The Evolution of Weed Control as a Science*

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In all frankness we should admit that the Science of Weed Control did not evolve as a series of planned logical technical studies, each building upon the other until the magic point of being scientific had been reached. The evolution of weed control as a science took place at an agonizingly slow pace until the mid-century mark in the 1900's.

Certainly, we must give due credit to all of the innovative scientists and practitioners of the art of weed control who concerned themselves with weeds and plant growth regulators prior to 1950. In recalling the names of those who had the foresight to document the importance of weeds or who had the insight which caused them to work on key botanical aspects of plant behavior from our viewpoint, we will forever pay tribute to individuals such as F. W. Went, G. E. Blackman, W. G. Templeman, R. E. Slade, J. W. Mitchell, P. C. Marth, P. W. Zimmerman, A. E. Hitchcock, A. S. Crafts, and C. J. Willard. Certainly, each weed Scientist is entitled to make his own nominations of individuals who deserve to be in the weed control hall of fame. In spite of the great contributions of all the efforts of such workers the subject of weed control, in my opinion, had not evolved to the point that it could be classed as a science in 1950

One approach for studying the beginnings of weed control as a science is to examine the appearance of various herbicides without which weed control could not have attained the scientific status which it holds today. In this respect the development of 2, 4-D in the mid 1940's is without parallel for its impact in stimulating interest in the field of weed control. The mark was made when the extreme potency of postemergence 2, 4-D treatments to control selectively broadleaf weeds in narrowleaf crops was demonstrated and it was reinforced when the principale of selective pre-emergence weed control with this compound was demonstrated. The more or less incidental discovery of 2, 4-D as a herbicide followed by the release of knowledge about phytoactive carbanilates, especially isopropyl carbanilate (propham) from a United States governmental research program.

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The advent of 2, 4-D and propham in the 1940's nodoubt served as one sound reason why a number of industrial firms initiated programs designed to generate new effective herbicides to be revealed as a reasult of such efforts appeared in the early 1950's when the substituated *N*-phenly ureas, illustrated by 3-(*p*-chlorophenyl)-1, 1-dimethylurea (monuron), were relased. Subsequent to this a wide variety of new classes of chemistry have been discovered including the acetamides, the *s*-triazines, the anilides, and the pyridines. Within these major classes and other classes there have been continued discoveries of sub-classes of special imortance and much refinement has come by selecting specific examples within each class to represent the ultimate attainable favorable atributes for each particular sub-class of chemistry. The net result is that within the last twenty years a large number of distinctive new herbicides have become available each ot which is more or less suitable for a specific set of conditions. Each individual who has a technical interest in weed control is aware of the great impact which these products have had on world wide management of weed problems and of the exciting possibilities which lie ahead.

Before we examine the relationship of these new herbicide discoveries to the evolution of weed control as a science let us review what the reaction of the agricultural manager has been to these compounds. There are six relationships which are useful to place the adoption of herbicldes at the use level into perspective (Figure 1). Without examining specific values these relationships show that as time progresses the amount of manpower available for weed control decreases, the willingness of people to undertake the laborius tasks such as manual weed control decreases, and the efficiency of farm labor at such tasks decreases. As a result of these relationships there is an ever increasing cost of farm labour for weed control purposes. Under these circumstances one bserves an ever increasing use of herbicides. This increased willingness to adopt the herbicidal mechanism of weed control frequently is based on the increased availability of herbicides and their observed capacity to perform more efficiently and efficaciously than alternate techniques. Often the increased adoption is based upont he necessity of choosing the use of herbicides as an alternate to the termination of profitable production. The final relationship is that crop yield potential increases as a function of time as a result of greater technological inputs such as fertilizers, improved varieties, insect control, and disease control. The use of these greater inputes requires the prudent grower to provide effective weed control in order to protect his investments and herbicides frequently provide the only suitable means of providing such control. When experessed as a function of time on a relative basis the relationships shown in figure 1 are inexorable. They occur in every country in

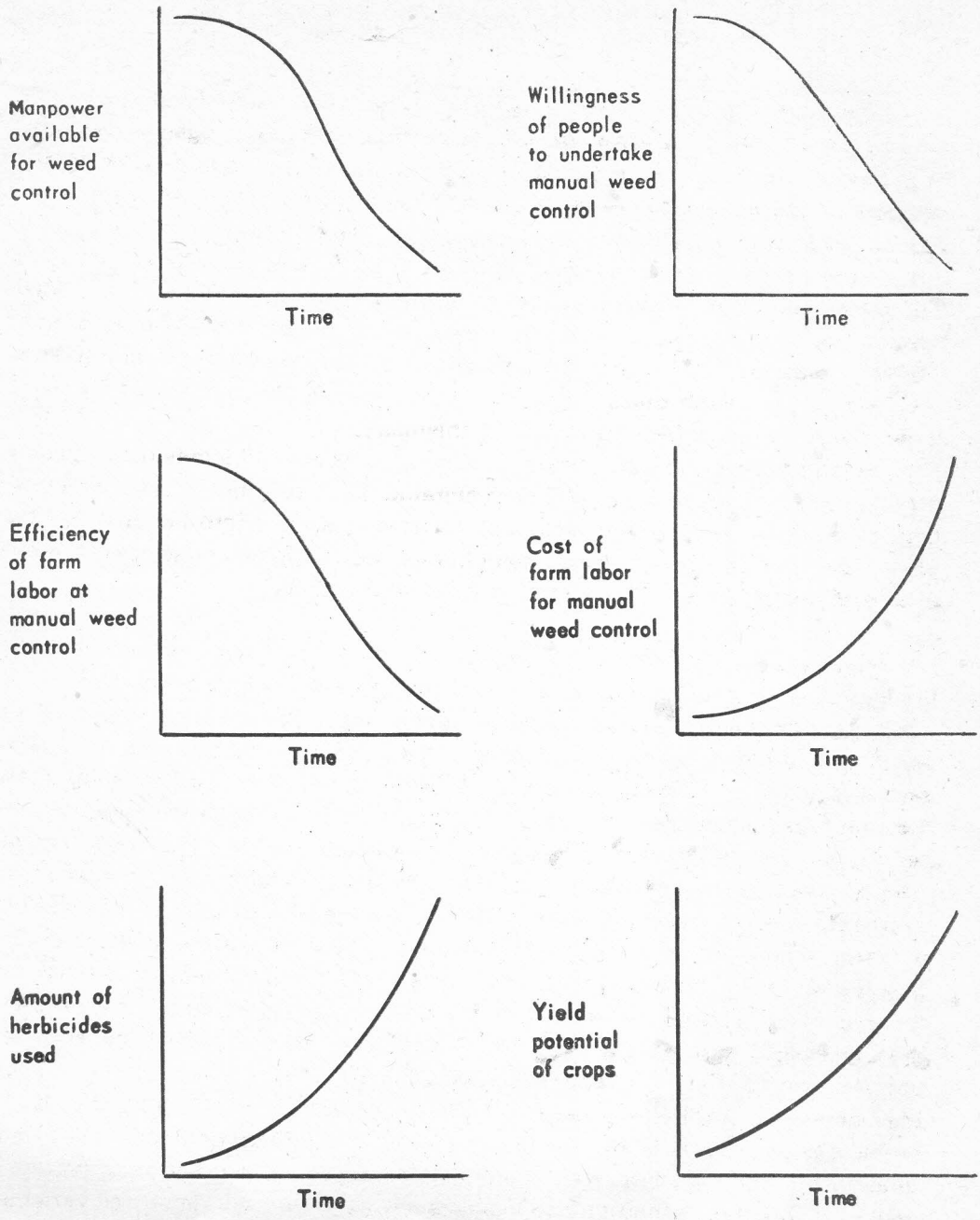

Figure 1. TYPICAL GENERALIZED CURVES SHOWING THE INCREASE OF HERBICIDE USAGE WITH TIME AND THE CHANGE IN OTHER FACTORS WHICH CAUSE OR MAKE POSSIBLE SUCH INCREASES IN HERBICIDE USAGE.

due course although the rate of change varies from province to province, from country to country and from crop to crop. These relationships are thoroughly established and are still unfolding in the highly industralized countries. There are unmistakable signs that these relationships are beginning to unfold at an ever increasing pace in the rapidly developing countries of the world. Surprisingly, the curves shown in Figure 1 can be observed even in those countries where labor is cosidered to be overly abundant. For the purposes of our consideration here, the important point is that forces are at work in the world which have led to the adoption of chemical weed control methods on a grand scale and that these forces will continue to work in this fashion.

Now, what does the observstion that many new herbicides have been discovered and widely adopted by faram managers in the last wenty years have to do with the development of weed control of a science? The fact is that these two occurrences have had a strong impact on the scientific nature of weed control. In the discovery and development process alone many new technical aspects are documented as may be seen by inspection of the proper publications, For example, highly sophisticated analytical techniques for a large number of new herbicides have been developed in conjunction with the introduction of these compounds. Furthermore, the discovery of a new herbicide which is unique in selectivity or some other respect provides yet another contribution of a scientific nature. The great interest of farmer groups in the practical aspects of using herbicides has encouraged public agencies to become more interested in herbicides. In some cases farmer groups have expressed their interest by encouraging appropriations of public funds for research and in many cases the commodity groups have provided direct finanicial or other types of support for scientific treatment of weed problems.

In addition to the farmer interest in weed control and the interest of industrial organizations there has been a continuing and ever increasing contribution to the science of weed control by those professional weed workers in the universities and in the public federal and provincial agencies. It Is primarily these workers, often with far less staff, administrative and financial support thanwas needed, who have provided the written documentation to estabiish weed control as a science. Perhaps the significant point is that farmers, public agency workers and industrial programs have all interacted in such a way as to collectively contribute to this establishment.

The scope of the field of weed science is not easily defined. It is similar to many well established disciplines in that the techniques and knowledge of

many diverse subject matter areas are employed. The theory of Weed Science embraces the pursuit, creation and understanding of all technology which relates to weeds and their control. In the narrow sense the key subjects embraced will include taxonomy, morphology, physiology, ecology, damages caused by weeds, methods of control, synthesis of herbicides, structure-activity relationships, enhancement of herbicidal action, mechanisms of herbicidal action, behavior of herbicidas in soil, plants and air, relationship of environment to control procedures, side effects of control procedures, application techniques, equipment used for control procedures and economics of control. In the broader sense other subjects which have a bearing on Weed Science will include Experimental Statistics, Toxicology, Organic Chemistry, Engineering (process and application techniques), Economics, Evolution, Genetics, Animal Ecology, Farm Management, Entomology, Plant Pathology etc. The practice of weed control is constituted by the practical application of control procedures developed from any of the above listed subject matter areas

While it is the conviction of many that weed control as a practice has outdistanced weed control as a science, it must not go unrecognized by any of us or by society at large that a good case can be made for weed control having arrived as a science during the past twenty years. How can this case be made? As far as I know their is no definite test which can be proposed to show whether the stage of being a science has been reached by any endeavor. But I would like to propose five key indicators in the present case although more no doubt can be described.

Indicator number one is that there are known many principles of weed control. Three such principles will be illustrated. Principle A concerns uptake and translocation of herbicides. A wide variety of herbicides applied to the root environment are swept into the plant across hydrophilic tissues and are carried to the shoot in the transpiratition stream where they are deposited in the shoot tissue as transpiration occurs. Some herbicides remain so deposited whereas others are partitioned further into the phloem tisssue and are moved with the assimilate stream. Herbicides applied to the shoot partition into the plant across lyophilic plant tissues are taken into the phloem and moved to a sink. Plants have characteristic capacities to modify organic chemicals in such a way that they may be more or less toxic than the original substance Principle B concerns herbicide behavior in soil. Herbicidies which reach the soil are degraded by soil micro-organisms at a rate which is controlled by pH, temperature, moisture, the presence of specific microbes, and the specific susceptibility of the particular molecular configuration to degradation. Detoxication

proceeds less rapidly in the lower, oxygen deficient soil horizons. Principle C concerns the bilogical control of weeds. When a biological control agent is introduced for the control of a given weed species the agent will typically be present in small numbers while the weed will be abundantly present. As the agent gains ascendancy over the weed, the former will increase in abundance while the latter decreases. This process will continue untill the abundance of the agent exceeds the capicity of the weed to sustain the agent, whereupon the agent will decrease in abundance followed in due course by an increase in the abundance of the weed. This cyclic pattren will continue with amplitudes which are controlled by the specific agent-weed interaction and the influence of environmental factors upon this interaction.

Indicator number two is that scientific organizations exist for the purpose of encouraging research and the exchange of ideas on weed control and related topics. These organizations must commonly occur at the national level in each country and meeting typically are held on a yearly pattern. However, there are notable examples of original conferences within a nation and of regional conferences which accomodate several nations. These conferences have a variety of specific purposes and distinctive characteristics. It is not necessary to list these organisations here but suffice it to say that they are adequate in number and scope that any weed worker who is so minded can certainly make the detailed case that they provide the basis for servicing a true science.

Indicator number three is that the priniciples of weed control have been and are regularly documented in technical publications such as journals, reviews and text books which especially devoted to the subject. The textbook and review documents embrace a rang of espects of weed control and many of them are periodicially updated as seems necessary. The publictions provide a basis for the publishing of descriptive scientific information and for the periodic review of such information; thereby leading to the establishment or modification of principles. Again, it is not considerd necessary to list the specific publications involved but they do provide a basis for making a strong point.

Indicator number four is that the knowledge set forth by indicators number one, two and three is being imparted to students in regular courses of instruction. Here the strongest case can be made for gradute programs becaus it is at this level that widespread detailed programs of study are utilized A young perfessional working towards his M.S. or Ph.D. degree in Weed Science may not be taking courses which are exclusively labeled "Weed Science" but they are courses selected to bear upon the subject. Undergradute programs designed

specifically for training in Weed Science are commonly available on a special arrangement basis, It is normal for each agricultural univerisity to have from one to three undergraduate weed control courses.

Indicator number five is that well trained scientistists are devoting their full time attention to the subject. This is certainly a valid indicator. Although precise figures are not available it is commonly known that full time weed scientists now must be counted in the hundred and if full time equivalents are counted we are dealing with an additional order of magnitude.

A convincing case can be made that weed control as a subject matter area has advanced to the point in the last twenty years that it rightfully may be classed as a science. Furthermore, the trends in accomplishments in this field are such that those who doubt the elevated status will certainly belong to a smaller group as the years go by.

In spite of the case which can be made for the status of the subject matter dealing with weeds, it is to the futrue and to the opportunity for service that we should look. The area has needed, justifies, and should be provided better organizational support. There is much that needs to be learned about the important economic weeds. What are they ? Where are they ? What is their denisyt and what kinds of damage are they doing and how much ? How effective are herbicides and other control procedures in solving the main weed problems ? What regulatory procedures (control vs eradication) are realistic based on technical knowledge ? What factors regulate success and what are the mechanisms of action and the mechanisms of failure ?

Man is engaged on a global basis an attempt to provide for himself. It is important for society at large that weeds should be dealt with effectively and it is for this purpose that Weed Science is important and should be recognised and developed fully.