Indian Journal of Weed Science **47**(3): 296–305, 2015

Problem weeds and their management in the North-East Himalayas

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Received: 20 June 2015; Revised: 31 July 2015

ABSTRACT

The North East Himalayan region recognized as one of the seven biodiversity hotspots of the world where Indo-Malayan, Indo-Chinese, and Indian bio-geographical realms have converged. Based on the elevation, climate and soil conditions, water availability and socio-economic aspects, different agro-ecosystems are prevalent in the north eastern India. However, the agro-ecosystems of the region can be broadly classified as i) *Jhum* agro-ecosystem, ii) Terrace land agro-ecosystem, and iii) Valley land agro-ecosystem. The major production ecosystems of the region are: rice, jute, sugarcane, tea, horticultural crops and forest and wetland. Shifting cultivation is a primitive agricultural system still practiced in some of the hill areas which is characterized by uniqueness of weed problem and its weed flora is primarily governed by altitude, slope of the land, *jhum*-cycle and fallowing, burning, rainfall, run-off, crops and cropping geometry and many other relevant issues like biotic interference coupled with climatic factors. The nature and severity of weed menace in different crop ecosystems vary according to the agro-ecosystems in which the crop is grown. Weeds are one of the main production constraints in all crop ecosystems. The common agronomic factors contributing to weed problems in different crops are inadequate land preparation, seed contamination with weed seeds, use of poor quality seeds, broadcast seeding in lowlands, use of overage rice seedlings for transplanting, inadequate water management, inadequate fertilizer management, mono-cropping, labour shortages for weeding operations, delayed herbicide applications and other interventions. In this article, the distribution of weeds and their management practices are reviewed exhaustively.

Key words: Himalayan region, Jhum cultivation, North-East, Weed

The Indian Himalayan Region spans over ten Indian states starting in Jammu & Kashmir and extending up to the North East Region (NER) of India. The Tibetan Plateau is to the north of this mountain range and the Indo-Gangetic Plain borders in the south. The north eastern part of this mountain is named as Purvanchal ranges which is parallel to Karakoram and Ladakh ranges. The NER is comprised of eight states which are characterized by diverse physiographic and climatic conditions. The region is surrounded by other countries like China, Bhutan, Bangladesh and Myanmar and a 'Chicken neck' corridor of 21 km length connects the region with the mainland India. The region in itself is a 'mini India' as a vast diversity in all aspects marks the region. The region has a unique ethnic diversity in customs, manners, value systems, attire along with the transitional diversity of the environment and biota. Apart from the valleys of Brahmaputra, Barak and Imphal, there are some flat lands in between the hills of Meghalaya and Tripura. The remaining two-thirds of the area is hilly terrain with valleys and plains in between the discreet hills. The altitude varies from near sea-level to about 7000 meters above MSL. A very high rainfall, undulating topography, a large number of rivers, tributaries and streams, high seismic activity and recent spurt in human activities like big construction works have resulted in natural problems like severe soil erosion and flood. Thus a fragile ecosystem has led to loss of biodiversity, loss of soil fertility, lower crop productivity and many other inevitable problems.

The climate of the region, in general, varies from warm humid sub-tropical climate with summer season hot and humid and winter season mild to extreme Alpine type. The region is classified under the humid-per humid agro-ecological zone with hot sub humid to humid and warm per humid eco-regions and soil type of alluvium-derived in valleys of Assam, brown and red hill in mountain ranges close to the Himalayas and red and lateritic in other north eastern hills (Sehgal *et al.* 1990). The NER has a total geographical area of 18.37 million ha of which about 55% is covered by forest. About 1.2 million ha land area is cultivated and about 2.2 million ha is not available for cultivation. The normal mean minimum and maximum temperatures vary between 18°C to

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32°C during summer months and 0°C to 22°C during winter months. Heavy fog is a common feature all over the high mountain areas throughout the year. The temperature in the snow-covered mountains is well below freezing point. It is marked by severe monsoons with very high rainfall and the highest annual rainfall of the world is received at Cherrapunji and Mawsynram in Meghalaya.

The Indo-Malayan, Indo-Chinese, and Indian bio-geographical realms have converged in this part of India and it is recognized as one of the mega biodiversity hotspots of the world. The region supports large number of plant and animal species and it is the 'center of origin' of many economically important plant species either cultivated or wild forms. There is a record of 40 out of 54 species of gymnosperms, 500 out of 1012 species of pteridophytes, 825 out of 1145 orchid species, 80 out of 90 rhododendrons, 60 out of 110 bamboo species and 25 out of 56 cane species and all these species belong to about 200 plant families out of 315. Thus the region is an open repository of phyllogenetically important biodiversity but gradually it has degraded and the existence of many species has been seriously threatened.

Major ecosystems and associated weed problems

Based on the elevation, climate and soil conditions, water availability and socio-economic aspects, different agro-ecosystems are prevalent in the north eastern India. However, the agro-ecosystems of the region can be broadly classified as : i) *Jhum* agro-ecosystem, ii) Terrace land agro-ecosystem, and iii) Valley land agro-ecosystem.

The *Jhum* agro-ecosystem or shifting cultivation is the major land use pattern of the tribes of the mountains and hills of the region. *Jhum* pattern is decided by the preference of the particular tribe, ecological conditions and *Jhum* cycle or the intervening gap between two cropping period in the same time (Kuswaha and Ramakrishnan 1987). It involves slashing and burning of natural vegetation followed by cultivation and then abandonment for the revegetation and regeneration (Ramakrishnan 1992). In some of the medium slopes of the hills, the tribal communities have replaced *Jhum* with terrace land cultivation which help *in situ* water harvesting, use of modern inputs and permanent nature of agriculture. Valley land agro-ecosystem is common in the plain areas and the scattered valleys among the hills of the region. This ecosystem offers an ample scope for cultivation of a variety of crops throughout the year with assured water supply.

Rice forms the main component in the *Jhum* lands and a variety of other crops including maize, millets like finger millet and foxtail millet, pulses, oilseed like sesame, fibre crops like cotton, spices like ginger, turmeric, chili and vegetables like cucurbits, colocasia, brinjal, tomatoes, beans, tapioca are grown in mixture in this ecosystem. Chatterjee *et al.* (2006) reported that there are as many as 35 crops of different varieties in the *Jhum*, the primal agricultural economy. At lower elevation of Meghalaya, Toky and Ramakrishnan (1981) recorded 13 different crops in mixtures in *Jhum* cultivation. Chatterjee *et al.*(2006) mentioned about the rich biodiversity in north-east India as evidenced by a number of plant species available in this region. The common weed flora of *Jhum* fields were listed as *Ageratum conyzoides*, *A. houstoniunum*, *Arundo donax*, *Borreria articularis*, *Erigeron canadensis*, *Chromolaena odorata*, *Hyptis suaveolensis*, *Imperata cylindrica*, *Lantana camara*, *Mikania micrantha*, *Osbeckia crinia*, *Panicum maximum*, *Phragmitis karka*, *Saccharum spont-aneum*, *S. procerum*, *Solanum* spp., *Thysanolaena maxima etc*. Neogi *et al.* (1992) observed that the number of weed species varied in different seasons in *Jhum* areas in the hills of Meghalaya; maximum number was observed during May to October during the rainy season and the number gradually decreased from November to February during the winter. The growth and vigour of crop plants coupled with climatic factors of a particular season played an important role in distribution of these weeds. The frequency of weeds like *Polygonum plebeium*, *Rotala rotundifolia*, *Pseudognaphalium luteoalbum*, *Hydrolea zeylanica*, *etc*. increased from winter to early summer till spring, whereas that of *Eragrostis unioloides*, *Galinsoga parviflora*, *Ageratum* spp., *Echinochloa colona* and *Ludwigia octavalvis* increased from late summer to winter. Altitude played a critical role in distribution of *Galinsoga parviflora*, *Rotala rotundifolia*, *Setaria pumila* and *Hydrolea zeylanica*. Besides altitude, other factors like slope, *jhum*-cycle, burning, rainfall, run-off, crops and cropping geometry and many other relevant issues govern the kind of weed flora in a particular *Jhum* field. High intensity of weeds is always noticed from the second year of cropping.

A study conducted by Barua *et al.* (2002) in the fields of pointed gourd crop under traditional shifting cultivation in the greater Silonijan area of Karbi Anglong district of Assam located in the north-eastern slope showed as many as 29 weed species during the cropping period. These weeds mostly belonged to Asteraceae, Poaceae and Cyperaceae families with seven, six and three species, respectively. Further, most of the weed species were exotic and migrated from tropical climate. *Ageratum houstonianum* was the most dominant species with maximum density, frequency and IVI value and it was followed by *Crassocephalum-Gynura* complex*;* these weeds were truly problematic in the field. Lower IVI values of perennial grassy weeds might be due to temporary suppression of growth by entire cultivation practices and smothering effect of the crop (pointed gourd). The authors also reported that most of the recorded weed species were common with the upland crops of the fertile plains of NER. The biotic interference coupled with climatic factors determine the life-form spectrum of *Jhum* areas and it was cited as the reason for much variation of the weed flora of *Jhum* fields of Karbi Anglong (Barua *et al.* 2002).

Intensity of weed problem in *Jhum* cultivation primarily depends upon the *Jhum* cycle (Cutting et al. 1959, Zinke *et al.* 1978 and Kushwaha *et al.* 1981). Fujisaka (1991) cited weed as a primary factor of lower rice yields in shifting cultivation and reduced system sustainability in northern Laos. The shorter *Jhum* cycle limits the resource build up in *jhum* lands. The crop-weed competition also intensified under shorter *Jhum* cycle besides hindering further regeneration of vegetation. Barua *et al.* (2002) also mentioned that the lowering down of *Jhum* cycle caused the domain of shrubby scrab jungles, that too of a few weedy species during the *Jhum* fallow period. Thus the weed community is maintained in a permanent state of arrested succession (Kushwaha *et al.* 1981). However, Saxena and Ramakrishnan (1984) reported that a *Jhum* cycle of 10-years kept the weeds under control through natural suppression by regenerated vegetation.

Keeping in view the severity of weed menace, weed management plays an important role in deciding productivity of crops in *Jhum* areas. Burning is an inevitable practice in *Jhum* cultivation and a good burn and right time of burning are very important at least for the first crop season. The *Jhumias* (*Jhum* farmers) do timely weeding manually for optimum yield especially during the months of June and July. Depending on the soil fertility status and weed intensity, farmers cultivate crops during the second year or even continue for longer time. As soon as the labour cost of weed management exceeds the cost of new site clearance, the *Jhumias* shift to a new site. While clearing a site for cultivation, the farmers cut the trees of the forest leaving tree stumps intact in their fields for a quick regeneration of the forest. Ramakrishnan (1992) justified this process by stating that it helped in proper weed management and the soil erosion in steep slopes is also checked due to a quicker coverage of the ground. The main practice of control in shifting cultivation is hand weeding 3-4 times during crop growth incurring higher labour cost and reduced net return (Rathore *et al.* 2012). The use of modern herbicides is also negligible in *Jhum* lands and some farmers are still using common salts for control of weeds especially the broad leaf weeds and sedges; the Asteracean weeds like *Ageratum houstonianum*, *Crassocephalum crepediodes*, *Gynura* spp., along with *Cyperus rotundus* were the most common weeds though many forest enduring seedlings also appear in *Jhum* fields. The extremely acidic soil condition in *Jhum* areas was cited as the reason for the good performance of common salt.

Fallowing is an essential part of shifting cultivation and three different types of fallow are found based on the gap period of the *Jhum* cycle and predominant vegetation type regrowing and covering the ground during the fallow period. These fallow types are forest fallow (20-25 years), bush fallow (6-10 years) and grass fallow (<5 years). Increasing population pressure and decreasing land availability have compelled the *jhumias* in NER to shorten the fallow period and now most of the *Jhum* areas could afford a fallow up to about 5 years only (grass fallow). *Imperata cylindrica* and *Saccharum* spp. were the predominant grasses; *Chromolaena odorata*, *Hyptis suaveolensis* and *Lantana camara* also appeared amidst the grasses which strengthened their population stand with the increase of fallow period.

Rice agro-ecosystem

Rice is the most important crop of all the states of the NER under terrace, valley and plain area agro-ecosystems. It is cultivated primarily in a rainfed production system with very meager area with irrigation facility. Rice ecosystems can be classified as different sub-ecosystems depending upon the land situations like upland, medium land, lowland and very lowland, accordingly a particular land situation decide the rice culture that is followed. The north east India being in primary centre of origin of rice, a vast diversity is observed in the crop with respect to morphology, growing habits, adaptability to environment, productivity and quality characters. Six species of wild relatives of rice are also reported to occur in Assam; theses are *Oryza meyriana*, *Oryza meyriana* var. *granulata*, *Oryza minuta*, *Oryza rufipogon*, *Hygroryza aristata*, and *Leersia hexandra* besides the doubtful species like *Oryza collina* and

Oryza sativa var. *plena* (Barua and Talukdar 2015). These wild rice types occur as weeds in rice fields depending upon the rice cultures. The total weed population comprised of 34.1% broad-leaved, 42.2% grasses and 23.6% sedges under puddled condition of sandy clay loam soil during rainy season (Singh *et al.* 2007). Ravisankar *et al.* (2008) reported that the wet seeded rice was infested with 51.5% grass, 30.9% sedge and 17.5% broad-leaved weeds. Barua and Gogoi (2002) enumerated as many as 134 weed species of upland direct seeded rice in Assam and classified according to life forms. The predominant weed flora of different rice ecosystems recorded in regular survey and numerous trials on weed management under All India Coordinated Research Programme on Weed Control (presently renamed as All India Coordinated Research Project on Weed Management), Assam Agricultural University, Jorhat is listed in Table 1.

Weeds are one of the main production constraints in any of the rice ecosystems (Adesina *et al.* 1994, Ampong-Nyarko 1996, Becker and Johnson 1999). Rodenburg and Johnson (2009) listed the common agronomic factors which contribute to weed problems in rice as inadequate land preparation, seed contamination with weed seeds, use of poor quality seeds, broadcast seeding in lowlands, use of overage rice seedlings for transplanting, inadequate water management, inadequate fertilizer management, mono-cropping, labour shortages for weeding operations, delayed herbicide applications and other interventions. The nature and severity of weed menace in rice vary according to the ecosystem in which the crop is grown. Weeds are a critical production constraint in the rainfed upland and unbunded medium and lowlands where water submergence is not done. Similarly, the deep water rice ecosystems is also affected severely by weeds that emerge along with dry-seeded crop prior to flooding and high water level and most of the weeds that are predominant can tolerate the water level. In the plains of the north-eastern region, the irrigated rice cultures during the pre-monsoon period as early *ahu* and *boro* is gaining popularity among the farmers due to higher productivity and less risk of flood under more sunshine hours during the period. But there is always a wetting and drying condition prevailing under such situation which encourages the emergence of weeds and their severe intensity posing

Table 1. Weed flora in different rice ecosystems

Weed	Weed	Reference
Nursery (boro rice or summer rice)		
Alternanthera philoxeroides	*Eleocharis acutangula*	Ann. Rep., (1999-2000, 2006-07),
Cyperus spp.,	*Monochoria hastata*	AICRP on Weed control, AAU,
Echinochloa crussgalli	*Sagittaria sagettifolia*	Jorhat
Echinochloa stagnina	*Scirpus* spp.	
Main field (boro rice or summer rice)		
Echinochloa spp.	*Ludwigia adscendens*	Ann. Rep., (1999-2000, 2006-07),
Eichhornia crassipes	*Polygonum* spp.	AICRP on Weed control, AAU,
Eragrostis unioloides	*Marsilea minuta*	Jorhat
Commelina diffusa	*Scirpus* spp.	
Ludwigia lini folia	*Physalis minima*	
Direct seeded upland rice (ahu or autumn)		
Ageratum houstonianum	*Cyperus rotundus, C. iria*	Ann. Rep., (1999-2000, 2000-01),
Alternanthera philexeroides	*Digitaria -Paspalum* complex	AICRP on Weed control, AAU,
Borreria aricularis	*Eleusine indica*	Jorhat
Cynodon dactylon	*Fimbristylis* spp.	
Ludwigia linifolia	*Melochia corchorifolia*	
Transplanted ahu (autumn)		
Aeschynomene indica	*Cyperus iria + Fimbristylis littoralis*	Ann. Rep., (2000-2001), AICRP on
Ludwigia linifolia	*Isachne himalaica*	Weed control, AAU, Jorhat
Polygonum glabrum	*Leersia hexandra*	
Echinochloa crusgalli	*Monochoria vaginalis*	
Melochia corchorifolia	*Scirpus* spp.	
Deep water rice (bao)		
Aeschynomene indica	*Hymanachne acutigluma*	Ann. Rep., (2000-2001,2002-
Alternanthera philoxeroides	*Oryza rufipogon*	03,2004-05) AICRP on Weed
Paspalum scrobiculatum	*Sacciolepsis interrupta*	control, AAU, Jorhat
Melochia corchorifolia	*Eichhornia crassipes*	
Eleocharis acutangulus, E. dulcis	*Hygroryza aristata*	
Echinochloa crusgalli	Weedy rice	

a major limiting factor of production. Uncontrolled weed growth causes yield losses to the tune of 28-74% in transplanted lowland rice, 28-89% in direct-seeded lowland rice and 48-100% in upland ecosystems in West Africa (Rodenburg and Johnson 2009). Weed problem of rice cultures in NER is as severe as in Africa and it is mainly because of very rich soil seed bank. A study at Jorhat, Assam recorded an emergence of about 12000-15000 and 4000-6000 numbers of weeds from the soil seed bank in rice-wheat and rice-rice sequence, respectively, even after fifth year in immigration controlled atmosphere (AICRPWC, AAU, Jorhat 2013-14).

There is a linear correlation between yield loss and weed population, however, beyond certain population limits, yield reductions become nearly constant due self competition among the weeds (Sridevi 2013). Like other crops, rice also faces maximum competition by weeds in its early growth stages. When the crop growth is only 2-3% during the establishment phase, the weeds already achieve 20-30% growth (Moody 1990). Researchers from different locations have reported a critical period of competition ranging between 40-45 days in transplanted rice (Govindarasu *et al.* 1998, Sathyamoorthy and Kandasamy 1998, Chinnusamy 2000, Tewary and Singh 1991, and Thapa and Jha 2002). Moorthy and Saha (2005) reported that the losses in grain yield of rice due to competition from weeds for a period of 30, 60 and 90 days were 17.7, 11.8 and 5.0%, respectively. Umapathy and Sivakumar (2000) found that the competition from grassy weeds, sedges and broad-leaved weeds in rice was in descending order. It was reported by Chauhan and Johnson (2010) that shoot competition between weeds like *Echinochloa* spp., *Ludwigia* spp. and direct seeded rice was more severe than their root competition and reflected on yield of rice; however rice grain yield was highly correlated with both above and below ground biomass of the weeds. The crop-weed competition was most severe in upland direct seeded rice and grain yield loss to the tune 76-78% due to unchecked weed growth was recorded (AICRPWC, AAU, Jorhat 2009-10). The plant characters like tiller number and leaf angle are more important for smothering of weed than plant height in upland rice. The findings of AICRPWC, AAU, Jorhat (1999-2000) showed that the variety *"IEI-15998"* recorded the highest tiller number (152/m^2) at 40 DAS, highest primary tiller angle (7.1^0), the lowest plant height of 67.6 cm and lowest weed dry weight but it recorded highest grain yield of 3.75 t/ha among the tested varieties.

Works carried out at AAU, Jorhat revealed that application of pretilachlor 0.75 kg/ha + safener + one hand weeding 30 DAS and butachlor 1.5kg/ha + one hand weeding 30 DAS resulted better weed control and grain yield in direct seeded upland rice as compared to other treatments. Time of sowing before or after pre-monsoon showers did not affect the density and dry weight of weeds as well as grain yield of rice. Different herbicides were compared in respect of performance in upland direct seeded rice and combination of oxyfluorfen 300 g/ha pre-emergence + 2,4-D 0.5 kg/ha post-emergence was found to be effective.

A two years trial during 2009 and 2010 showed higher grain yield in lowland rice under normal transplanting than SRI method. Among the weed management treatments, pretilachlor 0.75 kg/ha + mechanical weeding (paddy weeder) 30 days after transplanting resulted highest grain yield in rice and the increase was about 56% over weedy check (AICRPWC, AAU, Jorhat Centre 2009-10). During 2011 and 2012, pyrazosulfuron 20 g/ha + manual weeding 30 days after transplanting was as good as pretilachlor 1000 g/ha + Almix 4 g/ha in respect of weed control and grain yield in transplanted rice (AICRPWC, AAU, Jorhat centre 2011-12 and 2012-13). The threshold values of a few major weeds of transplanted rice were determined (AICRPWC, Jorhat Centre 2005-06 and 2013-14). Accordingly the values were 60/m^2 for *Echinochloa crusgalli*, 120/m^2 for *Monochoria vaginalis*, 140/m^2 for *Scirpus juncoides* and *S.maritimus*, 2/m^2 for *Ludwigia decurens* and *L. linifolia* and 70/m^2 for *Cyperus iria*. Beyond these threshold levels, there was significant reduction in grain yield of rice.

Jute agro-ecosystem

The hot and humid climate of the NER coupled with high rainfall during the summer season in which jute is an important crop of the valley regions encourages weed growth resulting in severe crop-weed competition (Saraswat 1999); yield losses may be up to 75 to 80% (Sahoo and Saraswat 1988); implying the need for judicious weed management. The major weed flora in the jute growing areas comprised of *Ageratum houstonianum*, *Alternanthera sessilis*, *Amaranthus spinosus*, *Axonopus compressus*, *Commelina diffusa*, *Cynodon dactylon*, *Digiteria setigera*, *Echinochloa colona*, *Eragrostis unioloides*, *Mikania micrantha*, *Murdania* spp., *Paspalum conjugatum*, *Spilanthes paniculata*, *Fimbristylis littoralis*, *Cuphea balsamona*, *Cyperus rotundus*, *Euphorbia hirta*, *Impatiens* spp. *etc*.

The weeds of jute could be effectively controlled by application of quizalfop-P-ethyl 60 g/ha at 15 days after emergence followed by one hand weeding 7 day after herbicide application (Anonymous 2010).

Suagarcane agro-ecosystem

Sugarcane is cultivated up to 183 m altitude from MSL in NER. Barua and Gogoi (1995) recorded as many as 48 species of common weeds in sugarcane fields of Assam belonging to 22 families and also observed 11 significant positive associations and 16 negative associations of weeds in their phyto-sociological behaviour. A reduction of cane yield in the range of 12 to 72% in sugarcane due to unchecked weeds has been estimated. The severity of weed infestation in this crop is primarily due to its planting with a wider row spacing, very slow initial growth (about 30-45 days to complete germination and another 60-75 days for developing full canopy cover), abundant water and nutrient supply to the crop, very little preparatory tillage in ratoon crop allowing the already established weeds flourish well. Among the weeds, *Mikania micrantha*, *Ageratum hostonianum* and *Borreria articularis* were found to occur throughout NER as the most common and problematic weeds of sugarcane. Barua and Gogoi (1995) recorded *Setaria-Paspalum-Panicum* complex along with *Borreria articularis* in Barak valley and *Digitaria-Paspalum* complex in the hill zone as the predominant weed groups in this crop. The average weed dry weight may go up to the tune of 250 g/m^2 in summer and 190 g/m^2 in monsoon. Unlike upland rice, the prevalence of perennial weeds is several times more than annual weeds.

The problem of weed menace in sugarcane can be efficiently managed with pendimethalin 1.0 kg/ha in sugarcane + cowpea intercropping (Anonymous 2010).

Tea agro-ecosystem

The environmental condition of the NER is very ideal for production of a wide range of plantation crops, *viz.* tea, coffee, rubber, coconut and arecanut. The plantation crops altogether occupy 8.97% of the total cultivated area of the region which is about 3.33 lakh ha and among these crops, tea alone accounts for 3.18 lakh ha (95.5%). In the middle of nineteenth century, tea was introduced in Assam and Tripura and the area expanded in a short time; the crop has further spread to more of non-traditional areas of the region.

Besides the one thousand plus corporate tea gardens in this region, tea has also found a place as a farmer's crop since the end of last century when the concept of small tea growers came into existence. At present, about 117 thousand acres of land (47,348 ha) is under small tea sector; 87% of the small tea farmers have less than 3 acres (1.21 ha) of plantation, further, 67% of such gardens are less than 10 years old (Barua and Nath 2015). Average productivity of the small sector is about 2379 kg made tea per ha (KMTH) while the average productivity of the gardens of corporate sector is about 1860 KMTH. The higher productivity in smaller tea gardens might be due to smaller holdings and thus a better individual bush care which is not possible in a large garden besides tea plantation is also done in marginal areas in a bigger garden.

Weeds are counted as one of most important critical factors limiting optimum productivity in tea plantations. Intensity of weed problem is primarily governed by agro-climatic conditions, type of tea culture, general management conditions, specific weed management schedule *etc*. Dominant weed flora in young tea in Assam comprises of *Scoparia dulcis*, *Borreria articularis*, *Mimosa pudica*, *Hyptis suaveolensis*, *Axonopus compressus*, *Cynodon dactylon*, *Paspalum conjugatum*, *P. longifolium*, *Ageratum hostonianum*, *Sida acuta*. Weeds like *Mikania micrantha*, *Paspalum* spp., *Borreria articularis*, *Gynura bicolor, Axonopus compressus*, *Cynodon dactylon*, *Hyptis suaveolensis*, *Melastoma malabathricum, Osbechia nepalensis, Sida acuta, Chromolaena odorata, Lantana camara, Mimosa diplotricha, Dicanthium* spp. mostly dominate in mature tea. In the seed *baris* (orchard) besides other terrestrial weeds, a parasitic weed, *Loranthus longifolius* has been noticed at many places. The organic tea cultivation is gaining popularity in recent times; the nature of weed is also changing. Other than the common weeds of tea, prevalence of several perennial grasses and bushy broadleaved weeds like *Urena lobata*, *Triumpfeta rhomboidea*, *Solanum torvum,* perennial climbers like *Lygodium flexuosum, L. japonica* and sedges belonging to *Carex, Scleria* etc. have also been recorded in organic tea plantations.

Like other agricultural and horticultural crops, tea also needs an adequate agronomic care for a high and sustained productivity. Uncontrolled weed growth can cause a loss of productivity to the extent of 50-70% in tea. Productivity losses due to weeds may accrue due to severe competition for growth factors, restricted branching and frame development, harbouring of disease pathogens and pests as alternate hosts, less plucking efficiency, contamination of plucked shoots, and water stagnation in the drainage outlets. Weed infestation and consequent damage to the crop is more severe in young tea up to two years before canopy closure and during the period of pruning at an interval every three to four years. Weed competition began at 8 weeks after weed emergence in tea plantation and was detrimental to young tea at 12 weeks or later (Prematilake *et al.* 2004). A period of 18 weeks of uncontrolled weed growth in young tea was enough for plant mortality. The period between April to September is very critical from tea productivity point of view and the season coincides high rainfall and temperature which provides a very favourable condition for weed growth and resultant menace for the crop. Different methods are used individually or integrated for an effective weed management in tea plantations. However, the use of herbicides still remains cheap and effective means for weed control. Model weed control schedules with combination of pre-emergence and post-emergence herbicides have been developed and followed. But option of herbicides (PPFs) in tea is very limited as number of herbicides registered for tea as per gazette notification of Ministry of Agriculture S.O. 2486 (E) dated 24th September, 2014 is few comprising only glyphosate 41 SL and 71 SG, glyphosate ammonium salt 5 SL, glufosinate amonium13.5 SL, oxyfluorfen 23.5 EC and paraquat dichloride 24 WSC. Cases of herbicide tolerance by specific weeds have been observed (AICRPWC, AAU, Jorhat 2006-07). Herbicide rotation, integrated weed management, vigilance on developing resistant ecotypes is some of the useful means to restrict herbicide resistance build up in weeds. Studies on herbicide residues till now have not indicated any residues above detectable level in context of standard herbicides in plant, soil or water in tea plantations. Developing clones with resistance to non-selective herbicides as in the case of some agricultural crops is also promising in tea.

A new challenge has emerged in recent time in regards to weed management in organic tea plantations. An effective and economically sound method is still eluding the organic tea planters.

Horticultural crops agro-ecosystem

Difficult terrain, wide variations in slopes and altitudes, land tenure systems and indigenous cultivation practices mark the North-East region of the country. The cereals dominate the rainfed hill ecosystem, dependence on horticulture as an alternative source of income is also remarkable. Banana, potato, vegetables, ginger, turmeric, citrus, apple are some of the major agro-ecosystems in the North East Himalayan region.

The predominant weeds of banana are listed in table 2 and these comprised of *Ageratum-Borreria-Commelina* combinations coupled with *Mikania micrantha*, of late *Mimosa diplotricha* throughout the states of Assam, Manipur, Tripura and foothills of the other hill states. Banana plantation is permanent and an ideal microclimate in these plantations favourably increases the weed problem and competition with the crop hampering its growth and productivity. Frequent inter-cultural operations and mulching are generally followed for weed control in addition to manual weeding operations. Further, growing an inter crop of cowpea and incorporation in soil followed by hand weeding at 30 days interval up to shoot stage help in managing the weed problem. Application of diuron 3 kg/ha or paraquat 1.5 kg/ha can check the weed problem in this crop (Anonymous 2005).

Pineapple is a major fruit crop of the entire north east India with an average productivity higher than the national average (15.3 t/ha). However, the crop cycle is long and it confronts severe competition from weeds. The weed flora has been surveyed under AICRP on Weed Control, and the dominant ones are presented in Table 2.

Vegetables are popularly grown by the farmers of north east India but various problems including seasonal and perennial weeds cause extensive damage to the crops and limit the productivity to a low level.

Table 2. Problem weed flora in horticultural crop-ecosystems of NER

Name of weed	Crop			
	Banana	Pineapple	Vegetables	Turmeric, ginger, chili
Ageratum houstonianum	v	v	v	v
Borreria articularis	v	v	v	v
Commelina diffusa	v			v
Mikcania micrantha	v	v	v	
Mimosa diplotricha	v			
Eleusine indica		v	v	
Digiteria setigera		v		v
Paspalum longifolium		v	v	
Chromolaena odorata		v		
Saccharum spontaneum		v		v
Imperata cylindrica		v	v	v
Cynodon dactylon			v	v
Panicum repens			v	v
Cyperus rotundus			v	v
Gnaphalium polycaulon			v	v
Colocasia esculenta			v	

Potato, cauliflower, cabbage, brinjal, coriander, tomato, okra and French bean are some of the very important commercial vegetables of the region. These crops are infested by numerous weeds; their type and intensity vary depending upon season, crop and management approach. The combination of broadleaved species like *Ageratum-Leucas-Gnaphalium* occur everywhere besides the weeds listed in table 2. Farmers mostly adopt cultural, manual or mechanical methods of weed control. Various herbicide recommendations have been made from AAU, Jorhat for different vegetable crops but they are yet to reach the field level in a big way.

Turmeric, ginger and chili are the most important spice crops of the region having large diversity. The region has enough surplus production and thus large scale exports are made from these states. Higher productivity and better quality of the produce could help the farmers to earn more from these crops. Adequate weed management is a priority in this respect. A number of grasses, broadleaved and sedges infest these crops and offer severe competition. Ginger and turmeric are long duration crops and a sustained management of weeds is very important. An integrated weed management approach involving chemical, cultural and mechanical methods will be cost effective as well as efficient in checking the weed problem for longer period. Pre-emergence application of herbicides like metribuzin 700 g/ha, atrazine 750 g/ha and pendimethalin 1000 g/ha or oxyfluorfen 20 g/ha followed by two hand weeding at monthly interval up to 60 days after planting has been found promising.

In recent years, infestation of *Parthenium hysterophorous* in citronella plantations has vigorously increased in Golaghat, Karbi Anglong and Dima Hasao districts of Assam and Dimapur district of Nagaland.

Forest and wetland ecosystems

Weeds are always a matter of concern in plantation forests, more particularly in first few years of their plantation. A good number of herbs, shrubs and climbers of invasive nature are the problem causing weeds, which vary from place to place and their pattern of dominance is governed by associated vegetation, availability of seeds and sources, and above all the elevation of the site. The most common sub-climax forming weeds amongst them are *Chromolaena odorata* in foothills and plains, whereas *Lantana camara* in lower elevations, and *Solanum xanthocarpum* and wild *Saccharum* spp. above the zone of *Lantana*. In disturbed lands, *Mikania micrantha* and *Imperata cylindrica* are the most common weeds all along the North Eastern Himalayan region except ice covered peaks in Arunachal Pradesh. Several Asteracean plants and species mostly belonging to *Borreria, Ficus* and reed grasses, along with climbers mostly belonging to Convolvulaceae and Fabaceae usually offered good competition to the newly planted seedlings of timber plants. Different climbers belonging to *Mukuna, Ipomoea* and *Merremea* were the problem weeds of teak and *sal* forests of this region.

In natural forests, the seriousness about weeds perhaps developed along with the problem created by the thorny and climbing straggler *Mimosa diplotricha* in the Kaziranga National Park. Since its appearance in around 2006, the weed is creating havoc in this park, by heavy smothering of associated vegetation, debarring wild animals from free grazing and passage besides cleverly escaping all kinds of mechanical and cultural management efforts taken up by the forest managements. Cutting and burning of *M. diplotricha* in the winter in the park area have damaged the grassy vegetation rather badly and encouraging its seed germination immediately after burning. Presently, this invasive weed has spread to newer areas, including Rajib Gandhi National Park, Assam many forests and non-forest areas of Arunachal Pradesh, Assam and Nagaland, and nearby settlement areas and crop fields. Consequently, another problematic and thorny invasive weed species, *Rosa bracteata* has also been found as newly introduced in the wetlands of Kaziranga National Park (Barua *et al.* 2014).

Mikania micrantha is another threat for the forests of Assam, mostly infesting the forest edges and open forests. Because of its excessive growth, the climber often covers the ground vegetation in the slope-lands, smothers the trees, bamboos and shrubby bushes, along the secondary forests and the edges of primary forests. Its smothering effect causes significant deterioration of the forest ecosystem and thus expansion of degraded area along the edges of primary forests; the ground vegetation in such damaged forest-lands is seen changing remarkably because of increasing predominance of other invasive weeds like *Chromolaena odorata, Hyptis suaveolensis, Lantana camara, Sida acuta,* etc. and several grasses belonging to *Cyrtococcum, Digitaria, Oplismenus,* etc. permanently replacing the autochthonous species. Thus, the smothering effect of *Mikania* not only triggered the shift of the indigenous vegetation of forests, but also seriously disturbed the food webs and micro-environments for faunal elements as well as opens up possibilities for human encroachment into the forest land as pioneer invader, in other words a driver species (Barua *et al.* 2013).

The riverine grasslands are another flagship vegetation of this region, more particularly of the Brahmaputra valley of Assam. This grassland is conserved by forest management machineries as these forest patches are the major source of food for the herbivores and birds and insects, which play an important role in energy flow system in the complex food web. These grasslands are usually subjected to partial burning during winter as a part of their management. Annual burning also destroyed its associated weed flora. Stumps of certain big trees, however, developed naturally because of annual burning or overgrazing, create trouble three to four years after their development, thus causing serious depletion of grasslands. *Oroxylum indicum, Dillenia pentagyna* and *Bombax ceiba* are such tree weeds in Manas Wild Life Sanctuary, Nameri Wild Life Sanctuary and many other forest areas. Out of these trees, the invasive migrants like *Mimosa diplotricha, Rosa bracteata, Mikania micrantha etc*. have also been recorded as serious weeds in several forest based grasslands. *Ludwigia peruviana*, the villous bush with tremendous seed production ability is one of the latest additions to this list, first sighted in the Dhansiri catchments of Assam and adjoining Nagaland. Satellite populations of this weed have also been developed in the eastern catchment of Kopili River, in and around the Lumding Reserve Forest and a few other districts of Brahmaputra valley.

Wetland of non-forest areas play very important role in nesting many indigenous and migratory avifauna and their foods, fishes and herpetofauna, leaches and reptiles, aquatic and semi-aquatic vegetation and ideal atmosphere for cultivation of deep water paddy, and other water-crops. Amongst the weeds, which damage the ecosystem are nothing but some invasive species, over-population of which have caused discomfort and harm to this ecosystem. *Mikania micrantha, Eichhornia crassipes, Ipomoea carnea*, several *Polygonum* species *etc*., parasites like *Cuscuta reflexa* and *C. campestris* and grasses like *Saccharum spontaneum* and *Leersia hexandra* have been recorded as serious weeds in majority of wetlands of NER.

REFERENCES

Adesina A, Johnson DE and Heinrichs EA. 1994. Rice pests in Ivory Coast, West Africa-farmers perceptions and management strategies. *International Journal Pest Management* **40**(4): 293-299.

AICRPWC. 1999-2000. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2000-01. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2002-03. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2004-05. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2005-06. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2006-07. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2009-10. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2011-12. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2012-13. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

AICRPWC. 2013-14. *Annual Report*. All India Coordinated Research Programme on Weed Control, AAU, Jorhat, Assam.

Ampong-Nyarko K. 1996. Weed management in rice in Africa, pp. 183-191. In: *Weed Management in Rice* (Eds. Auld BA and Kim KU), FAO, Rome.

Anonymous. 2005. *Package of practices- Horticultural Crops of Assam.* Assam Agricultural University, Jorhat. 4 p.

Anonymous. 2010. *Package of Practices Meeting for Kharif Crops of Assam.* Assam Agricultural University, Jorhat.

Barua IC, Barua KN and Gogoi AK. 2002. A study on the weed flora of pointed gourd fields under shifting cultivation in Assam. *Indian Journal of Weed Science* **34**(1&2): 104-109.

Barua IC, Deka J and Devi M. 2013. Invasive weeds and vegetation dynamics in Assam, pp 166-170. In: *Proceedings 24th Asia-Pacific Weed Science Conference* (Eds. Baker B, Kurniadie HD and Tjitrosoedirdjo S). APWSS, WSSI and Padjadjaran University, Bandung, Indonesia.

Barua IC, Devi M, Deka J, Vasu NK and Sarmah R. 2014. Invasiveness of wild *Rosa* in Kaziranga National Park,p. 61. In: *Proceedings of Biennial Conference*, Indian Weed Science Society, 15-17 Feb, ISWS and DWSR, Jabalpur.

Barua IC and Gogoi AK. 1995. Phytosociological studies of sugarcane weeds in Assam. *World Weeds* **2**: 107-115.

Barua IC and Gogoi AK.2002. Biodiversity of weed flora in upland direct seeded rice ecosystem in Assam, pp 108-116. In: *Biodiversity of Assam and its Conservation* (Eds. Bhattacharya MK, Dutta Choudhury and Mazumdar PB). Assam.

Barua IC and Talukdar PK. 2015. Assam's plant diversity conservation and utilization,pp. 269-298. In: *Agriculture in Assam* (Ed. Mishra P and Bhattacharjya A), Assam Agricultural University.

Barua Subhash C and Nath JC. 2015. Plantation crops of Assam-Conservation and Utilization, pp. 189-211. In: *Agriculture in Assam*. (Ed. Mishra P and Bhattacharjya A), Assam Agricultural University.

Becker M and Johnson DE.1999. Rice yield and productivity gaps in irrigated systems of the forest zone of Cte d'Ivoire. *Field Crops Res*, **60**(3): 201-208.

Chatterjee S, Saikia A, Dutta P, Ghosh D and Worah S. 2006. Review of biodiversity in North East India. *Background paper No.* 13, WWF, Delhi, India. p 45.

Chauhan BS and Johnson DE. 2010. Relative importance of shoot and root competition in dry competition in dry seeded rice growing with jungle rice and *Ludwigia*. *Weed Science* **58**: 295-299.

Chinnusamy C, Kandasamy OS, Sathyamoorthy K and Chandrasekhar CN. 2000. Critical period of crop weed competition in lowland rice ecosystems. In: *Proceedings of State level seminar on Integrated Weed Management in new millennium,* Ratnagiri, Maharashtra, 27-28 Feb, 2000.

Cutting CV, Wood RA, Brown P and Ambrose BB. 1959. Assessment of fertility status and the maintenance of productivity of soils in Nyasaland, pp. 817-824. In: *3rd International African Soils Conference,* Dalaba.

Fujisaka S. 1991. A diagnostic survey of shifting cultivation in northern Laos: targeting research to improve sustainability and productivity. *Agroforestry systems* **13**: 95-109.

Govindarasu R, Rammohan J, Ramamoorthi N and Hanifa AM. 1998. Direct seeding- a best substitute for transplanted rice cultivation in future. *Kisan World* **25**(11): 20-21.

Kushwaha SPS, Ramakrishnan PS and Tripathi RS. 1981. Population dynamics of *Eupatorium odoratum* L. in successional environments following slash and burn agriculture (*Jhum*). *Journal Applied Ecology* **18**: 529- 536.

Khuswaha SPS and Ramakrishnan PS. 1987. An analysis of some agro-ecosystem types of north eastern India, pp. 161-168. In:. *Proceedings of Indian National Science Academy*, B53 No.2.

Moody, K. 1990. Post planting weed control in direct-seeded rice. In*: Proceedings of Rice Symposium,* MARDI, Penang, Malayasia, 25-27 September, 1990.

Moorthy BTS and Saha S. 2005. Studies on crop weed competition in rainfed direct-seeded lowland rice (*Oryza sativa* L.). *Indian Journal. of Weed Science* **40**(3-4): 112-116.

Neogi B, Dey BP and Barua IC. 1992. Distribution pattern of some dominant weeds of East Khasi hills, Meghalaya. *Journal of National Botanical Society* **46**: 15-20.

Prematilake KG, Froud-Williams RJ and Ekanayake PB 2004. Weed infestation and tea growth under various weed management methods in a young tea (*Camellia sinensis* (L.) Kuntze) plantation. *Weed Biology and Management* 4: 239-248.

Ramakrishnan PS. 1992. *Shifting Agriculture and Sustainable Development: An Interdisciplinary Study from North-Eastern India.* Parthenon Publ. Group, Carnforth, U.K.

Rathore SS, Krose N, Naro M, Shekhawat K and Bhatt BP. 2012. Weed management through salt application: An indigenous method from shifting cultivation areas, Eastern Himalayas, India. *Indian Journal of Traditional Knowledge* **11**(2): 354-357.

Ravisankar N, Chandrasekaran B, Raja R, Din M and Chaudhari SG. 2008. Influence of integrated weed management practices on productivity and profitability of wet seeded rice (*Oryza sativa*). *Indian Journal of Agronomy* **53**(1): 57-61.

Rodenburg J and Johnson D E. 2009. Weed management in rice-based cropping systems in Africa. *Advances in Agronomy* **103**: 149-218.

Sahoo KM and Saraswat VN. 1988. Magnitude of losses in the yields of major crops due to weed competition in India. *Pesticide Information* **14**: 2–9.

Saraswat, V.N. 1999. Weed management in jute and jute based cropping system, pp. 193–200. In: *Jute and Allied Fibres: Agriculture and Processing* (Eds. Palit P, Pathak S and Singh DP). Central Research Institute for Jute and Allied Fibres, Barrackpore.

Sathyamoorthy K and Kandasamy OS. 1998. Critical period of crop weed competition in different rice culture (lowland transplanted and wet seeded rice). In*: Summary and Research Achievements-1998*. AICRPWC (ICAR), Coimbatore Centre, TNAU, Coimbatore.

Saxena KG and Ramakrishnan PS. 1984. Patterns of herbaceous vegetation development and weed potential under slash and burn agriculture (Jhum) in north-eastern India. *Weed Research* 24: 137-144.

Sehgal JL, Mandal DK, Mandal C and Vadivelu S. 1990. Agro-ecological regions of India. Technical Bulletin, NBSS Publ. 24, 73 p.

Singh P, Singh P and Singh SS. 2007. Response of aromatic rice (Pusa Basmati!) to establishment methods, fertility levels and weed management practices. *Indian Journal of Weed Science* **39**(1&2): 32-35.

Sridevi V, Jeyaraman S, Chinnusamy C and Chellamuthu V. 2013. Weed management in lowland rice (*Oryza sativa* L.) ecosystem a review. *International Journal of Agricultural Science and Research* **3**(3): 13-22.

Tewary AN and Singh RD. 1991. Crop-weed competition in direct seeded rainfed rice. *Indian Journal of Weed Science* **23**:51-52.

Thapa CB and Jha PK. 2002. Paddy crop weed competition in Pokhara, Nepal. *Geobios* **29**(1): 51-54.

Toky OP and Ramakrishnan PS 1981. Cropping and yields in agricultural systems of north–eastern hill region of India. *Agro-Ecosystems* **37**: 11-25.

Umapathy K and Sivakumar C. 2000. Studies on crop-weed competition in rice-rice cropping system, pp. 57. In: *Proceedings of State Level Seminar on Integrated Weed Management in New Millennium*. Ratnagiri, Maharashtra, 27-28 Feb, 2000.

Zinke PJ, Sabhasri S and Kunstadter P. 1978. Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation. In: *Farmers in Forest (*Eds. P. Kunstadter, E.C. Chapman and S. Sabhasri). Hawaii: East-West Centre.