, total carbohydrate and total phosphorus contents of the plants. Activity of the enzyme catalase was not affected by these herbicides.

HORMONAL APPRAISAL OF EVENTS FOLLOWING PHENOXY HERBICIDE APPLICATION ON LANTANA INDICA ROXB

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Experiments were initiated to probe into mechanism of action of phenoxy herbicides on one year old *Lantana indica* Roxb. in pot cultures. Hormonal changes of auxins, cytokinins, gibberellins, and inhibitors in the roots and stems of *Lantana* as induced by phenoxy herbicide mixture of 2,4-D and 2,4,5-T (Brush-killer-64) were assessed and estimated. The results of various bioassays showed that after seven days of treatment, the level of cytokinins in *Lantana* roots increased six times and that of auxins, three times. However, the stems and leaves had no appreciable changes in the levels of these two hormones. Gibberellins were not detectable in roots but their levels decreased in stem and levels. It appeared that immediately after the application of the mixture of 2,4-D+2,4,5-T there was a shift in the endogenic hormonal balance which in turn triggered the events responsible for the killing of *Lantana* seedlings.

SPIKE MALFORMATION IN DWARF WHEATS CAUSED BY 2, 4-D

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The herbicide 2,4-D is recommended for control of broadleaf weeds in wheat (*Triticum aestivum* L.). Malformation of spikes has been observed when 2,4-D was sprayed during the early stages of crop growth. Wheat plant escapes this injury when sprayed at least 35 days after sowing.

Intraspecific differential response was observed in wheat. Varieties like Sonalika (RR-21) and UP 310 have been observed to be relatively more susceptible than Kalyansona and Moti. The spike malformation was exhibited as looped bunchy, gappy brached and elongated spikes.

Better fertilized crop was found to produce more malformed spikes than poorly fertitized ones. Tank mix spray of 2,4-D at the rate of 0.50 kg/ha.+6% urea did not alter the malformation behaviour. Significant yield reduction in wheat was recorded when 2,4-D was sprayed before 30 days of sowing as compared to late applications and weedfree check. Mixed spray of 2,4-D and urea did not increase wheat yield.

CYTOLOGICAL STUDIES ON THE EFFECTS OF 2, 4-DICHLOROPHNOXYACETIC ACID ON *VICIA FABA* ROOT TIP CELLS

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An experiment was conducted to study the effects of 2,4-D at cytological level on *Vicia faba*. Growing roots were treated with 2,4-D at 10 and 50 ppm. for durations of 3, 6 and 12 hours. Root tips were collected and the progress of mitosis was studied. The result showed that the mitotic index of treated roots was very low and the inhiting action of 2,4-D on cell division increased with increase in concentration and duration of treatment. Most of the cells entering into mitosis were arrested into prophase. The effects on cromosomes were divided into the following four groups :

a. breakage of chromosomes due to erosion and stickiness ;

b. bridge formation due to stickiness and reunion of broken ends of chromatids ;

c. spindle inactivation resulting in the formation of polyploid cells. and

d. other effects including formation of micronuclei, chrosome condensation, and multipolar separation,

The frequency of these aberrations increased with 2,4-D concentrations and duration of treatment.

STIMULATORY EFFECT OF SUB-LETHAL DOSES OF SIMAZINE ON FORAGE PRODUCTION IN BERSEEM

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Field trials were carried out for two seasons (rabi 1974-75 and 1975-76) to assess the stimulatory effects of sub-toxic doses of simazine on forage production in diploid variety of berseem (*Trifolium resupinatum*). The Technique employed in the experiment comprised in spraying different dosages of simazine (0.25, 0.125 and 0.062 kg/ha.) before and after the first cut of fodder.

A repeat application of simazine (0.125 kg/ha.) after the first and second cuts was also included in the trial. Immediately ofter simazine spray, a light irrigation was given so as to reach the chemical and allow it to be absorbed by the roots of the berseem crop. An untreated check was also kept to serve as a basis for measuring the magnitude of stimulation. The experimental treatments were replicated four times in a randomised block design.

In both the seasons, the fodder production was substantially enhanced under a single application of simazine at 0.062 kg/ha. after the first cut, followed closely by the dosage levels of 0.125 and 0.062 kg/ha. applied before the first cut of fodder. The increase in forage production was obtained between the second and third cuts. The repeat application of simazine as 0.125 kg/ha. after the first and second cuts depressed the fodder yield. No unhydrolysed simazine could be detected in the forage samples collected from the plots which received the highest dose of simazine.

EFFECT OF S-TRIAZINES ON QUALITY OF FORAGE SORGHUM & OATS

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A study was conducted to determine the effects of low rates (0.05 and 0.10 kg/ha.) foliar sprays of atrazine, simazine, and ametryne on sorghum (*Sorghum vulgare* Pers.) in kharif and on oats (*Avena fatua* L.) in rabi at 0, 35 and 50 kg. N/ha. The data indicated a decrease in the yield of sorghum at the high dose of herbicides, if no N was applied. There is a possibility of increasing yield and protein content in sorghum by the use of herbicide but not in oats.

EFFECT OF SUBLETHAL DOSES OF S-TRIAZINE HERBICIDES ON GROWTH, YIELD AND QUALITY OF KABULI GRAM

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The field investigation was conducted during the rabi season of 1973-74 at the Agronomy Research Farm of the Haryana Agricultural University, Hissar. The treatments consisted of three doses (50, 100 and 200 g/ha.) each of atrazine, simazine, and prometryne and one untreated control.

The results showed that the treatments had no significant effect on the growth and yield attributes of kabuli gram. However there was a significant increase in the nitrogen content of grain as well as straw with the application of these herbicides. The total protein yield per hectare also increased by 21.9, 18.2 and 16.6% with the application of simazine at 200 g/ha, prometryne at 200 g/ha, and prometryne at 100 g/ha, respectively. The sublethal doses of s-triazines did not significantly control weeds.

A REVIEW ON THE INCREASE IN PROTEIN CONTENT OF CROP PLANTS TREATED WITH SIMAZINE

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The research reviewed clearly established the possibility of improving the nutritional composition of major food crops by the application of chemicals like simazine. However this type of study is just beginning in India, therefore, success in the future will be determined by understanding more about the primary sites in the plant that may be regulated, the discovery of chemicals that will favourably alter these sites, and then finding efficient and practical means of applying such chemicals.

EFFECT OF SIMAZINE ON YIELD AND MAJOR NUTRIENT UPTAKE BY MAIZE AND WHEAT

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The results of the experiment revealed that the application of simazine at 1 kg/ha and above reduced the yield of maize (Zea maize L.) and that of the following wheat (Triticum aestivum L.). Application of farmyard manure at the rate of 5 t/ha was not capable of reducing the toxic effect of herbicide to maize. However, the residual farmyard manure effectively reduced simazine toxicity to wheat grains and straw (statistically significant differences in grains only). Farmyard manure was superior to sludge and green manure (Ipomea cornea) in increasing wheat yield. The nitrogen content tended to increase with increasing levels of simazine in both the maize and wheat crops. The P and K contents were also found to rise with application of simazine over the control. The total uptake of major nutrients increased with simazine treatment.

RESIDUAL STUDIES ON THE TOXICITY OF ALACHLOR APPLIED IN CEREAL-LEGUME MIXED CROPS

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Field soil at 10, 20, and 30 cm depths were collected after the harvest of the maize (*Zea mays* L.)+lab lab (*Dolichos lab lab* L.) and sorghum (*Sorghum vulgare* Pers.)+lab lab mixed crops raised with and without alachlor at 1.5 kg/ha applied preemergence. Five hundred grams of air-dried soils were filled in pots and planted to

five test crops, cotton (Gessypium spp.), sorghum, sunflower (*Helianthus annus* L.), green gram (*Phaseolus aureus* Roxb.), and pearl millet (*Pennisetum typhoides* L.). The results indicated that the germination of all the test crops were not significantly affected by alachlor residues in soil. The dry matter of crops at 30 days showed no significant difference between treated and untreated control at all soil depths. From these observations it seemed that alachlor had been degraded in soil within 15 weeks of application in the mixed crops of cereal-legumes.

RESIDUE OF HERBICIDES ON CROPS FOLLOWING COTTON

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A field experiment was conducted during winter 1974 to find out suitable herbicides for the control of weeds in cotton (*Gossypium hirsutum* L.) and to study the residual effect of herbicides on the following crops, namely : finger millet (ragi), sorghum (cholam), cowpea, and lablab that normally follow in rotation with cotton. The chemical treatments were preemergence applied alachlor (2 kg/ha), fluometuron (1.5 kg/ha), dichlormate (3 kg/ha), dibutalin (2.5 kg/ha), and presowing applied fluchloralin (1.25 kg/ha). All the treatments were also tested in combination with postemergence directed application of paraquat (0.5 kg/ha) at 15 days. The other treatments were : split application of paraquat (0.5 kg/ha) at 15 and 30 days hand hoeing and weeding at 15 and 30 days, hand hoeing and weeding and weeding combined with paraquat (0.5 kg/ha) at 15 days, and an untreated control.

Preemergence fluometuron (1.5 kg/ha), the most remunerative treatment in this study, showed no phytotoxic residues on any of the test crops. Growth of lablab was affected by the residues from dibutalin and fluchloralin-paraquat combination, while sorghum showed phytotoxicity from alachlor-paraquat and fluchloralin-paraquat combinations. Tho other herbicides did not show phytotoxic residual effect on any of the crops tested.

SIMAZINE AND ATRAZINE DISSIPATION IN SOIL AND THEIR UPTAKE BY CORN

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Investigations have been in progress at Indian Agricultural Research Institute for studying the persistence of simazine and atrazine applied to hybrid corn (*Zea mays* L.) in summer and the residual carry over effeets of these two herbicides on winter crops.

Field trials involving different dosages (0.5, 1,2, and 4 kg/ha) of simazine and atrazyne indicated that either of these chemicals at 4 kg/ha applied preemergence to corn was not entirely safe to the subsequent wheat (*Triticum sativum* L.) crop. The ED50 values of simazine for wheat was 0.33 ppm and that of atrazine, 0.13 ppm. Residues in the soil from 2 kg/ha and less were negligible at the time of harvest of wheat. To determine the rate of dissipation of simazine and atrazine in soil and their uptake by corn, soil and plant samples were periodically analyzed by three different chemical methods, viz. colorimetry, ultraviolet spectophotometry, and thin layer chromatography.

During a trial conducted in 1971 where only three levels (0.5, 1 and 2 kg/ha.) of simazine and atrazine were applied pre-emergence to corn (Hybrid Ganga 5), the rate of dissipation of both herbicides was rather fast, possibly because of high rainfall (90 cm.). Residues of both these chemicals in soil at the time of maize harvest from all the dosages were negligible, about 95 to 98% reduction over the first day residues.

Analysis of maize plant samples and grains for simazine and atrazine residues did not show any detectable quantities of either of the chemicals, suggesting neglible translocation of the chemicals to aerial parts of the maize plant.

RECLAMATION OF LAND AFFECTED WITH TRIAZINE RESIDUES

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Continued indiscriminate use of triazines (simazine and atrazine) in maize (*Zea mays* L.) in Main Block 7 of the Genetic Division, Indian Agricultural Research Institute, resulted in toxic build up of residues in the soil on account of which neither cereals [wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.)] nor pulses [gram (*Cicer orientinum* L.), peas (*Pisum sativum* L.) and lentil (*Lens esculenta* Moench.)] could be raised in this land. A part of this land measuring 0.18 ha. was taken up for reclamation purposes during 1973.

The reclamation procedure consisted of giving inversion ploughings, discings, incorporation of farmyard manure, and raising of maize fodder and grain in 1973. The principle behind all the above operations was to expose the contaminated soil to various degradation agencies, such as volatilisation, photodecomposition, microbial degradation, adsorption, absorption and other similar factors. The effects of these procedures were tested by planting gram, peas and wheat in the rabi season.

The soil was periodically analyzed for the herbicide residues and it was observed that each practice scheduled above contributed to the reduction in the content of triazine residues in the soil. Of the three test crops (wheat, peas and gram) raised

after six months later in the rabi season, wheat was the most resistant and gram the most susceptible to the triazine residues. From this experiment a broad generalisation could be made that in triazine-residue-affected land, no pulse should be grown in the rabi season.

RESIDUE OF SIMAZINE IN TREATED GRAM PLANTS

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Herbicides used as preemergence treatments are absorbed by crop seedlings. They may accumulate in them and may prove hazardous when consumed by human beings and animals. Simazine is a commonly used herbicide and its residues was determined in treated gram (*Cicer arietinum* L.) seedlings. Gram seeds were sown in earthen pots containing 1.9 kg. of soil and sand (3 : 2) mixture. These were treated with simazine at 50 and 75 mg/pot one day after sowing. The amount of simazine present in gram plants was determined colorimetrically at 20 and 30 days after sowing. It was found that gram plants absorbed as well as degraded simazine.

EFFECT OF DALAPON ON JOHNSON GRASS AND ITS RESIDUAL EFFECT ON WHEAT AND BARLEY

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In pot studies conducted during 1974 and 1975, postemergence application of dalapon, when Johnson grass (*Sorghum halepense* L.) plants were about 15 to 20 cm tall, resulted in a remarkable reduction in the plant height and weight of rhizomes. Maximum reduction in the dry matter of shoots and rhizomes occurred when dalapon was applied at 5 kg/ha. followed by a repeat application at the same rate 5 to 10 weeks after the first application. This treatment resulted in 78 and 74% reduction in the matter of rhizomes and 93 and 80% reduction in the dry matter of top growth (above ground parts) during 1974 and 1975, respectively. The corresponding figures for two applications of paraquet, each at 0.5 kg/ha., were 59 and 71% reduction in the dry matter of rhizomes and 62 and 71% for dry matter of above ground parts. Dalapon applied twice was more efficacious than single application or when it was followed by one application of paraquet. Dalapon-treated plants showed tremendous reduction in the internodal length of the rhizomes and stem.

Dalapon or paraquet did not show any adverse residual effects on the growth and grain yield of wheat (*Triticum aestivum* L. 'Kalyan Sona') and barley (*Hordeum vulgare* 'C-164').

A REVIEW ON THE EFFECTS AND PERSISTENCE OF HERBICIDES IN AGRICULTURE

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The paper deals with the work done on the problem of herbicide persistence in the country including observations of the authors and by other workers on residues in water, their magnitude, disappearance, dissipation, effects on planktons, invertebrates and fishes. Application of herbicides to control noxious floating, emergent marginal, and submerged aquatic weeds and algal growths may lead to residues remaining in water or soil affecting fish and other animal life. While recommended doses of some of the herbicides harmless to the aquatic environment in other cases some adverse effects may become evident. The biodegradation and elimination of the herbicides from the aqcuaculture ponds is of utmost importance. Among the herbicides 2, 4-D appeared to be the least persistent and safest to use. Its application as foliar spray or in water or to bottom soil was found to be harmless to fish and other biota.

A FIELD TECHNIQUE FOR PREPARATION OF SLOW-RELEASE HERBICIDE FORMULATION AND RESULTS OF PRELIMINARY EXPERIMENTS ON THEIR USE FOR CONTROL OF ROOTED AQUATIC VEGETATION

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The advantages of root-zone application of herbicides for control of rooted aquatic vegetation has been well recognized for the following reasons : (1) economy of herbicides, (2) prolonged slow release of effective concentrations in limited vulnerable zones, (3) easier translocation of the herbicide, and (4) mitigration of pollutional effects. Though factory-made commercial formulations of some herbicides are available in India, their cost is disproportionately high for the quantum of the active ingredient available and the user has no choice on the size of pellets and the concentration of the active ingredient suitable to the requirements of the field situation. These considerations become crucial in the rural conditions where intensive aquaculture is becoming highly popular.

Investigations on this line of approach at the Central Inland Fisheries Research Institute have been guided by the special needs of the rural fish culturist. Granulated formulations have been prepared using sand granules and brick-pellets as the carriers for treatment of submerged foliage or the bottom root-zone. The active ingredients tried were 2, 4-D, simazine, and copper sulphate and the target plants included *Nymphaea* ssp., *Nymphoides* ssp., *Ipomoea* ssp., *Ottelia alismoides*, *Hydrilla*, *Utricu-*

laria, *Naias*, *Pithophora*, *Nechamandra*, and *Limnophila* sp. The persistence of phytotoxicity in the soil and water and the effects on non-target organisms and on fishes were noted and monitored. The results were higly encouraging and hold promise of achieving the ideal of chemical weed control using the minimum of herbicides with maximum desired effect and minimum side-effects.

SLOW-RELEASE HERBICIDE TO CONTROL *PARTHENIUM*

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Parthenium hysterophorus is an obnoxious weed which causes allergic diseases and which poses severe threat to animals and crops. Apart from Maharashtra, it has now invaded several other States and the Union Territory of Delhi. It can grow on all kinds of soil under different climatic conditions and can complete four life-cycles in a year. The seeds do not have a dormancy period and can germinate immediately after the fall and remain viable for a long time. Each plant produces over 5000 seeds.

Many persistent and nonpersistent herbicides have been reported to be effective in controlling *Parthenium*. Persistent herbicides are undesirable because of their residual effects and consequential hazards to ecology, while herbicides with short lives tend to be ineffective. In both cases the amounts applied are often grossly in excess of that actually required to control the weed because of the need to compensate for herbicide loss by leaching, evaporation, and decomposition. The ideal solution to control Parthenium would, therefore, be a preventive, preemergence, slow-release, selective herbicide treatment.

Development of slow-release pesticides is one of the major objectives of current international pesticide research. There have also been some significant and recent successes in the application of slow-release pesticide technology to global problems. In a slow-release system the pesticide is released at a fairly constant rate for a desired period of time. The effect of the pesticide is felt over a long period of time. The effect of the pesticide is felt over a long period of time at a minimum essential level at which pollution hazards are minimal. Such systems can give better control with less active ingredient and can reduce damage to non-target objects (such as desired crops and grasses) and to the environment. A single application of such a preemergent herbicide, can do the work of two or three conventional applications of postemergent herbicides such as 2, 4-D which has been suggested for control of *Parthenium*. The latter suffers from the various defects of conventional herbicides described above.

A new slow-release, selective, preemergent herbicide formulation has been developed in the National Chemical Laboratory (NCL) in Poona which controls *Parthenium* but allows grasses to grow. The active ingredient of the present formulation is a well known cheap herbicide, which is known to cause drift hazards on suscep-

tible species and pose residue problems in soil and irrigation water. The novelty of the new formulation is that it contains safe levels of the active ingredient in the free and in a slow-release from for selective action on *Parthenium*. The formulation affords better control with considerably less quantity of the active ingredient and reduces damage to non-target objects (grasses and crops) and to the environment. A single application of the new formulation has the same effect of two conventional applications of 2, 4-D. The cost of application is also significantly reduced. Considerable data on mode of application, dose, residues, and phytotoxicity have been collected from a number of field trials. Multilocational field trials on evaluation of the efficacy of the new formulation are in progress in different parts of the country.

A demonstration plot in Nayudi Hospital, Poona, in the middle of a *Parthenium* covered ground which was treated in the first week of June 1976 with the NCL slow-release herbicide has remained nearly free of *Parthenium* whereas all around the plot this weed is growing profusely. Further field trials on a larger scale are necessary to confirm the above results. The NCL discovery, nevertheless, holds high promise to eliminate the menace of *Parthenium* which is threatening agriculture and animal husbandry in Maharashtra and several other States.

The NCL in cooperation with the Government of Maharashtra, some Agricultural Universities and the Poona Municipal Corporation hopes to carry out further field trials starting June 1977 to confirm these initial promising results.

PHYSIOLOGICAL ASPECTS OF HERBICIDAL ACTION IN PLANTS

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(No abstract.)

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13. WEED PROBLEMS AND CONTROL OF PROBLEM WEEDS, PARASITIC AND AQUATIC WEEDS

WEED PROBLEMS AND HERBICIDE USE IN INDIA

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India is loosing yearly about Rs. 5000 crores of agricultural production (about 18% of the gross national production) due to the ravages of weeds, plant diseases, insects, rodents, and storage pests. The maximum loss is due to weeds (33%).

At present the spread of 18 major weeds in different parts of India are posing serious problems in increasing agricultural production. These major weed species are : *Avena fatua* (wilt oat), *Cyperus rotundus* (nutgrass), *Carthamus oxycantha* (wild safflower), *Chara* sp. (stonewort), *Eupatorium odoratus*, *Eichhornia crassipes* (water-hyacinth), *Salvinia* sp. (waterfern), *Potomogeton* sp. (pond weeds), *Lantana camara* (Lantana), *Nitella* sp. (Algal weed), *Oxalis latifolia* (Indian sorrel), *Orobanche* sp. (broom rape), *Parthenium* hysterophorous (carrot weed), *Phalaris minor* (canarygrass), *Striga* sp. (witchweed), *Solanum elaegnifolium* (whitehorse nettle), *Saccharum spontaneum* (wild cane) and *Xanthium strumarium* (cocklebur).

The quantity and efficiency of about 43 herbicides imported into the country since 1948 have been recorded. Among the hercicides, the following are significant : alachlor, atrazine, amitrole, barban, bentazon, bromacil, butachlor, chloramben, chloropropham, dichlormate, diquat, dalapon, diuron, DNOC, DSMA, EPTC, fluchloralin, glyphosate, MSMA, MCPA, MCPB, monuron, MH, MCPB, nitrofen, propanil, PCP, paraquat, pebulate, picloram, simazine, TCA, triflurain, terbacil, triallate, 2,4-DB, 2,4-D, 2,4-5-T, and sesone.

The country at present is manufacturing three herbicides, ammonium sulfamate, 2,4-D, and 2,4,5-T. The total licensed capacity of herbicides (2,4-D, 2,4,5-T, MCPA, MCPB, TCA, propanil, nitrofen) is 4285 tonnes and the installed capacity is 2435 tonnes. Besides these, some other promising herbicides (i. e. MSMA, DSMA, dalapon, alachlor, butachlor, triallate, paraquat, fluchloralin) will also be produced in the country with a licensed capacity of about 9640 tonnes.

In order to reduce crop losses due to weeds the efforts made by the Central/ State Governments/Agricultural Universities and the Indian Council of Agricultural Research and various other Institutes in the country requires frequent review in order to maximise the use of resources to solve urgent problems.

CHEMICAL WEED CONTROL IN ANDHRA PRADESH

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Andhra Pradesh is one of the biggest States in India with more than two-thirds of its population depending on agriculture. The State has three major irrigation systems along with some minor irrigation sources. Rice is the major crop, followed by sugarcane, cotton, millets, oil seeds, and vegetables. The day-to-day increase in farm wages has made the cost of inputs higher for agricultural production and the farmer has to find alternatives to manual labour such as mechanical or chemical techniques for weed control. In this context the use of herbicides has become very fitting as one of the regular practices of crop husbandry. The weed control division at the Agricultural College in Bapatla has worked for the last two decades on several herbicides in different agroclimatic zones of the State. As a result of these studies, herbicidal recommendations for different crops and aquatic weeds in the State are now available.

WEED PROBLEMS OF MADHYA PRADESH

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Diversified crop zones and climatic conditions in Madhya Pradesh offer most congenial conditions for a large flora of weeds to grow and compete with all crops. There are situations where half or more of the total efforts of farming are diverted to the battle against invading weeds. The extent of weed severity is as much as to make crop production impractical in some deep black soil areas of the State.

The survey was undertaken in 1973 and 1974 to list the weed problems of five major regions comprising eight divisions of the State. Different zones and divisions included in the survey were : (A) Western Region - Indore; (B) Western Central Region - Bhopal, Hoshangabad, Sagar; (C) Mahakoshal and Vindhya Region - Jabalpur, Rawa; (D) Northern Region - Gwalior; (E) South Eastern Region - Raipur.

Some of the most dominant weeds regionwise are summarised below :

Region A - *Alysicarpus regosus, Celosia argenta, Dinebra arabica, Commelina* spp., *Chenopodium* album.

Region B - *Sonchus* spp., *Cirsium arvense, Portulaca oleracea, Ageratum conyzoides, Avena fatua, Eragrostis* spp.

Region C - *Caesulia axillaris, Eclipta alba, Dinebra arabica, Euphorbia* spp., *Phalaris minor, Vicia* spp.

Region D - *Striga* spp., *Eragrostis* spp., *Eclipta* alba, *Amaranthus viridis*, *Eragrostis* spp., *Paspalum* spp., *Vicia* spp., Chenopodium album.

Region E - *Cyanotis axillaris*, *Eichhornia crassipes*, *Aqeatum conyzoides*, *Sphaeranthus indicus*, *Saccharum munja*, *Eleusine indica*, *Vicia sativa*.

Cyperus spp. and *Echinochloa* spp. were found to occur throughout the State, though the *Echinochloa* spp. were a more serious problems in Jabalpur and Raipur divisions. Amongst the perennial weeds, *Saccharum spontbneum* in the Western and Central regions and *Zizyphus* spp. in the Western-Northern regions were very serious problems.

PROBLEMS OF WEED CONTROL IN CHOTANAGPUR

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Chotanagpur being a rainfed tract with no irrigation facilities worth the name, the problem of weeds is serious only in kharif with practically no problem in rabi season. Surveys of weed flora in small plots, big farms, and cultivators' fields have shown that there were only a few predominant weeds such as *Echinochloa colonum*, *Ageratum conyzoides*, *Eleusine*, *Cvnodon dactylon*, *Cyperus species*, *Commelina Setaria Dactyloctenium aegyptium*, *Digitaria longitoria longiflora*, *Ipomoeai* and *Tridax procumbens*. They were found in the uplands (constituting about 60% of the cultivated area) of Chotanagpur where water does not stagnate for more than a couple of hours even with very heavy rains. There appeared to be no crop-weed association; rather, it was more of an ecological association determined mainly by moisture regime in the soil. The different terraces of lowlands which support only the paddy (*Oryza sativa* L.) crop of different durations depending on the duration that optimum moisture is available in each terrace is dominated by weeds such as *Commelina nudiflora*, *Echinochloa colonum*, *Panicum repens*, *Commelina benghalensis*, *Cyperus* species, *Fimbristylis miliaecea*, *Eichhornia crassipes*, *Monochoria vaginalis*, and *Ludwigia* species.

Chemical weed control schedule for both paddy and upland crops like upland paddy, maize (*Zea mays* L.), jowar (*Sorghum bicolor* Pers.), groundnut (*Arachis hypogaea* L.), moong or green gram (*Phaseolus aureus* L.), urid or blackgram (*Phaseolus mungo* L.), soybean (*Glycine max* Merr.), horsegram (*Dolichos biflorus* Roxb.), and cotton (*Gossypium hirsutum* L.) have, however, been worked out. But in the wake of the rise in prices in agricultural chemicals since 1973, the cost of the recommended doses of these chemicals is very high and beyond the reach of the poor tribal cultivators of the region. However, there is little doubt that it is still profitable to resort to chemical weed control as compared to the other methods.

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COMMON WEED PROBLEMS OF DRYLAND RABI ZONE OF THE DECCAN AND THEIR CONTROL MEASURES

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There are various aspects of the problems of weeds in dryland rabi zone of the Deccan, including the composition of weeds in the different soil types, the importance of weed control and its effect on crop production, the competition between crop nd weeds, the critical period to control the weeds, and the scope of herbicides and their economic aspects.

SOME NEW WEEDS SIGHTED IN AND AROUND DELHI

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Waste lands and other non-cropped areas serve as sources for the spread of weeds into cultivated lands. Recently, some weeds were observed growing in areas adjoining some residential buildings in the National Physical Laboratory (NPL) Complex in Delhi. As the NPL complex is surrounded by agricultural fields it was felt that proper identification of newly sighted weeds may go a long way in preventing the spread of these weeds to crop fields. A description of these is given below :

Hyptis suaveolens Poit. is an annual belonging to the family Labiatae. It is a tall herb growing in waste places and along hedges and borders of fields. This species flowers and fruits during October to January. It is a prolific seed better on account of which there is a great likelihood of the plant species gaining entry into crop fields.

Parthenium hysterophorus L. is a much talked and maligned plant species belonging to the family Compositae. Because of its very fast growth rate, enormous production of seed which is very light in weight and armed with a pappus, it has spread far and wide invading at present waste lands. It was observed for the first time in Delhi in kharif crops in the Cantonment area.

Lolium temulentum L. (Poison ryegrass) is an annual belonging to the family Gramineae. The grains of this species carry a fungus which is thought to be the cause of their poisonous nature. This plant was observed for the first time in wheat crop at Badarpur. The seeds were also noticed in the wheat ration.

Abelmoschus ficulnens is a member of the family Malvaceae. It is an annual herb flowering and fruiting in the kharif season. The seeds of this species resemble that of bhindi or lady's finger (*Hibiscus esculentus* Moench.) but are small in size and hairy. It was observed in bhindi and cotton (*Gossypium* spp.) fields.

Blainvilla latifolia L. is an erect, dichotomously branched herb flowering and fruiting during August to October. Its seeds are very similar to *Eplicta alba* except that they are bigger in size. It was observed growing in soybean (*Glycine max* Merr.).

AGERATUM CONYZOIDES L.-A NEW TROUBLESOME WEED IN SUGARCANE

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Ageratum conyzoides L., a member of the family compositae and commonly called as Bill goat weed, was noticed in 1975 as a very troublesome weed growing extensively in ratoon sugarcane (*Saccharum officinarum* L. 'Co 419') crop in farmers' fields in Chittoor District. A survey was conducted in the villages of Aragonda and Kalodapalli to study this weed problem. The soil was sandy loam of medium fertility. *Ageratum* was observed to come up luxuriently under the shade of sugarcane at about 6 to 7 months old. An estimate of the *Ageratum* population showed that there were 250 to 400 plants/sq. m.

Controlling *Ageratum* by hand weeding was not convenient and had to be repeated to be effective. Hence, trials in ratoon sugarcane were laid out in these two villages in farmers' fields to study the efficiency of five herbicides, paraquat at 0.5 kg/ha, paraquat at 0.5 kg/ha + 2,4-D (as Na salt) at 1.6 kg/ha, MSA at 0.24 kg/ha+2,4-D at 0.8 kg/ha, ametryne at 2 kg/ha + terbutryne at 2 kg/ha. All the herbicides were applied as directed sprays with a high volume sprayer using 500 L/ha. of the solution. At Aragonda village, paraquat (0.5 kg/ha) + 2,4-D (1.6 kg/ha) was effctive on weeds which were about to flower. At Kalrodapalli village where the weeds were in tender (early vegetative) stage, the above combination of paraquat+ 2,4-D (0.5+1.6 kg/ha.) and terbutryne+amettyne (2+2 kg/ha.) were both effective. The herbicides were not toxic to the crop. Further studies are required to confirm the above observations.

EUPATORIUM ADENOPHORUM SPRENG.-A NEW WEED MENACE IN NAGALAND

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Eupatorium adenophorum Spreng. (Syn. *E. glandulosum* H.B. & K.) a composite plant of Mexican origin, was probably introduced to India in the early part of this century (Specimen collected by R.E. Proudlock No. 225217 in 1914 deposited at the Central National Herbarium Calcutta). The weed has subsequently invaded other hilly areas of India. It has explosively invaded Nagaland about 20 years ago and has now almost completely eclipsed natural grass covers in the state between 1066 and 2130 m. and it is particularly dense in newly cleared forest areas.

The weed germinates after the rains in September and October and flowers in the middle February. The numerous light cypsellas are aerially dispersed in millions. The weed has posed a danger to the tribal economy by causing fodder scarcity. Thus, the tribal people of the state have started to dispose off their main beef animal, the semi-domestic cattle, mithun (*Bos fontalis*), a symbol of their wealth and social status. The replacement of grass is causing also a threat to herbivous wild life and preventing regeneration of timber trees. The weed is also found in cultivated fields and plantations. At the request of the State Government conveyed through the Government of India and ICAR, the author was deputed to assess the problem and to submit a report.

The weed is susceptible to MSMA at 3.5 L (total product), amine salt of 2,4-D, at 1.5 kg/ha, 2,4,5-T at 1,5 kg/ha, mixture of 2,4-D and 2,4,5-T (2 : 1 ratio) at 1.5 kg/ha. The terrain being hilly, the possibilities of herbicide drift hazards, the costs involved, and the magnitude of the problem, proposals for aerial spraying of chemicals for control do not find concurrence by authorities concerned. Therefore, biological control methods need to be assessed. Among the possible aggressive plants which might be of help to control this weed by smoothering and competition, the following are suggested : *Pueraria* sp. *Centrosema pubescens*, *Calopogonium mucunoides*, and rhizomatous palatable grasses such as kikuyugrass *(Pennisetum clandestinum)*. The gall fly (*Procecidochares utilis* Stone.) which was reported to be effective in Hawaii, the crown boring cerambycid *Dihammus argentatus* Auriv.) and the fungus, *Cercospora* eupatorii Peck. are among other biological agents which might be explored for their effectiveness against *Eupatorium*. The combined effects of all these measures might help reduce the species population. Eupatorium probably represents a pioneer phase in autogenic succession. It remains to be seen whether or not *Eupatorium* changes its habitat after invasion. Research must continue irrespective of the crisis of the moment ; in the meanwhile only *ad hoc* measures could only be tried.

CHEMICAL CONTROL OF *PROSOPIS JULIFLORA* (SW.) DC.

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Prosopis juliflora (SW.) DC (locally known as Bellary jali) was introduced in Bellary district of Karnataka to check wind erosion of soil along the Hagari River. In a span of 4 to 5 decades, it has spread to most of the northern districts of Karnataka and has become a menace to the farmers and the engineers as it is encroaching the cultivated fields, edges of the roads, and open sites.

In this study, three stages of *Prosopsis* were considered :

(a) brush stage, where the stem thickness was about 1 to 2 cm;
(b) small tree stage. where the stem thickness was 2.5 to 5 cm; and
(c) Tree stage, where the trunk thickness was more than 5 cm.

Two chemicals, ammonium sulphamate and a mixture of 2,4,5-T+2,4-D were sprayed at three concentrations each at the brush stage. Ammonium sulphamate at three concentrations was applied only in two methods : (a) girdling and (b) stump treatments. All these treatments were compared with hand cutting and a check.

Quarterly observations for one year had indicated that overhead spray on brushes with ammonium sulphamate at 125 kg/ha and the brush killer mixture of 2,4,5-T+2,4-D (3.75 kg/ha) were very effective against *Prosopis*. Out of 20 brushes sprayed with the above chemicals, only 2 to 3 brushes showed new shoots after three months. Likewise, application of ammonium sulphamate paste (3 and 4 kg/5 litres of water) with a hand-brush on the girdled and stumped portions of the trees was very effective in killing 80 to 90% of the trees. Fresh shoots appeared on 1 to 2 trees after six months, Hand-cut treatment had fresh shoots within one month while the untreated tree had doubled in the number of fresh shoots. Similar observations were recorded twelve months after treatment.

BIOLOGY AND CHEMICAL CONTROL OF WILD GARLIC

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Biology and chemical control of wild garlic (*Oxalis acetosella* Linn.) was studied separately at Bangalore during 1975 and 1976 under field laboratory conditions. Growth pattern of the weed to tailor suitable chemical control, and herbicide suited for control were also studied. The multiplication of the weed was very slow up to 75 days after planting necessitating usage of mechanical or cultural methods for effective and early control. The multiplication of the weed both in top shoot production and tuber production was fast up to 120 days after planting. Shoot production declined slightly after this, while tuber multiplications and development continued. Even under senescence of top growth underground tuber development appeared to proceed. This underground tuber would produce new shoots when exposed to favourable conditions. Under this rapid growth stage, utility of herbicides was an effective means of killing the weed or in preventing regeneration. Among several herbicides screened before flower initiation during 1976, picloram (1.5 kg/ha) and amitrol (2 kg/ha) gave effective control of multiplication and checked the growth within a month after the spray. Propanil (2 kg/ha) and metoxuron (1 kg/ha) did not control the weed effectively. Use of these herbicides under large scale field conditions and their persistence in minimising the regeneration of this weed needs to be persued.

HERBICIDAL STUDIES ON NUTGRASS IN RELATION TO ITS ENVIRONMENT

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Nutgrass (*Cyperus rotundus* L.) is a pestiferous perennial weed enjoying a wide range of agroclimatic zones of the world. It is more prevalent under tropical and subtropical compared to temperate climates. The extreme prolific capacity of this weed due to its underground rhizomes and tubers is a challenging problem to all weed scientists. The translocation of the foliar applied herbicide to the tubers is the key factor in the success of the control technique. The moisture percentage, total water soluble carbo-hydrates, starch, and soil moisture are the limiting factors for its spread and mortality. Some herbicides such as atrazine and terbacil appear to kill the tuber with its buds where as the post-emergence herbicides sush as dalapon and MSMA appear to stimulate tubers to sprout before the plant is killed. The above factors are significantly related to the survival and death of the nutgrass tubers and of the whole plants.

EFFECT OF HERBICIDES ON TUBERIZATION IN *CYPERUS ROTUNDUS* L.

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A replicated trial to study ihe effect of herbicides on tuberization of *Cyperus rotundus* L. was conducted at Agricultural college, Jobner, from October, 1975 to January 1976. One-month old seedlings of *Cyperus* established without tubers in pot culture were treated with postemergence sprays of 5000 ppm (0.5% solution) each of cacodylic acid, MSMA, nitrofen, and the combinations of cacodylic acid+MSMA, nitrofen+MSMA, and nitrofen+cacodylic acid, and an untreated control. Each component of the combinations had the concentration of 5000 ppm. These treatments were replicated four times in a randomized block design. Plant characters were noted periodically and the tuberization was recorded 90 days after the application of the treatments.

All the herbicides, whether used singly or in combinations, adversely affected the treated plants which were either completely killed or partially retarded tuberization. The synergistic effect of nitrofen and MSMA was most prominent in rapidly killing the plants and in reducing significantly the number and weight of tubers.

CHEMICAL CONTROL OF NUTSEDGE IN JUTE FALLOWLAND AND AFTER EFFECTS ON FIBRE YIELD OF JUTE

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Twelve herbicides were tried to control nutsedge on sandy loam soils during the years 1971-72 and 1972-73. The herbicides were applied preplant on ploughed land or on standing nutsedge of 4 to 5 weeds old. They were applied 20 days before sowing of jute (*Corchorus* sp.); some treatments were repeated 10 days later. In 1972, dalapon treatment was replaced with Tetrapion. The nutsedge shoots and number of grasses were counted periodically before sowing of jute, in the jute crop, after jute harvest in the fallow land and in the succeeding crop of wheat (*Triticum sativum*).

2,4-D considerably reduced nutsedge population but ineffective against the grasses. Paraquat temporarily suppressed the nutsedge and grasses but did not improve the final yield of jute. Dalapon was also ineffective against nutsedge but reduced grassy weed population. MSMA, DSMA, and tetrapion considerably reduced nutsedge and grasses and improved fibre yield. Other herbicides like pebulate, EPTC, and molinate also gave moderate to satisfactory control of nutsedge.

EFFECT OF *CYNODON DACTYLON* INFESTATION ON THE YIELD AND YIELD ATTRIBUTES OF SAFFLOWER AND WHEAT

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Hariyali or burmudagrass (*Cynodon dactylon* (L.) Pers.) is a very hardy, much branched leafy grass with numerous stems below and above soil. The extent of yield reduction in safflower (*Carthamus tinctorius* L. 'A-1' and wheat (*Triticum aestivum* L. 'Bijaga yellow') due to the infestation of hariyali in deep black cotton soils during the rabi season of 1974-75 was studied at Agricultural College farm, Dharwar. Number of aerial shoots per 5 sq. m. were 324 in safflower and 295 in wheat in the infested plot area. Infestation of hariyali significantly reduced the plant height, number of heads per plant, number of seeds per head, and 1000 seed weight. Seed yield of safflower per 5 sq. m. was 619 g in infested plot and 1029 g in weed-free plot (control). The extent of yield reduction was 40%.

There was significant reduction in all the characters of wheat. Grain yield of wheat was only 175 g in infested plots and 515 g in control plots. The extent of yield reduction was 65%.

CONTROL OF PHALARIS MINOR RETZ. IN WHEAT IN TARAI REGION OF UTTAR PRADESH

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The influence of 2,4-D, methabenzthiazuron, nitrofen, triallate, and terbutryne was studied on the population of *Phalaris minor* Retz. and on the yield of wheat (*Triticum aestivum* L.) crop in the Tarai region of Uttar Pradesh during 1973-74.

Except 2,4-D all other herbicides reduced the population of *Phalaris* in wheat fields. Maximum grain yield was obtained with the application of terbutryne at 1 kg/ha 5 weeks after sowing during 1973-74 and with methabenzthiazuron at 2 kg/ha as preemergence during 1974-75.

SOME OBSERVATIONS ON THE BIOLOGY AND CONTROL OF PARTHENIUM

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Parthenium hysterophorus L., a member of the family Compositae, is an annual weed reproducing through seeds and grows throughout the year. It is hardly affected by soil, climate and other environmental conditions. The above-ground portions (leaf axils, stems, and branches) carry growing points which sprout at the slightest provocation. With the advancing age of the plant, the sites of these growing points, lying dormant inside, increase. *Parthenium* has the capacity to produce four generations in one year. Its prolific seeding ability, the extremely light weight of seeds armed with a pappus and the non-dormancy of seeds are some of the factors responsible for the extensive spread of the species through natural agencies such as wind, water, birds, and animals.

Some observations made at the Indian Agricultural Research Institute New Delhi, indicated the sensivity of *Parthenium* to urea. Spraying the plants to drip with 20% urea solution was lethal. A repetition of urea spray of necessary to kill mature plants.

A trial was carried out in 1976 in a naturally infested site at the Patelnagar Railway Station Yard. The spray treatments employed were : (1) 20% urea, (2) 20% ammonium sulphate, (3) 20% urea + teepol, (4) 5% ammonium sulphate + teepol, (5) 5% ammonium sulphate + 10% urea, (6) mechanical cutting with 'talwar', and (7) an untreated control. A spray with a 20% ammonium sulphate during the pre-monsoon months (March to May) completely killed the plants at all stages and there was no regrowth. Further, the chemical was lethal to *Xanthium strumarium*, another widespread weed belonging to Compositae.

In all waste places at Delhi where *Parthenium* had established securely, a few plants were seen affected with a malady (probably caused by a virus or mycoplasma) on account of which the floral parts were modified into leaf-like structure (phyllody). Plants affected with the disease died without producing seeds. Somehow the spread of this malady appeared very late in the life cycle of the plant. If the casual agent of this affliction could be identified and if it could be made to spread fast, Parthenium could probably be controlled by this biological agent.

ECOLOGICAL STUDIES ON NOXIOUS WEED *PARTHENIUM HYSTEROPHORUS* L.

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Ecological life history of noxious exotic emigrant weed *Parthenium hysterophorus* L. was investigated to determine its growth responses and vulnerable points on its life cycle. Results indicated that the plant prefers moist, shady, organically rich habitats. The plant has remarkable plasticity and adaptability to environmental extremes ; it is photoperiodically and thermoperiodically neutral. It is a prolific seed setter ; a single plant produces about 3500 seeds in three polymorphic forms. Seed leachings inhibit germination of other weed seeds. Its association detrimentally affects seedling growth and root proliferation of wheat, indicating allelopathic syndromes.

Phytosociologically, the plant is a rapid coloniser and competes out other vegetations in its vicinity within two growing seasons.

PARTHENIUM WEED MENACE IN INDIA AND ITS CONTROL

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Parthenium hysterophorus L., an American weed, has spread to many parts of India covering approximately five million hectares, replacieg many dominant weeds in wide range of habitats including cultivated fields. The weed has high ecological amplitude and remains flowering during most part of the year. Each plant produces an average of 7,000 cypsella (fruits) which emerge into a dense mat of seedlings after a few showers. The young rosettes with their radial leaves closely pressed to the ground allow no other species to come up in their midst. Different parts including pollen of the weed exert allelopathic influence on neighbouring species. Reports of contact dermatits due to the weed make hand weeding inadvisable.

Herbicides to which different crops are known to be tolerant were tried to control emergence of the weed. Atrazine (1.5 and 3 kg/ha) prevented seed emergence for

five to eight months in the fields of cereals like maize (*Zea mays* L.), sorghum (*Sorghum vulagree* Pers.) and bajra (*Pennisetum typhoideum* L.). Nitrofen and alachlor (2 kg/ha) controlled weeds for two and a half months. Nitrofen controlled *Parthenium* in the fields of potato (*Solanum tuberocum* L.), turnip (*Brassica campestris* L.), radish (*Raphanus sativus* L.), carrot (*Daucus carota* L.), onion (*Allium cepa* L.), cauliflower (*Brassica oleracea* L. 'Capitata'), and groundnut (*Arachis hypogaea* L.) ; and alachlor in fields of soybean (*Glycine max* Merr.), okra (*Abelomoschus esculentus* (L.) Moench.), tomato (*Lycopersicum esculentum* Mill.), French beans (*Phaseolus vulgaris* L.), and banana (*Musa paradisiaca* L.). Metribuzin (2 and 4 kg/ha) controlled *Parthenium* for six to nine months in potato and tomato. Terbacil (1.5 kg/ha) was effective for three months in fields of mentha (*Mentha viridis* L.) and watermelon (*Citrulus vulgaris* Schard.). In sapota (*Achras sapota* L.), grapes (*Vitis vinifera* L.), pineapple (*Ananas comosus* (L.) Merr.), and citrus orchards, bromacil and diuron (1.5 kg/ha) checked weed emergence for eight months. Metribuzin, atrazine, diuron, and bromacil were also effective in controlling the weed in fallow lands and other situations ; but the selection of the herbicide should depend on the subsequent use of the land.

SURVEY ON THE DISTRIBUTION OF *PARTHENIUM HYSTEROPHORUS* L. IN KARNATAKA STATE

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A survey on the occurrence and distribution of *Parthenium hysterophorus* L. in Karnataka State was conducted during 1975-76. The information was collected by means of questionnaire which was answered by officers of the Department of Agriculture who have knowledge of situations of *Parthenium*.

The survey results indicated that the degree of infestation of *Parthenium* was maximum in Dharwar, Bangalore, Bijapur and Belgaum districts ; medium in Bellary, Gulburga, Kolar and Mysore districts and low in other districts. N. Kanara, S. Kanara Coorg. and Chickmagalur districts were free from this weed.

GROWTH OF PARTHENIUM UNDER DIFFERENT SOIL CONDITIONS AND RELATIVE EFFICACY OF PREEMERGENCE HERBICIDES

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Two studies were conducted on *Parthenium hysterophorus* L. during 1976 around Bangalore. The growth of the weed under different soil conditions was studied to determine the factors favouring its better growth. It was observed that *Parthenium* could grow under varied soil pH. Soil alkalinity depressed weed growth

yet the seed production was unaffected, in view of numerous branches. High soil moisture availability and organic carbon in the soil favoured the plant height, number of branches per plant, total dry matter production and dry matter distribution to flowers. All these eventually lead to higher seed production.

In another study, 22 pre-emergence herbicides were tried to determine their relative efficiency on the prevention of *Parthenium* emergence. The pre-emergence applied herbicides which completely prevented emergence of *Parthenium* for 60 days were: terbutryne (6 kg/ha), RH 8817 (5 kg/ha. of formulated product?), atrazine (1.25 kg/ha), simazine (1.25 kg/ha), butachlor (3.75 kg/ha), and dimethylamine salt of 2,4-D (5.4 kg/ha). Reasonable control of weeds was also obtained with AC 92,553 (1.88 kg/ha), benthiocarb (2.25 kg/ha), methabenzthiazuron (1.75 kg/ha), bentazon (2.4 kg/ha), sodium salt of 2,4-D (4 kg/ha), and ethyl ester of 2,4-D (2,7 kg/ha).

(Note: The rates converted from kg. or litre per acre to kg/ha. There are no indications in the paper wheather the rates are in active ingredient or acid equivalent. Ed.)

POSTEMERGENCE CONTROL OF *PARTHENIUM HYSTEROPHORUS* L.

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In a field experiment during 1976 several herbicides, 2,4-D (sodium and amine salts and ethyl ester), 2,4,5-T, paraquat, diqut, MSMA, aminotriazole-T, terbacil and glyphosate, were tried at varying concentrations and combinations for the control of *Parthenium hysterophorus* L. at three stages of growth (rosettee, flowering and maturity). The results indicated that Na salt of 2,4-D (2.5 and 3 kg/ha). amine salt of 2 4-D (1.5 kg/ha), ethyl ester of 2,4-D (3.6 kg/ha), 2,4,5- T (4.8 kg/ha) paraquat (0.5 and 0.75 kg/ha), diquat (0.5 and 0.75 kg/ha), and MSMA (3.6 kg/ha) were effective in controlling *Parthenium* at rosette and flowering stages. Combinations of 2,4-D Na (2.5 and 3 kg/ha) with paraquat (0.5 kg/ha), MSMA (3.6 kg/ha), or aminotriazole-T (20 L/ha of formulated product) were more effective in killing matured plants.

CHEMICAL CONTROL OF *PARTHENIUM HYSTEROPHORUS* L.

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Parthenium hysterophorus L. is an exotic weed with dominant charaters such as prolific seed bearing and effective spread to several locations. The weed is important

both from agricultural point of view and as health hazards. The results of the chemical control of this weed at mature and flowering stages indicated that the best treatment was spraying of diquat at 0.5 kg/ha in combination with Na salt of 2,4-D at 2 kg/ha. In addition, MSMA, asulam and paraquat also gave satisfactory control of *Parthenium*.

EVALUATION OF SUITABLE HERBICIDES FOR THE CONTROL OF PARTHENIUM

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A field trial was conducted during April, 1976 in a private holding at Pollachi, Coimbatore district, to find suitable herbicides for the control of *Parthenium hysterophorus* L. The experiment was conducted in a randomized block design with three replications. Treatments comprised of four herbicides, diquat (2 kg/ha), MSMA (3 kg/ha), glyphosate (2 kg/ha), and sodium salt of 2, 4-D (2 kg/ha). The first three herbicides were tried individually and in combination with 2, 4-D. An untreated check was also maintained.

Weed counts taken 15 days after spraying indicated that diquat, glyphosate and their combinations with 2, 4-D gave superior control of weeds when compared to other treatments. Number of weeds per sq. m. in plots treated with diquat and glyphosate were 15 and 7, respectively, while the control had 110 weeds.

At 30 days after treatment, there was complete weed control in plots treated with glyphosate, whereas MSMA and diquat had 2 and 19 plants per sq. m. respectively. At this stage, the control plot had 153 plants/sq. m. There were no added advantage by the addition of 2, 4-D to the above herbicides. Diquat, glyphosate, and MSMA can be used for the effective control of *Parthenium* weed.

CONTROL OF *PARTHENIUM* WEED

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Parthenium (*Parthenium hysterophorus* L.) weed has become a nuisance in waste and vacant lands in many states of India.

In order to find out a suitable method and an effective herbicide for the control of Parthenium, a field trial was initiated in New Delhi. Weeding out of Parthenium was attempted by manual hand pulling, use of a specially devised hand hoe, fire, and postemergence and preemergence herbicides.

Manual methods of control may be useful provided such operations are repeated after an interval of 30 to 45 days till the seeds at various depths in the soil are completely exhausted. Preemergence treatment with herbicides after initial pulling of Parthenium plants was found more effective and economical than the subsequent manual control alone.

In the preliminary evaluation of postemergence and preemergence herbicides, 0.5% solution of MSMA was found to give satisfactory control of 0.9 to 1.2 m tall Parthenium plants. Salts like sodium chloride, sodium hydroxide and sodium carbonate showed excellent dessicating effects on matured Parthenium plants. Treatment with sodium chloride and subsequently burning of dry plants were effective and economical. Atrazine at 4 kg/ha and diuron at 2 kg/ha applied preemergence were very effective in suppressing germination of Parthenium seeds 23 days after application. Detailed studies with preemergence control of parthenium need to be conducted.

FURTHER EVALUATION OF HERBICIDES FOR PARTHENIUM

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Dutta *et al* (1976) had reported the evaluation of 21 herbicides for the control of *Parthenium hysterophorus* L. These studies were extended further with new herbicides, bromoxynil, C-6989, methazole, and metribuzin (1,2, and 3 kg/ha) as overall spray at flowering and vegetative stages of the weed. Complete kill was obtained with bromoxynil at all doses and with methazole and metrabuzine at 3 kg/ha. No regeneration *in situ* was observed after one month.

PRELIMINARY STUDIES ON THE EXTRACTION OF PROTEIN FROM *PARTHENIUM HYSTEROPHORUS* L.

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The study was planned to explore the potentialities of *Parthenium hysterophorus* L. as a source of protein for ruminants and non-ruminants. Using the technique and equipment devised for the International Biological Programme, the extractabilities of the total nitrogen and protein as well as the yields of residual fibre from *Parthenium* harvested at different stages of growth were determined during the monsoon seasons of 1975 and 1976. The extractability of nitrogen was correlated with the % dry matter and with the fibre to juice ratio and declined significantly with the age of the plant. The chemical composition and *in vitro* digestibility of the protein concentrate prepared by heat coagulation were determined.

EFFECT OF REPEATED APPLICATION OF 2, 4-D WITH GLYCERINE AND TREE-KILLER ON THE CONTROL OF WHITE HORSENETTLE

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An experiment was conducted during 1973-74 at Peedampalli, Coimbatore district to study the effect of repeated applications of 2, 4-D with glycerine and tree-killer combined with fork digging and mulching on the control of white horsenettle. Glycerine at 10 L/ha and tree-krller at 50 L/ha were combined with 2, 4-D at 2.5 kg/ha and applied at fortnight intervals. Digging to a depth of 15 cm and mulching with black polythene and straw were provided after each spraying of 2, 4-D.

Treated plots showed significant reduction in number of white horsenettle compared to the untreated control. Increased control of the weed was not obtained by the combination of glycerine and tree-killer with 2, 4-D. Similarly, digging and providing straw mulch did not increase the control of the weed by 2, 4-D. Significant increase in weed control was obtained in black polythene along with repeated application of 2, 4-D. At 30 days after the final application of 2, 4-D, the degree of control was 48% in non-mulched plots and 60% in mulched plots. Similar trend was observed at 180 days but the use of black polythene was uneconomical. The study indicated that repeated application of 2, 4-D at 2.5 kg/ha alone will be sufficient for the control of white horsenettle.

NOTE : (Tree-killer is a mixture of the following chemicals : arsenic pentoxide, 6 kg ; sodium hydroxide, 4 kg ; phenol, 250 ml, and casein, 180 g. This mixture is made up to 20 litres with water.)

STUDIES ON THE WHITE HORSENETTLE CONTROL WITH TORDON 101 MIX, TORDON 22 K AND 2, 4, 5-T

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Investigations were carried out at Kunkarupalayam, Coimbatore district, in a private holding heavily and uniformly infested with white horsenttle (*Solanum elaeagnifolium* Cav.) for its control during 1973-74. A field experiment was laid out with ten treatments in randomized block design with three replications. The treatments comprised of Tordon 101 Mix at 10, 15 and 20 L/hr, Tordon 22K (2L=0.5 kg, 2L+1.5 kg and 2L+2.5 kg) and an untreated check.

The herbicides were applied when the white horsenettle weed was at 3 to 4 leaf stage. Irrigations were given at intervals of 15 days and the plots were maintained free from other weeds. White horsenettle population was estimated at 30, 90, 180, 270 and 360 days after the herbicide application.

At 30 days, 98% control was obtained in Tordon 101 Mix at 20 L/ha and in Tordon 22K at 6 L/ha. In the rest of the treatments weed control ranged from 77 to 97%. At 20 days, 100% control was obtained in Tordon 22K at 6 L/ha whereas in the other treatment control ranged from 69 to 97%. Thereafter, the percent control decreased rapidly and at 360 days control of the weed was observed only at Tordon 22K 6 L/ha and 4 L/ha. The results indicated that Tordon 22K was better than Tordon 101 Mix. Addition of 2,4,5-T with Tordon 22K did not increase efficacy.

NOTE : (Rates of Tordon 22K and Tordon 101 Mix are based on commercial products but the rates of 2,4,5-T are on active ingredient. Authors.)

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EFFECT OF 2, 4, 5-T AND DIFFERENT FORMULATIONS OF 2, 4-D UNDER GRADED DOSES AND INTERVALS OF APPLICATIONS ON THE CONTROL OF *SOLANUM ELAEAGNIFOLIUM* CAV

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The efficiency of 2,4,5-T and different forms of 2,4,5-D on the control of *Solanum elaeagnifolium* was evaluated in a field trial conducted during 1973-75 at Peedampalli. The treatments comprised of 2,4,5-T (butoxy ethanol ester) and five different formulations of 2,4-D, namely : Sodium salt, ethyl ester (EC and WP), dimethylamine, and butoxy ethanol ester. An untreated check was included. The doses tried were 0.5, 1.5 and 2.5 kg/ha with two intervals of application at 15 and 30 days. The herbicides were applied as per schedule up to 375 days and the observations recorded at 30, 90 and 150 days after final application. During the period of the experiment a total of 25 sprayings for once in 15 days and 13 sprayings for once in 33 days were given.

Weed control was significantly superior in treated plots compared to the untreated check. At all stages there was no significant difference due to different doses. The percentage control of the weed ranged between 54 and 55 on 30th day, 40 and 54 on 90th day and 37 and 45 on 150th day after final application. There was no significant difference among the different intervals of application. Control of weed varied from 61 to 67% at 30 days 48 to 62% at 90 days, and 46 to 52% at 150 days due to 2,4,5-T and bifferent forms of 2,4-D. The differences were not significant. The results indicated that 2,4,5-T or any form of 2.4-D at 0.5 kg/ha applied at intervals of 30 days was sufficient for the control white horsenettle.

INFLUENCE OF CERTAIN ADDITIVES AND TIME OF APPLICATION ON THE EFFICIENCY OF PICLORAM AND SAN H 9789 ON THE CONTROL OF WHITE HORSENETTLE

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A field experiment was conducted at Peedamplli, Coimbatore district during 1974 to 1976 to study the effect of molasses, urea, and potassium nitrate on the efficiency of certain herbicides on the control of white hersenettle (Solanum elaeagnifolium Cav.) under fallow field conditions. The experiment was laid out in split-plot design with two herbicides and three times of application in the main plots. The sub-plot treatments included three additives at two doses each with a control (no additive).

The herbicides studied were picloram at 5 kg/ha and SAN H9789 at 15 kg/ha. Three times of application were before 8.00 A.M. at mid-day (12.00 noon to 1.00 p.m.), and after 5.00 p.m. The doses of additives were 3 and 5% of the spray fluid. The treatments were imposed to white horsenettle grown for 20 days. The spray solution was used at 600 litres per hectare.

The population of white horsenettle was estimated in the different treatments at 150, 450, and 750 days after application of herbicides. Picloram gave 100% control of white horsenettle up to 150 days and thereafter some regrowth occurred. At 750 days the regrowth was only 24% of the original population. The population in plots treated with SAN H9789 was highly variable and was 43, 45, and 88% of the original population, respectively, at 150, 450, and 750 days after application.

The effects due to the time of application and apditives were not significant. It may be concluded that the efficiency of picloram and SAN H9789 was not increased by the time of application and additives used.

CONTROL OF WHITE HORSENETTLE WITH PICLORAM AND BLACK POLYTHENE MULCH

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To study the combined effect of picloram and black polythene mulch a field experiment on white horsenettle (*Solanum elaeagnifolium* Cav.) was laid out at Peedampalli, Coimbatore district. Trial was conducted in randomized block design with three replications. Treatments consisted of the application of picloram at 5, 10, 15 and 20 L/ha with and without polythene mulch. An untreated control was also maintained. Mulches were provided for the respective treatments after the spraying of picloram. Weed counts were taken at monthly intervals.

Complete control of white horsenettle was observed at 60 days after spraying in all treatments. The untreated (control) plots had 153 plants per sq m. At 120 days mulched ptots continued to give weed-free condition while the plots treated with picloram at 5, 10, 15, and 20 L/ha had 21, 13, 8, and 2 plants per sq m. respectively. At 180 days weed control varied from 96 to 99% in mulched plots while it ranged from 48 to 99% in non-mulched treatments. Similar trend was observed at 270 days. After one year, control of weeds varied from 35 to 87% in mulched plots and 22 to 79% in non-mulched plots.

The study revealed that by applying picloram at 5 L/ha the white horsenettle weeds can be controlled completely for three months and with black polythene mulch for five months.

EFFECT OL 2, 4-D AND PICLORAM ON CEREAL CROPS INFESTED WITH WHITE HORSENETTLE

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Field experiments were conducted during kharif and rabi 1975 for the control of white horsenettle (*Solanum elaeagnifolium* Cav.) in cereal crops. In kharif the experiment was conducted in a field at Peedampalli and in rabi at Somanur in Coimbatore district of Tamil Nadu.

In the kharif season, the following treatments were tested: manual weeding (twice), 2,4-D (1 kg/ha), and picloram (0.25 kg/ha) were tried in maize (*Zea mays* L.), sorghum (*Sorghum vulgare* Pers.), finger millet (*Eleusine coracana* Gaerth.), and pearl millet or bajra (*Pendisetum typhoideum* L.). In the rabi season, pearl millet was not included.

In both the seasons, picloram gave significantly superior control of white horsenettle than both 2,4-D and manual weeding. However, maximum yield of maize grain was obtained in 2,4-D at both the centres (5069 and 5841 kg/ha at Peedampalli and Somanur, respectively), followed by picloram and manual weeding. Similar trend in yield was also observed in finger millet and pearl millet. In sorghum, differences in yield were not significant between the weed control practices.

EFFECT OF PRONAMIDE AND CHLORPROPHAM ON CUSCUTA IN NIGER

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Cuscuta (*Cuscuta chinensis* Damk.), a parasitic twining weed, is troublesome in niger (*Guizotia abyssinica* L. f. Cass.) cultivation. A study was undertaken at the

Central Research Station, Bhubaneswar, Orissa, from 1971-72 to 1973-74 with varying doses of pronamide and colorpropham for the control of *Cuscuta* in association with niger crop. Chlorpropham as granular formulation applied at 4 kg/ha to the surface of moist soil 6 days after sowing controlled *Cuscuta* most effectively with no injury to the germinating niger seedlings. Pronamide also showed promise for the control of *Cuscuta*. Pronamide at 1.5 kg/ha applied 15 days after germination of *Cuscuta* or 2 kg/ha at 20 days controlled *Cuscuta* infestation selectively without any phytotoxic effect on the niger crop.

SOME STUDIES ON OROBANCHE CERNUA LOEFL, A PARASITIC WEED ON TOBACCO IN INDIA

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Orobanche cernua Loef 1. is a serious root parasite on tobacco crop in India. It is endemic in the country, developing to epidemic proportions in certain years depending upon soil moisture and temperature. In the presence of its natural host, tobacco (*Nicotiana tabacum*), *Orobanche* seed germinates during the second week after planting tobacco, infects the tobacco roots during the third week, and develops underground sprouts of varying sizes till the fifth week. *Orobanche* shoots start emerging above ground from the sixth week onwards. Flowering is completed by the seventh week. Seed formation and capsule drying is completed by the eighth and ninth weeks. Stem drying commences by the tenth week and withering of stem and dehiscence of capsules are completed during the eleventh and twelth weeks. Thus, the life cycle of the parasite is completed in about 3 months after planting tobacco.

The diseased tobacco plants are stunted in growth and leaves start drooping as early as 8.00 A. M. gradually reaching complete wilting by 12.00 noon. The wilted leaves recover at night.

Loss in yield of tobacco has been estimated from 24 to 52% depending on the time and intensity of infection and availability of soil moisture.

Laboratory studies revealed that water inundation of *Orobanche* infested soil for 4 weeks greatly reduced seed viability.

The months of November to February peiod favoured maximum germination of *Orobanche* seeds, while minimum germination was obtained during April to June.

Forty-two crop plants were screened against *Orobanche* in pots and differentiated them into 4 groups based on their reactions. Among them, crop plants like sorghum (*Sorghum bicolor* Pers.) cowpea (*Vigna* sp.), wild mungo (*Phaseolus* sp.), chilli (*Capsicum frutescens* L.), Deccan hemp (*Hibiscus cannabinus* L.), black gram (*Phaseolus mungo* L.), and green gram (*Phaseolus aureus* Roxb). were found to induce abundant germination of *Orobanche* seeds, thus acting as promising trap crops for *Orobanche* control.

EXPERIMENTAL APPROACHES FOR STRIGA CONTROL

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Witchweed (*Striga* sp.) is an important phanerogamic parasite in sorghum (*Sorghum bicolor* L.) and pearl millet (*Pennisetum typhoides*) in the country. Two approaches have been made for the control of witchweed, namely : chemical cotnrol in the fieldand pot culture study to see the effect of trap crops on the incidence of this parasitic weed.

The field experiments comprised of preemergence application of atrazine (1 kg/ha) and 2,4-D (0.5 kg/ha); postemergence application of atrazine (0.5 kg/ha) or 2,4-D (1 kg/ha) at 30 days after sorghum planting; 2,4-D (0.5 kg/ha) at 70 days, and 2,4-D (0.5 kg/ha) or paraquat (0.75 kg/ha) at 90 days. These treatments were compared either singly or in combinations with two hand-weedings at 70 and 90 days after sowing.

Application of 2,4-D at 30 days gave a season long control of witchweed in respect of population and dry weight. However, the highest grain yield (6800 kg/ha) of sorghum (CSH-I) was obtained from the repeat application of 2,4-D at 30 and 70 days after sowing. Hand weeding at 70 and 90 days produced 6700 kg/ha of sorghum grains as compared to 5100 kg/ha of grain yield in untreated control.

The cost of repeat application of 2,4-D worked out to be Rs. 74/ha while the two hand-weedings cost Rs. 100/ha.

In the pot culture study the effect of trap crops [cowpea (*Vigna* ssp.), groundnut (*Arachis hypogaea* L.), linseed (*Linum usitatissimum* L.) cotton (*Gossypium* spp.) castor (*Ricinus communis* L.), and sunflower (*Helianthus annuus* L.)] was studied on witchweed emergence. No incidence of witchweed was observed in any one of these crops. However, it was observed that after harvest of these trap crops, sorghum raised in the pots were less affected by witchweed in those pots where cowpea, groundnut, linseed, and cotton (Hybrid 4) were grown.

A pot culture study was also made to assess the susceptibility or resistance of 28 sorghum genotypes. No one was cent percent resistant to withchweed, however, CS-3541 (male parent of CSH-5) had the lowest witchweed population followed by 303, 285, BS 81-3, 434, and SB-101.

THE SALVINIA WEED PROBLEM IN KERALA - FACTORS AFFECTING GROWTH AND METHODS OF CONTROL

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During the last decade *Salvinia molesta* (=*S. auriculata*) had spread to nearly 19000 ha of wetland paddy cultivated areas of Kerala, causing problems to agriculture,

water transport, irrigation, hydroelectric generation, public health, and sanitation. Manual or mechanical control is time and resource consuming and ensuring no complete eradication. Chemical methods have met with limited success. The cost of chemicals and the problem of pollution makes the method prohibitive. Biological methods have been the most unsuccessful so far. A more profitable alternative method would be utilization of the weed in industry or as a carbon source in fugal (yeast) protein manufacture.

Observations in natural habitates showed a maximum growth of *Salvinia* during July to November. The weed could be more economically destroyed manually or mechanically during March to May when growth is minimum and by chemical means during the more susceptible early flat phase of growth in June to July. The submerged leaves are absorptive. Destroying these leaves would reduce weed growth, Salt inhibits growth. *Salvinia* removed to saltish backwaters or sea connot survive long. The plants connot regenerate sexually. Destroying the vegetative bunds controls multiplication. *Salvinia* conserves dry matter at 650 g/sq m/year which can find industrial utility. It conserves water at 0.010451 cu m/sq m/day during summer from being lost through vaporization. In a hydroelectric reservoir like Kakki with a water spread area of 1700 ha a mat of *Salvinia* can conserve 27 million cubic meter of water during rainless months of December to May. This water so conserved can be utilized for generating an additional 45 million KWH electricity worth Rs. 4.5 million per year.

STUDIES ON THE CHEMICAL CONTROL OF WATERHYACINTH

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Waterhyacinth (*Eichhornia crassipes* Solms.) is a pestiferous and free-floating aquatic weed causing enormous losses and inconveniences in the irrigation and navigation systems of several parts of the world such as Africa, Australia, USA, Indonesia, and India. In Andhra Pradesh, very heavy infestation of this weed is observed in Kolleru lake and drains of Krishna, East and West Godavari districts. This weed can be successfully controlled by a combined spray of the Na salt of 2,4-D at 2 to 4 kg/ha +paraquat at 0.5 kg/ha.

GENUS TYPHA IN THE CHAMBAL COMMAND – ITS PROBLEM AND CONTROL

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Soil and Water Management Station, Kota, Rajasthan.

Two species of *Typha*, T. *anqustata* Bory and Chaub and T. *elephantina* Roxb., are commonly found in the Chambal Command area of Kota. Out of these species,

T. angustata is growing profusely in almost all the drainage ditches, irrigation channels, ponds and water-logged fields reducing the flow capacity of water and helping in rapid silt deposition. This weed also causes heavy loss of water as a result of evapotranspiration. More than 10,000 ha have been found to be infested by *T. angustata*.

To control this weed, several experiments were conducted during the years 1966 to 1976. These studies included preventive as well as mechanical, chemical, and biological control measures of the weed.

For the newly constructed drains or irrigation channels, spray of soil sterlant at 20 to 30 kg/ha during non-crop season proved very effective to check the establishment of Typha and many other weeds for more than a year. Lining of small channels was also found effective but needed timely removal of mud and silt.

Mechanical control by weed bucket or weed cutter appeared to be very expensive. A good road along the channels is very essential for this operation. Manual cutting of this weed if done systematically and timely was very economical and effective. In the areas of deep water, three under-water cuttings done at one month interval specially during rainy season killed 90 to 95% of *Typha*. The regrowth was less when the first cutting was done at flowering stage.

For the localities having shallow and (or) deep water, spraying with dalapon (25 to 30 kg/ha) in combination with 30 litres diesel and 1 kg detergent, amitrol (8 kg/ha), paraquat (1.2, 1.6 kg/ha), dalapon+amitrol (15+3 kg/ha), and amitrol+TCA (5+10 kg/ha) were very effective. Paraquat gave fast top kill but heavy regrowth started two months after spray. This herbicide may be advantageous if sprayed before the onset of monsoon.

In the water-logged fields, planting of paragrass was very promising in replacing *Typha* weed. If planting was done after cutting *Typha*, it completely replaced the *Typha* within 8 months. Also, the first harvest of the paragrass as a green fodder was obtained in a period of four months. In this way, the water stagnant areas would be brought back to greenary and obtain a fodder yield of about 10 to 13 t/ha.

Typha can also be controlled to some extent by utilizing it in making mats, huts, watersheds, rope for cots, and as a raw cellulosic material in paper industry. When used as a mulching agents in row crops it effectively controlled field weeds and also helped in conserving soil moisture.

STUDIES ON THE CHEMICAL CONTROL OF TYPHA

D. J. Chandra Singh and K. Narayana Rao

Weed Control Division, A.P. Agricultural University, Agricultural College, Bapatla, A.P.

Typha angustata Bory. is an aquatic weed belonging to the group of cattails. The plant grows to a height of 2 to 3 m producing minute seeds which are dispersed by

wind and a rhizomatus base which is responsible for its hardy nature and ability to resprout. The infestation of this weed is in an alarming situation in Nagarjuna Sagar Project area of Andhra Pradesh. Several herbicides were tried for the control of this weed. The best treatment was combined spray of the Na salt of 2. 4-D at 20 kg/ha + paraquat at 5 kg/ha which gave complete control of the plant with minimum resprouting.

TWO LESS KNOWN WEEDS IN RICE

K. CHANDRASEKHARAN and V. SRINIVASAN

Monsanto Chemicals of India Private Ltd., Caithness Hall, 310/311 Linghi Chetty Street, Madras 600 001.

Weed species numbering over 100 have been listed occuring in rice grown in dry and wet conditions. Information as to their relative importance (extent and density) is lacking. Among the broadleaf weeds, *Sphaeranthus indicus* and *Dopatrium* spp. are of concern to rice farmeres. The two less identified weeds occur in wet lands predominantly irrigated by canals and thanks.

For *Sphaeranthus* an average density of 80/sq m was recorded with some plots having as high as 200/sq m in Madurai district of Tamil Nadu. Density in Coimbatore, the other district surveyed, was lower (about 40/sq m). Occurrence was more frequent in Madurai than in Coimbatore. *Dopatrium* appeared to be of lesser importance from the point of view of occurrence as well as density. Its density in Madurai was 30/sq m and 60/sq m in Coimbatore. It was more frequent in Coimbatore than in Madurai.

14. BIOLOGICAL CONTROL OF WEEDS

SELECTION OF THE POTENTIAL ENEMIES FOR BIOLOGICAL OF WEEDS

S. S. LAL

Central Tuber Crops Research Institute, Trivandrum 17

Biological control of weeds is a natural consequence of nature's immutable law of keeping the balance of populations. To a certain degree, this method is an affective, economic, and easy method of pest control free from undesirable side effects. Several successful examples of biological weed control have proved beyond all doubts of its utility as well as its harmlessness to nontarget organisms. The aggressiveness of introduced weeds is often due to the absence of its natural enemies in its habitat. This situation justifies efforts in exploring the potentials and benefits of this natural method of control.

Some successes in the control of *Opuntia*, *Lantana* and *Eupatorium* in India are in favour of initiating further work against a few problematic weeds on a priority basis. Selection of potential insect enemies and their release are important and require utmost care, supervision, and evaluation. Determination of host-specificity based on starvation on negative-oviposition test has been improved by more systematic investigations including host-recognition test.

Due attention is required for the study of this natural method of control while formulating the future policy of weed control in India.

BIOLOGIGAL CONTROL OF WEEDS IN INDIA

(MRS.) MEERA GUPTA

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The development of resistance to pesticides and the hazards involved in their use has given impetus to research on other means of combating pests. Biological control of insects and weeds by their natural enemies offers a permanent solution for more satisfactory than chemicals, traps or other temporary measures. It is well known that weeds starve crops by robbing them of their nourishment. They are a serious menace and the cost of control by mechanical means and by herbicides are not only expensive but also not permanent.

In this paper, the status of control by biological agents on the following weeds is discussed : prickly-pear (*Opuntia vulgaris*), Lantana (*Lantana camara*), crofton weed (*Eupatorium adenophorum*), witchweed (*Striga densiflora*), nutsedge (*Cyperus rotunaus*), waterhyacinth (*Eichhornia crassipes*), waterferns (*Salvinia molesta*) (=*S. auriculata*), willow primrose (*Ludwigia abscendens*), alligatorweed (*Alternanthera philoxeroides*), carrot weed (*Parthenium hysterophorous*), and cocklebur (*Xanthium strumarium*).

Considering the importance of biological means of controlling pests, the Central Biological Control Station has been established in the campus of the Central Plant Protection Training Institute at Rajendranagar, Hyderabad, to undertake further work on the biological control of weeds, primarily Lantana and waterhyacinth. Control of insect pests of major crops is also undertaken at the Station.

15. NEW EQUIPMENT

DESIGN, DEVELOPMENT AND FIELD EVALUATION OF A HAND RAKE HOE WEEDER

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Adoption of high yielding, short duration varieties of paddy with higher doses of fertilizer poses serious problems of weed in upland. In line sown paddy, yield is comparatively much higher when weeds are controlled in the early stages (within 15-20 days) of sowing. Keeping this in view, a rake hoe was designed for removing the weeds (uprooting them while they are still very small) without pushing the soil in the sides on the small paddy plants. The hoe works quite satisfactorily in the field and, on an average, replaces 8-10 khurpi-man days. Its construction is simple. It is being prepared by the village artisans in Orissa. The tool costs only Rs. 6.00 per unit but it will be still cheaper when produced in bulk.

CONCEPT OF ULTRA LOW VOLUME SPRAYING OF HERBICIDES

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(No abstract.)

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16. ECONOMICS OF WEED CONTROL

ECONOMICS OF DIFFERENT WEED CONTROL METHODS IN TRANSPLANTED RICE UNDER GRADED DOSES OF NITROGEN

M. NARAYANASWAMY and S. SANKARAN

Tamil Nadu Agricultural University, Coimbatore-3

Studies were made in transplanted rice (*Oryza sativa* L. 'IR 20') during summer and kharif of 1975 in deep black heavy type and clay loam soils of wetlands at the Agricultural College, Coimbatore to work out the economics and to fix up the remunerative combination of nitrogen and weed control for the crop.

There were 32 treatment combinations with four levels of nitrogen (0, 60, 120, and 180 kg N/ha) in the main plots. The herbicide treatments, assigned as sub-plots in split-plot design, were as follows; granular (G) and emulsifiable concentrate (EC) formulations of butachlor (2 kg/ha), benthiocarb (1.5 kg/ha), and AC 92553 (1.5 kg/ha).

Among the levels of nitrogen, the comparative cost of cultivation was maximum at 180 kg N/ha and minimum for no nitrogen treatment. Among the weed control methods, butachlor (G) gave the maximum cost of cultivation while benthiocarb (EC) and AC 92,553 (EC) gave the minimum cost.

The highest net income of Rs. 3944 per ha was recorded under a combination of nitrogen 120 kg/ha and AC 92,553 (G) at 1.5 kg/ha during summer and Rs. 3617 per ha under a combination of nitrogen 180 kg/ha and AC 92,553 (G) at 1.5 kg/ha during kharif season.

The cost of production per kg of grain was minimum (Rs. 0.47/kg in summer and Rs. 0.51/kg in kharif season) under 120 and 180 kg N/ha during summer and kharif with the combination of AC 92,553 (G) 1.5 kg/ha in boch the seasons.

ECONOMISING NITROGENOUS FERTILIZATION IN CROPS THROUGH CHEMICAL WEED CONTROL

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Experiments have been in progress at Indian Agricultural Research Institute for working out the efficiency and economics of chemical weed control in relation

to the levels of nitrogenous fertilization in various crops such as wheat *(Triticum aestivum* L.), maize *(Zea mays* L.), paddy *(Oryza sativa* L.), sugarcane *(Saccharum officinarum* L.) and barley *(Hordeum vulgare* L.).

A field trial carried out with barley cv. Jyoti (rabi 1975-76) involved the application of methabenzthiazuron (0.70 and 1.40 kg/ha. pre-emergence) and 2,4-D (0.50 and 1 kg/ha, applied post-emergence 35 days after sowing barley). Three levels of N (0, 20 and 40 kg. N/ha.) were applied at sowing time. A weedy check and a weed-free check realised through repeated manual weeding were included in the experiment for working out the efficiency and economics of weed control under different fertility levels.

At all fertility levels, manual as well as chemical weeding increased grain production over the weedy check. Grain production under a low fertility levels (20 kg. N/ha) in the absence of weeds (manual or chemical weeding) was as high as that under the high level of nitrogen (40 kg. N/ha) in the presence of weeds (weedy check). Either 2,4-D or methabenzthiazuron, even at the lower dosage of 0.50 and 0.70 kg/ha, respectively, maintained the grain yield at a high level.

ECONOMICS OF CHEMICAL WEED CONTROL IN CROPS

V.S. MANI AND K.C. GAUTAM

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Crop production involves expenditures in terms of seed material, fertilizer, irrigation, pesticides and weed control operations. The various methods of weed control through human, animal and tractor powers and chemical energy are all useful to contain weed growth in crop fields. The acceptibility of these methods is determined by the effectiveness, the cost and the increased crop yields resulting from these inputs. Field experiments carried out at the Indian Agricultural Research Institute for the last one and half decades tested the comparative performance in regard to effectiveness, economics and increment in yield of chemical weed control compared with manual weeding in various crops such as direct-seeded and transplanted rice *(Oryza sativa* L), sorghum *(Sorghum bicolor* L.), maize *(Zaa mays* L.), wheat *(Triticum aestivum)*, sugarcane *(Saccharum officinarum* L.) soybean *(Glycine max merr.)*, peas *(Pisum sativum* L.) potato *(Solanum tuberosum* L.), *onion (Allium cepa* L,) and carrot *(Daucus carota* L.).

In all these crops it was observed that herbicide use for weed control was more profitable and less costly as compared to physical method of weeding. In almost all the crops the yield resulting from chemical weed control was comparable, if not more, with physical weeding but the cost involved in the chemical method (cost of the chemical plus application charges) was less by 30 to 50% compared with the expenditure incurred in manual weeding.

Other advantages of chemical weed control consist in (a) adoption of this practice at the proper time on an extensive scale, (b) more efficient utilization of the costly inputs such as fertilizer, water and pesticides and (c) affording full protection from the menacing weed growth to the high yielding and short duration crop varieties. In the case of crops requiring high levels of fertilizer and irrigation, great economy can be effected by the elimination of early weed competition through herbicide use.

ECONOMICS OF CHEMICAL WEED CONTROL IN FIELD CROPS

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Field experiments were conducted to compare the efficiency of herbicides with the conventional method of weed control at Tamil Nadu Agricultural University, Coimbatore. Crops like rice *(Oryza sativa* L.), bajra *(Pennisetum typhoides* L.), finger millet *(Eleusine coracana* Gaertn.) and maize *(Zea mays* L.) were studied for this purpose. The growth and yield of the crops under different methods of weed control were investigated. Economics of different weed control practices were worked out with reference to cost of weed control and the yield obtained. In rice var. IR-20, butachlor at 2 kg/ha. gave an additional net income of Rs. 420/ha. over conventional method.

In bajra, pre-emergence atrazine at 0.5 kg/ha. either alone or in combination with one late manual weeding was more remunerative than conventional hand-hoeing and weeding. In finger millet, pre-emergence nitrofen yielded an additional income of Rs. 238/ha. over two hand-weedings. Pre-emergence simazine at 1 kg/ha. in maize gave Rs. 230/ha. additional net income as compared to conventional method of two manual weedings for the crop.

ACKNOWLEDGEMENT

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2. Indian Council of Agricultural Research, New Delhi.
3. International crop Research Institute for Semi Arid Tropics, Hyderabad.
4. U.N.D.P. Project, CPPTI, Hyderabad.
5. Central Plant Protection Training Institute, Hyderabad.
6. All India Co-ordinated Rice Improvement Project, Hyderabad.
7. All India Co-ordinated Sorghum Improvement Project, Hyderabad.

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I. Donations for general purpose:

1.	University Grants Commission, New Delhi	Rs.	3000-00
2.	Government of Andhra Pradesh, Hyderabad		3000-00
3.	M/S. Andhra Pradesh Agro-Industries Corp. Hyderbad		1000-00
4.	Andhra Pradesh State Federation of Co-op. Sugars Ltd.		500-00
5.	The Alkali and Chemical Corp. of India Ltd.		1525-00
6.	M/S Agricultural & Industrial Corp. New York		757-00
7.	M/S. Monsanto Chemicals of India Pvt. Ltd.		500-00
8.	M/S. Sai Chemical International		500-00
9.	M/S. U.P. Agricultural Inputs Corporation, Lucknow		500-00
10.	M/S. Sandoz India Ltd.		155-00
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12.	Sri Hingorani, G. H. Bayer India Ltd., Bombay		200-00
13.	Sri K. Rajamani, CIBA Beigy of India Ltd., Bombay		200-00
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17.	Dr. Anderson, Canadian Expert, Dry Farming Project, (ICAR) Hyderabad		125-00
18.	Dr. Bibhas Ray-Farm Chemicals Ltd., Bombay		51-00
19.	Others donations		50-00
		Total Rs.	13513-16

II. Hosting the Lunch :

1.	M/S. Shaw Wallace & Company Ltd.	2000-00
2.	Dr. J.A. Lowe, UNDP Project, CPPTI	3000-00
3.	M/S. Hyderabad Asbestoes Cement Products Ltd.	2000-00
4.	The Andhra Bank Ltd.	2000-00
	Total Rs.	9000-00

III. Hosting the Tea :

1.	Staff, Dy. Director of Agriculture, Hyderabad	300-00
2.	M/S. Premier Irrigation Equipment Pvt. Ltd.	300-00
3.	M/S. Indian Farmers Fertilizer Co-op. Ltd.	300-00
4.	M/S. Union Carbide India Ltd.	300-00
5.	M/S. Bharat Pulverising Mills Pvt. Ltd., Bombay	300-00
6.	M/S. Mon santo Chemicals of India Pvt. Ltd.	300-00
7.	M/S. Mysore Insecticides Company	300-00
8.	M/S. May & Baker (India Pvt. Ltd.	300-00
9.	M/S. Cynamid India Pvt. Ltd.	300-00
10.	State Bank of Hyderabad	300-00
	Total Rs.	3000-00

Financial statement of local organising committee for Weed Science Conference/Workshop held at Hyderabad (January 1977)

RECEIPTS	Rs. P.	EXPENDITURE	Rs. P.
1. Delegate fee @ Rs. 20/- each for (215) members	4300-00	1. Catering	13609-00
2. Hostel accommodation rent	1275-00	2. Labour charges & overtime	1589-75
3. Donations for tea and lunch	12000-00	3. Stationary	3645-62
4. Advance paid by the delegates for the proceedings of weed science conference	825-00	4. 'Take it Easy' magazine	1520-00
		5. Entertainment & decoration	4190-53
		6. Hire charges	2291-00
		7. Telephone charges	650-00
5. Advertisements for proceedings.	*2000-00	8. Purchase of crokery etc.	922-75
		9. Fuel charges	1421-59
6. Donations for general purpose	13513-16	Total Rs.	**29840-46
Total Rs.	33913-16		

*Excluding the amount yet to be realised from some of the advertisements.

**Excluding the cost of paper & printing charges of proceedings, postage etc.