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Weeds in Indian Agriculture

Problems and prospects to become self sufficient

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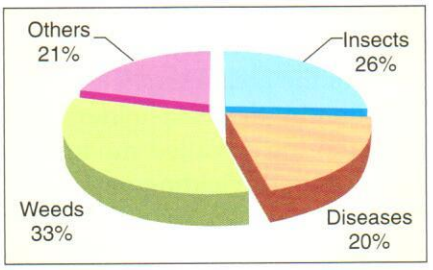
THE extent of crop yield losses due to weeds, vary depending on the crop and associated agro-ecological factors. At a conservative average loss of about 10% in crop yields, at current production levels and minimum support prices, the weeds in cereals, pulses and oilseed crops alone cost the nation an economic loss of over ₹ 50,000 crores per annum. The figure could be quite high if the cost of weed management, reduced efficiency of inputs, losses in quality, diseases and insect pest occurrences due to weeds are taken into account. Losses of similar magnitude are likely to occur in other commercial crops, vegetables, horticultural and plantation crops. Weeds are also a problem in non-crop areas, forestry, public amenity areas and water bodies. The invasive weeds such as *Parthenium*, water hyacinth or *Lantana* are a potential threat to biodiversity and impact human and animal health. Given the projected increase in demand for food by 2050, effective and sustainable ways of preventing losses due to weeds are urgently needed.

Despite the development and adoption of weed management technologies, the weeds continue to be major biotic constraints in cropped and non-cropped lands of India, due to dynamic nature of weeds, their adoption to high-input and intensive cropping systems and management practices including herbicides, shifts in weed flora and several other reasons. The dynamic nature of weeds necessitates the continuous monitoring and refining management strategies for alleviating their adverse effects on agricultural productivity and environmental health in India.

Research work on weed management is in progress in India for the past 6 decades since the initiation of a coordinated scheme in principal crops like rice, wheat and sugarcane in 1952. It was strengthened by the launching of All India Coordinated Research Project on Weed Control in 1978, which is now being implemented all over the country. The establishment of National Research Centre for Weed Science in 1989 at Jabalpur and its upgradation as Directorate of Weed Science Research in 2009 (currently renamed as Directorate of Weed Research [DWR]) was a major step forward to undertake systematic research and development programmes on weed management in a holistic and comprehensive manner by adopting multi-disciplinary approach. Over the last 25 years, the Directorate has played a meaningful role in developing and promoting sound weed management technologies in the country, which have helped in reducing costs and drudgery involved in weed control, and increasing crop productivity.



Crop yield losses caused by weeds and other pests in India

Weed Problems of India

Weed species associated with any ecosystem depends on the ecosystem's environmental characteristics, crops grown, management practices used and several associated biotic and abiotic factors. Despite increased awareness and adoption of technologies, some of the weeds have attained a presence of serious magnitude in different parts of the country. A National Database on Weeds is available at DWR, which provides information on the occurrence and diversity of major weeds in different crops, cropping systems as well as non-cropped areas of the country along with their distribution maps. Major weed species in different situations are given as follows.

Weeds are plants out of place and they cause economic losses by competing with crop plants for nutrients, water and space resulting in significant reductions in crop yields. The losses caused by weeds (33%) are more than the losses caused by either diseases (20%) or insect pests (26%) in India. High seed production capacity, seed dormancy, ability to germinate and grow rapidly, tolerance to a wide range of biotic and abiotic are some of the reasons for their success over crop plants. Weeds reduce the quality of farm produce, increase cost of cultivation and serve as alternate hosts for pests and diseases.

Crop fields: Phalaris minor, Echinochloa crussgalli, wild rice, *Ageratum conyzoides, Cyperus rotundus, Cynodon dactylon* and *Parthenium hysterophorus.*

Non-crop lands: Parthenium hysterophorus, Lantana camara, Mikania micrantha, Mimosa, Ageratum haustonianum, Saccharum spontaneum, Chromolaena odorata, Alternanthera philoxeroides and paragrass.

Water bodies: India has a total area of about 7 million ha under different kinds of water bodies such as reservoirs, tanks, ponds, lakes, and brackish water. In addition, about 1.7 lakh km is under rivers and canals. The area under aquatic bodies is increasing with the building-up of dams, canals and tanks for irrigation and fisheries production. Water hyacinth, *Salvinia molesta, Hydrilla verticellata, Typha aungastata, Alternanthera* are major aquatic weeds of concern in India.

Parasitic weeds: Orobanche cernua, Striga asiatica, Cuscuta reflexa, Dendropthoe are the major parasitic weeds. Parasitic weeds are posing serious problems in some of the major crops and cropping systems. Cuscuta is a major limitation for cultivation of niger in Odisha; lucerne in Gujarat; blackgram and greengram in rice-fallows of Andhra Pradesh, and niger, berseem, lentil, linseed and chickpea in parts of Madhya Pradesh and Chhattisgarh. Some species of Cuscuta also infest ornamental plants, hedges and trees. Orobanche is a major root parasite in tobacco, tomato, and potato in parts of Karnataka, Andhra Pradesh, Tamil Nadu and Gujarat; in mustard in parts of Gujarat, western Uttar Pradesh, Rajasthan, Haryana and Madhya Pradesh. Serious infestation of *Orobanche* in many mustard growing areas of Rajasthan (Jhunjhunu) and Haryana are causing huge losses in productivity. *Striga* infests mostly sugarcane, maize, sorghum and pearlmillet grown in dry areas in some parts of Karnataka, Madhya Pradesh and Chhattisgarh. Loranthus is noticed on economically useful tree crops such as mango, neem, teak, *Cassia* spp., rose wood, *Dalbergia, Albizia, Terminalia, Pongamia*, Gulmohar, *Madhuca, Ficus*, etc.

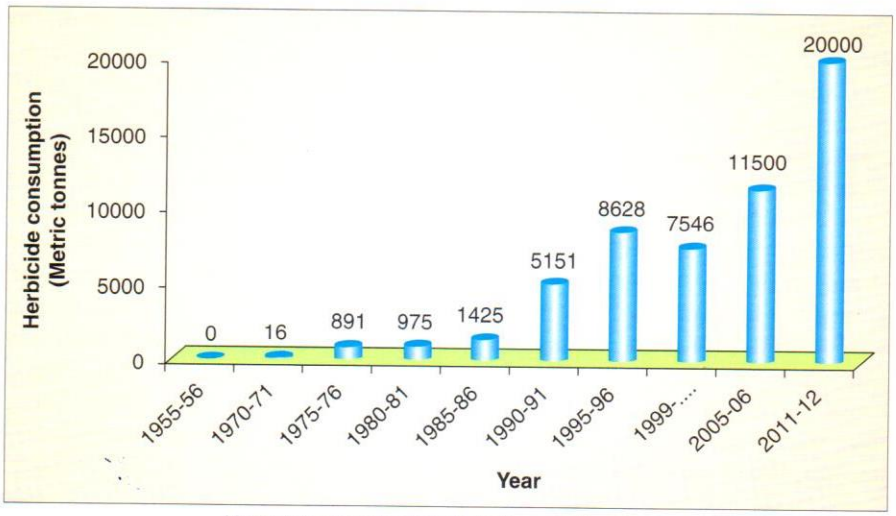
Obnoxious weeds: Many invasive, obnoxious and harmful weeds like *Lantana, Ageratum, Parthenium, Mikania, Chromolaena, Mimosa*, etc. have encroached terrestrial areas by replacing the native flora, and threatening the existence of wild animals. These weeds have invaded vast areas of forest, grasslands, wastelands, orchards and plantation crops. *Parthenium* is estimated to have spread on over 35 million ha of geographical area throughout the country. Previously a problem on road sides and non-cultivated areas, *Parthenium* is now entering into the field crops. *Chromolaena odorata* was earlier restricted to north-eastern regions and Western Ghats but it is now fast spreading to other areas. Similarly, *Mikania micrantha* is a big nuisance in forestry and plantation crops in north-eastern and southern India. *Lantana camara* has invaded large areas of non-crop lands in north-western Himalayan region. *Ageratum* has become a big nuisance in both crops and non-cropped areas. Weedy rice is an emerging problem in direct-seeded rice in many states. Widespread infestation of these weeds has not only threatened agricultural production systems but also biodiversity, human and animal health.

Another major concern is the development of herbicide resistance in weeds, e.g. *Phalaris minor* in the 1990s. Recent wheat imports during 2006-07 have reportedly led to introduction of five regulated weed species, viz. *Cenchrus tribuloides, Solanum carolinense, Viola arvensis, Cynoglossum officinale* and *Ambrosia trifida*. Due to dynamic nature of weeds, it is likely that more serious weeds may emerge in the coming years due to high-input agriculture, climate change, globalization and a host of other factors.

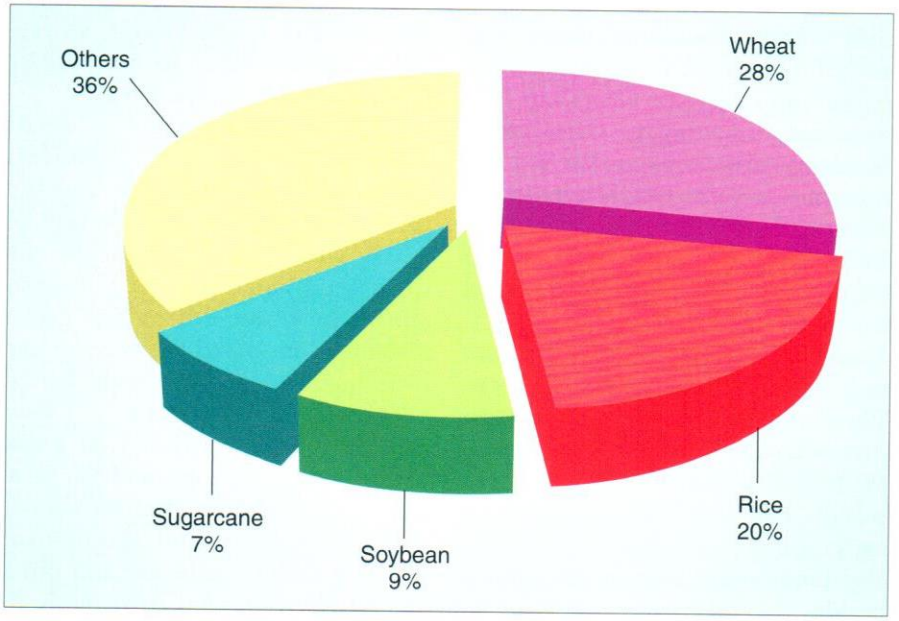
Weed Management

Non-chemical: Weeds are as old as agriculture. The technology/methods adopted for management of weeds have undergone major changes over the years. In India, the manual removal of weeds is the predominant method of weed management practiced. It is highly laborious, inefficient and often uneconomical. Due to paucity of labour and increased labour cost, often the weeding is not done on time. Weed competition during early stages of crop growth is detrimental to crop growth and yield. A weed free period of 3-5 weeks is ideal for optimal crop growth. The success of weeding using hand- and animal- drawn implements, is dependent on the soil moisture content. It is inefficient if the soil is too dry or too wet. Further, inter-row mechanical weeding fails to control weeds growing along the crop row. High cost of maintenance of draught animals has made things worse. Power weeders suited to small holder farmers have to become a reality.

Chemical: Management of weeds through the use of chemicals (herbicides) is slowly but steadily gaining popularity. The invasion of grassy weeds more specifically the little seed canary grass (*Phalaris minor*) in wheat during the green revolution era paved the way for the introduction and large scale use of herbicides in India. Close morphological similarity of grass weeds with wheat crop and the close planting of wheat (often broadcast) rendered manual and mechanical weeding totally inefficient and often proved uneconomical particularly in north-west regions where wages were relatively higher. Herbicides are used either before planting, immediately after planting or after the crop emergence. This ensures control of weeds during the initial stages of crop growth. Chemical weeding is easy and convenient with minimum requirement of labour. Thus it enables diversion of labour to more productive and profitable farm work. With increasing availability of locally manufactured herbicides, the chemical weeding has become cost-effective. In view of the unavailability of labour due to social welfare schemes such as NREGA, more and more farmers' are opting for the use of herbicides. Currently, wheat, rice, soybean and sugarcane account for major share of the total herbicide consumption in the country. It has been estimated that herbicides are



Herbicide consumption in India over the years



Crop-wise herbicide use in India

currently being used on more than 20 million ha, which constitute about 10% of the total cropped area in the country.

Need for safe use of herbicides: Herbicides, like any other pesticide is poisonous in nature and results in toxicity to the user and the environment, if used injudiciously. Proper awareness and training in the use of herbicides are needed as different herbicides may be required in different crops at recommended dose of application and uniformly over the given area using an appropriate sprayer and the nozzle, often to control the same weeds. With judicious use, the herbicides have not been found to have any negative impact. It has been well established that there have been no residues of herbicides at detectable level either in the soil or in the crop at harvest time as the wide gap between application and harvesting ensures full detoxification of the chemical in the crop plants. The effect on soil microbes has been found to be transient with the microbial population recovering to their original levels after a gap of 4-6 weeks of application. The carry-over effect of some herbicides on the succeeding crops is evident only in short duration crops and in cold climates. Proper selection of succeeding crops will however, overcome any possible negative effect. Continuous use of a herbicide results in weed flora shifts. It is likely that a minor weed may become a major weed. This necessitates the use of different herbicides alone or in combination, in different years (herbicide rotation).

Integrated weed management: The chances of a long-term and sustainable management of weeds are more evident when a strategy involving more than one method of weed control is followed. Hence it is always advocated. Preventive measures such as use of weed free crop seeds, well decomposed farm yard manure (FYM), clean farm machinery, etc will go a long way in preventing the entry of new weeds. Although simple and very cost effective, farmers seldom follow these. The cultural methods such as summer tillage, stale seed bed preparation, proper application of fertilizers and irrigation, mixed and intercropping with fast canopy forming crops etc have been found to minimize weed infestation significantly. There are opportunities for selecting a cultivar which is more competitive by virtue of its height, leaf orientation and ability to form faster canopy cover.

Crop-weed interaction under changing climate: It is now a widely accepted fact that climate is changing, which is likely to have consequences on crop-weed associations and agricultural productivity. It is expected that growth of C3 plants would be enhanced more by CO_2 enrichment as compared to C4 plants. The differential effect of CO_2 enrichment on C3 and C4 plants may have significant implications for crop-weed interaction, since majority of crops belong to C3 whereas large numbers of weeds belong to C4 category. For instance, *Parthenium hysterophorus* (C3) and *Amaranthus viridis* (C4) show enhanced growth and biomass production under elevated CO_2, and result in increased flower production. Many crops such as rice and maize face the dual problem of increased competition from weeds and reduced yield in a harsh environment due to global warming. Climate change is expected to promote proliferation of new weed species and cause shifts in the composition of weed flora and may influence the efficacy of herbicides and other weed management.

Opportunities for Weed Management

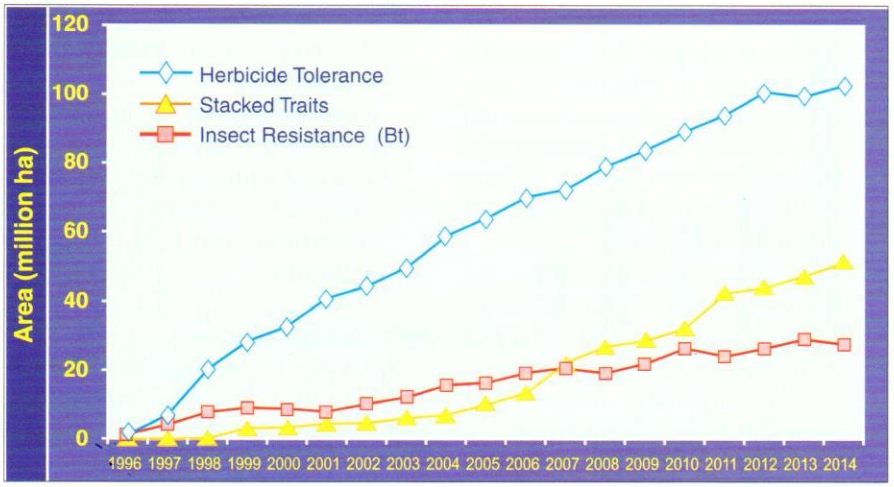
In view of the emerging challenges in weed management, innovative approaches are being attempted to check the weed menace in an effective and eco-friendly manner. Following opportunities are available for weed management in Indian agriculture.

- Herbicides are becoming increasingly important for weed management due to labour scarcity in many parts of the country. Safer low-dose synthetic molecules of various modes of action are being introduced to replace more hazardous conventional herbicides. New, low-dose and high-potency molecules and formulations have become available in the last 4-5 years. It is expected that more number of such new generation chemicals will become a reality in near future.
- Research on nano composite-based controlled release formulation is essential for precision weed management. The controlled release of herbicide molecules in application zones provides long-term control of weeds avoiding repeated application of herbicides. These formulations minimize herbicide residues in the environment, increase the efficacy and longevity of the herbicide by protecting it from environmental degradation, and decrease the application cost. Research and development of nano-herbicides and other slow release chemicals is continuing, and is expected to yield results in the coming years.
- Precision farming based on remote sensing techniques for site-specific weed monitoring is being developed. This will greatly help in avoiding wastage of herbicides and minimize residue hazards.
- Herbicide tolerant crops are being grown in many parts of the world. It is expected that such crops will be introduced into India in near future after the legitimate concerns are adequately addressed. This may change the spectrum of weed management programmes in India.
- Innovative production systems like conservation of agriculture are being developed for enhancing resource-use efficiency, crop productivity and environmental sustainability. Weed management in such systems would require greatly enhanced knowledge of herbicide application.
- New generation machines for tillage, sowing, interculturing, spraying, harvesting, residue management are being developed, which will provide cost-effective means of weed management.
- Search of bioactive botanicals and microbial metabolites, which may act as lead molecules for herbicide development, is an essential component of weed management programme. Research on biotechnology can provide breakthrough for development of bio-herbicides, which are host-specific and environment friendly. Similarly, new strains of bioagents effective against problem weeds can be identified.
- Emphasis is being given to develop solar energy-aided microwave generating device for the control of target weeds. The success of it may reduce herbicide consumption by many folds. This device coupled with sensor technology will be the part and parcel of precision and automated weed control technology.
- New tools aimed at more effective transfer of technology for weed management are available in the era of ICT. Farmers will have easy and quick access for such tools in the coming decades. A weed management data repository and effective Management Information System (MIS) is being established at the Directorate.
- Efficient diagnostic techniques for monitoring herbicide residues would lead to safer chemical weed control and cleaner environment. Effective decontamination techniques for active and transformation products will provide opportunity for mitigation of residue hazards.
- Climate change research would provide further insights into crop-weed association, herbicide and bioagent efficacy for developing effective weed management technologies.
- Weed utilization techniques are available for effective conversion of weed biomass into enriched compost, medicinal use, bioremediation and industrial application.

Future strategies

Need for herbicide-tolerant crops: The advances in molecular biology and biotechnology have enabled scientists to develop crop plants which resist the application of non-selective herbicides. In fact, imparting resistance to normally herbicide susceptible crops to produce herbicide-tolerant crops (HTCs) has been the most extensively exploited area of plant biotechnology. There has been a boom in adoption of GM crops over the last 15 years as the total area covered with GM crops has increased from 1.7 m ha in 1996 to more than 181.5 m ha in 2014. These crops have already been adopted by 30 countries and India stands fifth with 11.6 m ha area covered with Bt cotton. The HTCs make efficient management of problem weeds easy with minimum risk to the crop. Resistant genes for several herbicides or specific modes of action have been incorporated into the genome of various crops, viz. maize, cotton, canola and soybean. The herbicide tolerance is the principal trait occupying about 80% of the total acreage under GMCs. Consequently, worldwide area under HTCs is increasing rapidly.

The advantages of growing HTCs are many. With a single application of such a non-selective herbicide to which the crop has been made resistant, one could kill all weeds with no injury to the crop plants. With zero weed competition and no phytotoxicity to the crop plants, the farmer is assured of higher crop yields than would be expected with the use of a cocktail of herbicides to manage all weeds. The HTC technology will also enable farmers to raise crops under resource conservation technologies. However, the adoption of GMCs has been the subject of



Global area of biotech crops by trait. *Source*: James (2014)

much public debate and controversy in India. Apprehensions are being raised regarding the possibility of development of 'super weeds' due to introduction of these crops. If HTCs are introduced in India, training the farmers on proper use is a prerequisite.

Dissemination of weed management technologies: Improved weed management technologies have not reached the farmers at the same pace as it happened in case of high yielding varieties, fertilizers and insecticides. Lack of awareness among the farming community is the major reason for poor adoption of weed management technologies. It is important to involve farmers in developing, testing and refining technologies keeping in view the location-specific problems and resources available with the farmers. Suitable mechanism of linkage between public and private sector in assessing and transferring appropriate technologies in a complementary fashion should be developed. Information about safe use of herbicides, herbicide application technology for higher efficacy and integrating chemicals with other methods of weed management are also to be disseminated.

Multidisciplinary research efforts: Enhanced research efforts on weed species are assuming importance in different parts of the country and are causing havoc to agricultural production, biodiversity and environment. Focussed multi-disciplinary research programmes need to be formulated to address the emerging challenges and develop location-specific weed management strategies aimed at increasing productivity and input-use efficiency while reducing costs and environmental hazards. Sustainable weed management practices in diversified cropping systems should address issues of weed management in conservation agriculture systems; adoption of systems approach with emphasis on horticultural, rainfe and organic farming systems improving use-efficiency of wate nutrients and other resources throug weed management; and efficien spraying techniques for low-volum high-potency herbicide molecules an mechanical tools for wee management. Weed managemen research in the context of climat change and herbicide resistance nee to focus on the effect of CO_2 an temperature on crop-wee associations, biochemical an physiological aspects of herbicid resistance development in weeds, an weed risk analysis.

SUMMARY

Despite decades of research an development and advances i management practices aimed at thei management, weeds remain as constant threat to productivity profitability and sustainability i agriculture. Impact of globalization climate change, genetically modifie crops and other recent trends als have an impact on weeds and wee management. Severe labour scarcity shortage of water for agriculture emphasis on organic an conservation agriculture, ar redefining the way we address wee problems.

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Global warming: Heat's on

As global warming becomes a real threat, it is time to upgrade technology to tackle the isssue

For most of us, the only effect the word "global warming" has is to make us freeze over. But if decades of warning by environmentalists of a climate crisis have fallen on deaf ears it's not really our fault but theirs. Activists fail to move the public, not because they are wrong about the problems but because the solutions they offer are unappealing to most people.

They called for tightening belts and curbing appetites, turning down the thermostat and living lower on the food chain. They rejected technology, business and prosperity in favour of returning to a simpler way of life. No wonder the movement got so little traction. We trash the planet not because we are evil but because our industrial systems leave us with no choice.

Our high-rises, factories and farms, freeways and power plants were conceived before we had a clue how the planet works. They are primitive inventions that have been designed by people who didn't fully grasp the consequences of their actions. But as comprehension has grown, a market has emerged for more sensible alternatives.