Vision 2030

Directorate of Weed Science Research

Jabalpur

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Directorate of Weed Science Research
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सचिव एवं महानिदेशक
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Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Weeds in crop fields directly cause enormous losses, quantitative as well as qualitative. Proper weed management, therefore, is necessary to realize potential output level of a given corpping system and to sustain farm income. Weed control scheme was started as early as 1952 in different states, In 1986, the ICAR established National Research Centre on Weed Science (NRCWS) at Jabalpur which war later upgraded as the Directorate of Weed Science in 2009. The Directorate is primarily mandated to undertake basic and strategic research for developing strategies for efficient weed management in different agro-climatic zones.

it is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

Date : 13th June, 2011
New Delhi

(S. Ayyappan)

Preface

Weed problems are likely to increase due to increased emphasis on high input agriculture. Further, globalization would also result in new weed problems notwithstanding strict quarantine regulations. With the increased public awareness on environmental pollution, the focus would shift to the development of eco-friendly weed management technologies in the new millennium. As the future weed problems will be multi-pronged, a holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative. Effective linkages will also be forged with all the national as well as international agencies working on weed management to harness the technological developments.

Continuous development and improvement of weed management technologies is essential to reduce production costs, and also in light of both ever-changing socio-economic conditions of the farmers and international agricultural trade policies. Rapid expansion of weedy rice infestation, recent introduction of alien invasive weeds, lack of low-cost environment friendly weed management technologies for our water bodies and for dryland farming systems are some of the burning issues require immediate attention. Suitable technologies to be developed to tackle the probable scenario that may emerge in the area of crop-weed competition due to increased atmospheric CO_2 concentration and subsequent global warming are some of the major future challenges. To meet these challenges, capacity building of scientists is very essential in the frontier and emerging fields of weed science. The present document *DWSR Vision 2030* provides the strategies to deal with the upcoming challenges towards weed management in crop and non-crop situations including water bodies.

I sincerely thank Dr. S. Ayyappan, Secretary (DARE) and Director General (ICAR) and Dr. A.K. Singh, Deputy Director General (NRM) for their unstinted guidance in preparing this document. Thanks are due to Dr. J.C. Dagar, Assistant Director General (Agronomy, NRM) for his keen interest. The valuable suggestions by the members of the Research Advisory Committee are gratefully acknowledged. I sincerely thank the scientists of the Directorate for giving valuable inputs. I deeply acknowledge the efforts made by Dr. K.K. Barman, Dr. V.P. Singh, Dr. Anil Dixit and Dr. M.S. Raghuvanshi for their painstaking efforts in preparing this document.

Date: 08 July, 2011
Jabalpur

Director
Directorate of Weed Science Research
Jabalpur

Preamble

Weeds are the most severe and widespread biological constraint to crop production and cause invisible damage till the crop is harvested. Weeds are responsible for reduction in crop yield and degrade quality of produce besides raising cost of production. Of the total losses caused by the agricultural pests, weeds contribute to as high as 37 per cent. Unlike other pests, weeds are ubiquitous and affect almost all the crops. Presence of weeds in general reduces crop yield by 31.5 per cent (22.7 per cent in *rabi* season and 36.5 per cent in *kharif* and summer season). The composition and competition by weeds are dynamic and dependent on soil, climate, cropping and management factors. The biology, ecology and management of weeds cannot remain constant for all the regions and hence, weed management strategies will have to be different for each agro-ecological condition. Many of the weed problems are location-specific requiring local solutions. Further, the farmers because of a variety of reasons largely ignore weeds. Greater awareness about the losses caused by the weeds and the need for improved weed management technologies are therefore very vital. Proper training and reorientation of the personnel involved in weed science research at different SAUs are also essential in successful management of weeds.

Considering the problem of weeds in crop field and the need for weed research in India, a Coordinated Weed Control Scheme on wheat, rice and sugarcane was initiated by ICAR in 1952 in 11 states of the country to monitor the weed flora and also to find out the relative feasibility of economic weed control. In 1978 the All India Coordinated Research Project on Weed Control was started by the ICAR in collaboration with the United States Department of Agriculture (USDA) at 6 locations. At present, it is operating at 22 locations covering different agro-ecological zones all over the country. This project has not only assisted farming community by developing effective weed management technologies but also brought out the need for carrying out more in depth studies. In view of this it was decided to set up a nodal centre for basic, strategic and applied research in Weed Science in VII Five Year Plan. Consequently, the National Research Centre for Weed Science was established in April, 1989, which was further upgraded to Directorate of Weed Science Research (DWSR) in January, 2009.

The Directorate, since its inception has significantly contributed in the areas of identifying major weeds in different crops and cropping systems of the country, development of national database of weeds, evaluation of new herbicides and

development of herbicide recommendations, monitoring of herbicide residues in food chain and environment, identifying weed competitive crop cultivars, weed smothering intercrops, non-chemical and biological methods of weed control, weed dynamics in crops and cropping systems, management of parasitic weeds, management of perennial weeds and other invasive weeds in non-cropped areas and transfer of improved weed management technologies.

Weed science is a multidisciplinary and dynamic area of research. This area essentially needs the development in weed management with minimal role of labour by harnessing the advances made in cutting edge disciplines such as farm mechanization, biotechnology, information and space technology, etc. In view of the current advances in the area of Weed Science and changing dynamics of weeds in crops and cropping systems in the country, it was thought necessary to revise and prioritize the research programmes for the next 20 years to ensure increased role of research technologies for eco-friendly weed management in the sustainable crop production. The weed problems are likely to increase the enhanced emphasis on high input agriculture. Further, notwithstanding strict quarantine regulations, possibility of emerging new weed problem is always there in this era of globalization. Recently five alien invasive weeds have entered our country along with wheat imported in 2006, and among these one namely *Solanum carolinense* has already made its presence felt in the different parts of our country. With the increased public awareness on environmental pollution, the focus is shifting towards the development of eco-friendly weed management technologies in the new millennium. The past experiences in weed control as well as the challenges that are likely to emerge in future such as impact of alien invasive weeds, the role of global warming on weed diversification, new weed introduction of quarantine importance, etc. are also necessitated a thorough revision of perspective plan.

To prepare this document thread-bearing discussions were held among the scientists of the Directorate and RAC. The suggestions of the QRTs of the Directorate and AICRP-WC have been considered while finalizing the document.

Contents

Weed Management Scenario

India has made impressive strides on the agricultural front during the last six decades. During this period the foodgrain production has increased by over 4.5 times from a meager 50.8 million tonnes in 1950-51. To achieve this growth the agricultural research system has focused on breeding varieties that increased the yield potential of individual crops by enabling more intensive use of inputs. Proper weed management has a potential to yield substantial increase in the production of food grains as weeds alone are known to cause productivity in the range of 15 to 85 per cent under diverse situations.

Weeds are always associated with human endeavours and cause huge reductions in crop yields, increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect pests, diseases and nematodes. Weeds compete with crop plants for various inputs like water, nutrients, sunlight. The importance of their management seldom requires any mention especially under the present day high input farming systems.

Weeds also interfere in the management of all the terrestrial and aquatic resources, create problems in the maintenance and inspection of various defense, electrical, railway and airport installations besides being a potential fire hazard in forests and cause health hazards like skin allergy, nasal asthma, diseases, etc.

The impact of weeds on the Indian economy estimated about two decades ago ranged from Rs. 20 to 28 billion (Sachan 1989, Sahoo and Saraswat 1988). A recent study undertaken at DWSR suggests that proper weed management technologies, if adapted, can result in an additional income of Rs. 1,05,036 crores per annum (NRCWS, 2007). This figure would be greater if the direct and indirect impact of weeds on aquatic systems, forestry and industrial sites are also included. Besides, huge amount of money is spent on controlling the weeds. At a conservative estimate, an amount of Rs. 100 billion is spent on weed management annually in India, in arable agriculture alone. The potential yield losses due to weeds can be as high as about 65 per cent depending on the crop, degree of weed infestation, weed species and management practices (Yaduraju *et al.*, 2006).

Weed management is as old as agriculture itself, but the methods and concept of controlling weeds have changed over the years. The present weed control practices in India are characterized by intensive use of manual labour and animal power. Both of them are in short supply and are increasingly becoming uneconomical. Manual weeding, besides laborious is inefficient (not done on time in most cases) and always not practical because of adverse soil conditions. The weeds are more competitive with crops during the initial stages of their growth (2-6 weeks after planting). Controlling weeds during this time is very essential for realizing maximum crop yield. Because of this, chemical weed control method is rapidly gaining ground in the country, which on the other hand is raising several environmental concerns. Therefore, future weed science research and related technological developments need to match emerging weed management scenario of the country.

Invasive Alien Weeds

Invasive alien weeds (IAWs) are plants that are moved from their native habitat to a new location and in the absence of their co-evolved predators and parasites they eventually become established and spread rapidly causing tremendous harm to the environment, economy and in some cases to human health (IUCN 2000).

Majority of the important weeds in India have been introduced into the country in the past either accidentally or deliberately. Several exotic weeds, many of them potentially harmful, have gained entry into India as contaminants in wheat imported from different countries. Even in the wheat imported recently during 2006-07, seeds of five regulated weed species, viz., *Cenchrus tribuloides*, *Solanum carolinense*, *Viola arvensis*, *Cynoglossum officinale* and *Ambrosia trifida* have been intercepted by the Plant Quarantine Officials.

Solanum carolinense

Some of the major alien invasive weeds, viz., *Lantana camara, Parthenium hysterophorus, Chomolaena odorata, Mikania micrantha, Mimosa spp.* have already become great problem to the country. These weeds have invaded vast areas of forest, grassland, wastelands, orchards and plantation crops. *Chromolaena odorata,* earlier restricted to NE region and Western Ghats is now fast spreading to other areas. Similarly *Mikania micrantha,* which is popularly called *mile-a-minute* weed on account of its rapid growth is a big nuisance in forestry and plantation crops in NE and South India (Yaduraju *et al*., 2003). Similarly, *Parthenium hysterophorus* is a serious weed which has spread throughout the country. *Eichhornia crassipes is a well known problem for aquatic bodies across the country. The* alien invasive weeds that have invaded our ecosystems are already causing an annual loss to the tune of US$117 billion (Pimentel *et. al*., 2000).

Management of parasitic weeds

Parasitic weeds are posing problem in the productivity of some of the major crops and cropping systems (Bhan and Sushilkumar 1998). *Cuscuta* spp. is a major problem in niger in Orissa, parts of Madhya Pradesh and Chhattisgarh; in lucerne in Gujarat; in blackgram/ greengram in rice-fallows of Andhra Pradesh (Kumar 2000) and in berseem, lentil, linseed and chickpea in parts of Madhya Pradesh. Some species of *Cuscuta* also infest ornamental plants, hedges and trees. *Orobanche* spp. is a major parasite in tobacco in parts of Karnataka, Andhra Pradesh, Tamil Nadu, and Gujarat, mustard in parts of Gujarat, western Uttar Pradesh, Rajasthan, Haryana, etc., and in tomato and potato in Karnataka. *Striga* sp. infest mostly sugarcane, maize, sorghum and pearl millet grown in dry areas in some parts of Karnataka, Madhya Pradesh and Chhattisgarh. *Loranthus* is noticed on economically useful tree crops in southern states. The most preferred host trees are mango, neem, teak, *Cassia* sp., rose wood, *Dalbergia* sp., *Albigizzia* sp., *Terminalia* sp., rain tree, *Pongamia* sp., Gulmohar, *Madhuca* sp., *Ficus* sp., etc.

***Loranthus* attack on mango**

The problem of perennial weeds is increasing enormously. It is necessary to develop the management technology for such weeds.

Aquatic weed management

The aquatic weeds increase the loss of water through transpiration, interfere in navigation, affect fisheries, mar recreational value of water and severely impede the flow of water in canals. India has a total area of about 7 million hectares under different kinds of water bodies such as reservoirs, tanks, lakes, ponds, oxbow lakes, derelict water 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 fish production.

Global climate change and crop-weed interactions

The CO_2 level in the atmosphere has been rising owing to various human activities such as burning of fossil fuels, deforestation, industrialization urbanization etc. If the present trend continues, the concentration of CO_2 in the atmosphere would be about 600 ppm accompanied by an increase of 1.5^0C - 4.5^0C in mean surface temperature by the middle of the 21st century. Increasing levels of CO_2 will directly influence plant physiology, through its effect on photosynthesis, transpiration and respiration, which seem to be the processes by which elevated CO_2 can be sensed directly by plants and ecosystem (Drake *et al*. 1997). However, rising temperature will have contrasting influences on these primary processes. As weed populations show greater variations, it is possible that with a changed global climate weeds will achieve a greater competitive fitness against the crop plants. The growth response of *Parthenium hysterophorus* (C_3) and *Amaranthus viridis* (C_4) to CO_2 enrichment (55030 ppm) showed that elevated CO_2 enhanced the growth and biomass production in both the weed species. There was a an increase (274 per cent) in the flower production under elevated CO_2 (Naidu and Paroha, 2008).

Weed flora Shift

Organic farming and conservation agriculture are becoming popular now-a-days. Change in farming system practices often leads to weed flora shift in the

crop field, this in turn also dictates the requirement of new weed management technology. Development of integrated weed management practices involving non-chemical methods such as mechanical and cultural (soil solarization, zero tillage, conservation tillage, plant residue management, growing intercrops, cover crops and green manure crops) is expected to gain importance in organic farming. Conservation agriculture may favour the shift towards perennial weeds besides increasing the herbicide use.

Weed management using herbicides

Herbicides have become a big boon to farmers in areas where the labour supply is limited and wages are high. The major impact was first felt in Punjab where most of the agricultural operations are done by immigrant labour. Other states where the herbicide consumption is high are Haryana, western U.P. and Uttaranchal. The advantages of herbicides over the other methods are appreciated mostly in wheat and rice crops in managing the grassy weeds. Due to the morphological similarities it is difficult to identify and remove grassy weeds manually whereas selective herbicides could kill them successfully without causing any damage to the crop. Further, the use of hoes and other intercultivation tools is difficult in these crops, as they are closely planted. In addition in many regions the crop is sown by broadcast thus making matters still worse. Currently wheat and rice crops account for about 60 and 20 per cent respectively of the total herbicide consumption in the country, the third crop being soybean which accounts for about 4 per cent. The data on herbicide consumption shows that they are being used in approximately 20 million hectares, which constitute about 10 per cent of the total cropped area (Yaduraju *et al*. 2006). However, immediate attention is needed to develop suitable chemical technologies for managing weeds in pulses and rainfed areas, parasitic weeds, weedy rice and invasive weeds.

Over-reliance and repetitive use of the herbicides belonging to the same class can also led to the development of herbicide-resistant weed biotypes. Recent instances of resistance *to isoproturon* in *Phalaris minor,* an important weed in wheat in parts of Punjab and Haryana is a case in point, which was evident in an estimated area of nearly one million hectares. Although it was controlled in

Punjab and Haryana with this herbicide for over two decades but continuous long-term use, however, resulted in the development of resistance during early 1990s. Large scale yield reductions in wheat were recorded even with use of herbicide isoproturon. In extreme cases of heavy infestation, farmers chose to plough down or pre-maturely harvest the crop for fodder. The use of new herbicides clodinafop, fenoxaprop and sulfosulfuron though have successfully contained the problem at present, thus restoring the productivity of wheat in this region which is considered the wheat basket of the country. This technology alone is estimated to have saved wheat production to the extent of 1.5 million tonnes annually valued at Rs. 100 crores at current prices. The new herbicides are currently used in an area of about 1.8 million hectares. Similarly the resistance of *Echinochloa colona*, a major weed in rice to butachlor, one of the prominent rice herbicide in several parts of the country has posed a serious threat to the sustainability of rice-wheat system in the country. As the plant systems have their own build up mechanisms for their defence, there is likelihood that this will continue to be a problem in the foreseeable future as well. We need to be watchful of similar problems emerging in other crops and cropping systems.

Some of the unintended negative impacts of herbicide use are persistence in soil, pollution of ground water, toxic residues in food (contamination), feed, fodder and adverse effect on non-target organisms. The potential of herbicide contaminating the ground water have gained considerable attention in recent years. Some herbicides like triazine, diuron, alachlor and metolachlor have been detected in ground water in India. Herbicides that are highly water soluble and weakly adsorbed to soil particles such as sulfonyl urea and imidazolinone have potential for contaminating the ground water. There are indications that few herbicides not only damage the microbial population but crops too when applied in succession. Notwithstanding these apprehensions, herbicides would remain as one of the major tools in weed management as it offers huge benefits to the farmers and as herbicide use is likely to increase substantially in the future, their judicious use is of utmost importance.

Further, in the new WTO regime our products have to be competitive both in price and quality. The presence of pesticide residues is another major issue in

world trade, which may be used as a non-tariff barrier affecting food exports. Although herbicide consumption in the country is very low at present, bulk of the herbicide use is in wheat, rice and soybean while commercial crops like groundnut and some spice crops (e.g. fennel) also consume considerable quantity of herbicides. As the country is exporting all these commodities we must ensure that these do not contain any herbicide residues.

Reduction in manual weeding

Weed control through manual/ mechanical though very effective, has certain limitations such as unavailability of labour during peak period, high labour cost, involves drudgery, unfavourable environment particularly in rainy season etc. In addition, the manual labour traditionally being employed for weeding is gradually becoming scarce and expensive owing to rapid urbanization and industrialization. It may be noted that proportion of economically active population engaged in agriculture decreased from 64% in the year of 1990 to 57% in 2005 (IASRI, 2008). Liberalization policies and welfare activities initiated by the Government coupled with diversification of agriculture etc. will further limit the labour availability. At present, an estimated 8 to 10 billion man-days are engaged in weed control in a year which in other words means that every Indian is involved in weeding for at least 8 to 10 days in a year. According to some estimates, by the year 2020, nearly 50 per cent of the population would be living in urban areas, creating unprecedented shortage of labour force for use in agriculture. Therefore, in future, management of weeds through improved technologies involving herbicides and improved weeding tools will attain more significance which will result in labour saving, better and timely weed control and increased food production besides promoting gender equality and reducing human drudgery. The economic analyses of the data obtained from large number of trials and demonstrations carried out in farmers fields through

out the country have also reflected higher levels of productivity coupled with benefit:cost ratios of over 2:1. In addition, the labour saved (about 20-40 man days per hectare) through adoption of improved weed management practices, can be utilized in other related and more productive enterprises such as livestock rearing, poultry, fishery, mushroom cultivation, sericulture, bee keeping etc. which would yield greater income. This will also raise the esteem of women and provide them with more free time which can be devoted towards children, sanitation, health care etc.

Competitiveness in world market

In the new WTO regime our products have to be competitive both in price and quality. Weed management forms an important input in crop production. At present the production costs are high as weeding operations are performed mainly by manual labour which is not only becoming scarce in supply but also expensive. The country is, therefore, losing on crop production heavily due to inappropriate weed management technologies being adopted. There is big scope for reducing the cost of production by adapting improved weed management technology which would also enhance the efficiency of other inputs like fertilizers and irrigation as weeds waste both these resources. In addition to herbicides, resource conservation technology like zero-tillage can cut down the production cost substantially without penalizing productivity.

The presence of pesticide residue is another major issue in world trade, which may be used as a non-tariff barrier affecting food exports. Although herbicide consumption in the country is very low at present, bulk of the herbicide use is in wheat, rice and soybean while commercial crops like groundnut and some spice crops (e.g. fennel) also consume considerable quantity of herbicides. However, as the country is exporting all these commodities we must ensure that these do not contain any herbicide residues.

Biological control of weeds

Biological management of *Parthenium* by the Mexican beetle (*Zygrogramma bicolorata*), water hyacinth by *Neochetina* spp. and *Salvinia* by *Cyrtobagous salviniae* have been found successful. This approach is inexpensive and self-

perpetuating besides being user-friendly and environmentally benign. The Directorate has done commendable work in the bio-control of *Parthenium* by releasing the Mexican beetle in different parts of the country during the last of couple of years. It is expected and hoped that it would spread on its own to vast areas in the next 4-5 years. Though, the technology is not expected to completely eradicate the weed, as it is slow and the plants are not killed before their seed is set thus ensuring weed infestation in the coming years, but it would sufficiently restrain a highly invasive and competitive plant like *Parthenium* to the extent that the local plants would get a chance to out compete it. The insect is also highly specific to the weed and has so far not reported to feed on any crop or weed plants. Several competitive plants such as *Cassia tora, Cassia serecia, Tagetus* spp. etc., have also been reported to suppress *Parthenium* effectively. Spreading them in *Parthenium* infested areas is being done which needs to be stepped up in the future. Australia is using about 6-7 bio-control agents against *Parthenium*. Similarly, several bio-herbicides, mostly based on fungal formulations (mycoherbicides) are being commercialized in some developed countries. This technology has tremendous potential in our country also.

The control of water hyacinth through *Neochetina spp.* has shown some promise. As the other methods of control are not practical and cost-effective, control through *Neochetina* may still be considered as the only viable option. It may be noted that mechanical removal is highly expensive costing anywhere between Rs. 4000-5000/ha. The Ooty lake (18 ha) was cleared at a very high cost of Rs. 1.74 crores (The Hindu, 12 April, 2002). Where as, two weevils, namely, *Neochetina bruchi* and *N. eichhorniae* and a hydrophilic mite *Orthogalumna terebrantis* have been able to suppress water hyacinth in ponds and water bodies in Karnataka, Madhya Pradesh and NE States. Clearing of Loktak lake in Manipur and Himayat Sagar in Hyderabad are particularly noteworthy.

A gall fly (*Cecidochares connexa)* for the bio-control of *Chromolaena odorata* and rust fungi (*Puccinia spagazzinii*) against *Mikania* have already been imported and are undergoing initial trials at NBAII, Bangalore. The Directorate has recently established a quarantine insectory and would work in close collaboration with NBAII for evaluating these biocontrol agents.

Weed Management Research System

Considering the problem of weeds in crop fields and need for weed research in India, ICAR initiated a Coordinated Weed Control Scheme in the year of 1952 to monitor the weed flora in wheat, rice and sugarcane in 11 states, and to find out the relative feasibility of economic weed control. Later on a number of Crop Research Institutes of ICAR and State Agricultural Universities were involved in weed control research. Different State Agricultural Universities (SAUs) also initiated the syllabus for weed management at under- graduate and post-graduate level to teach and train students and researchers in weeds and their management.

It was in 1978 the Weed Research Programme was strengthened through All India Coordinated Research Project on Weed Control (AICRPWC) by the ICAR in collaboration with the United States Department of Agriculture (USDA). Initially, AICRPWC was started with six centres at different state agricultural universities for a period of six years. Later on seven more centres in II phase and nine more centres in III phase were added during 1982-83 and 1985-86, respectively, for a period of five years each. The programme was continued with plan funds of ICAR. This project assisted farming community through the effective utilization of scientific technologies for alleviating the yield losses due to weeds in field crops. The research programme tackled problems of weed management for which facilities were not available at different centres. In VII Plan, it was decided to establish a National Research Centre for basic as well as applied research in Weed Science in India. Accordingly, the National Research Centre for Weed Science (NRCWS) was approved during the middle of VII Five Year Plan. Approval of Govt. of India for establishing NRCWS was conveyed vide DARE letter no. 13-13/85/AFC,dtd. Nov. 14,1986. The Centre actually came into existence on 22.04.1989 which was then further upgraded to Directorate of Weed Science Research (DWSR) in January, 2009.

The DWSR and its Coordinating centres have identified major weed problems in different production systems and developed the strategies for managing them. The impact of research can be gauged by the facts there have been significant increase in the yield of crops in the framers' fields with improved weed management technologies. The increase acceptance of herbicides as a tool in weed management is another proof of research contribution made by the weed scientists of the country. The contribution made by the weed scientists in

identifying and suggesting alternative methods of controlling herbicide resistant weeds like *Phalaris* minor is also worth mentioning. Realizing the public apprehension about the adverse effect of herbicides on the environment, research on control of weeds through use of bio-control agents and bio-herbicides have been stepped up. The control of *Parthenium hysterophorus* through the use of Mexican beetle (Zygogramma bicolorata) is one outstanding example of biocontrol of weeds.

Mandate

To undertake basic, applied and strategic researches for developing efficient weed management strategies in different agro-ecological zones;

To provide leadership and co-ordinate the network research with State Agricultural Universities for generating location-specific technologies for weed management in different crops, cropping and farming systems;

To act as a repository of information in weed science;

To act as a centre for training in the areas of weed science and weed management;

To collaborate with national and international agencies in achieving the above mentioned goals; and

To provide consultancy on matters related to weed science.

DWSR, being a nodal Directorate has to play a pivotal role in developing integrated weed management strategies for improving the crop yield and to reduce the problems in other ecosystems. However much needs to be done in future in the field of weed management to work out effective strategies in the light of the new emerging weed problems and address issues related to globalization and WTO. The Directorate will continue to have collaboration with the SAUs and other ICAR institutes located at different regions of the country, which will act as out-reach centres to generate the location specific research recommendations. Weed menace in forestry, pasture, grassland, and non-cropped areas like wasteland public amenity areas etc. is also equally important as they threatened biodiversity and adverse impact on human and animal health as well as quality of environment.

DWSR 2030

The Directorate of Weed Science Research is marching ahead with renewed vigour to face complex challenges of weeds in all ecosystems for the welfare of the farmers and other stakeholders. The efforts would be to develop eco-friendly and low cost weed management technologies.

Vision

"Developing the innovative; economic and eco-friendly weed management technologies to address challenges ahead for sustainable agriculture and other societal benefits"

Mission

"To provide scientific research and technology in weed management for maximizing the economic, environmental and societal benefits for the people of India"

Focus

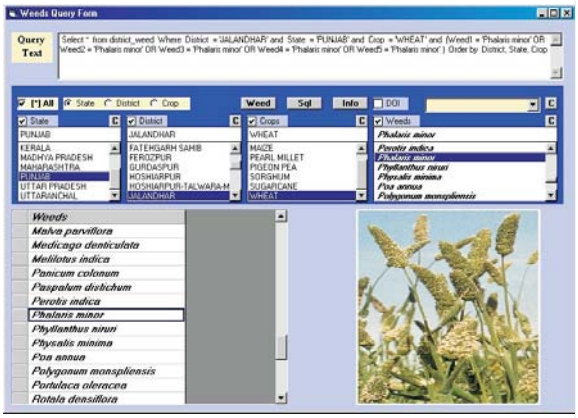
The weed problems will likely to increase due to increased emphasis on high input agriculture. Globalization would bring new weed problems. To meet the future challenges in weed management in the era of increased environmental awareness, DWSR will concentrate on the following key areas:

- Developing and up scaling economical and eco-friendly weed management technologies in different field– and horticultural crops / cropping systems under rainfed and irrigated ecosystems and in non-crop situations.
- Research on aquatic and parasitic weed management
- Management of Alien Invasive Weed Species
- Mitigating the emerging threat of bio-similars (weeds) through molecular and other approaches.
- Identification of herbicide metabolites.
- Effects of climate change on crop-weed interaction and productivity.
- Weed utilization
- Strengthening advisory services of weed management to stakeholders and impact assessment.
- Creating awareness among farmers, policy planners, administrators and other stakeholders about utility and losses by weeds.

Harnessing Science for Weed Management

The Directorate of Weed Science Research would strive to harness power of science in evolving effective, efficient, sustainable, environmentally safe and relatively cheaper weed management technologies with an ultimate aim of increasing productivity, enhancing input use efficiency, reducing production cost and improving quality of produce. Despite several constraints of facilities and manpower, the Directorate has been able to accomplish good achievements in this direction. It will continue to proceed towards this endeavor keeping in view continuously changing social demand, world trade scenario and latest scientific developments.

National Data Base On Weeds: From the huge data built-up over years by the AICRP-Weed Control, the Directorate has developed a *National Database on Weeds*. The database can provide 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. Currently information on major and minor weeds of 435 districts of the country was incorporated in the database. The database can offer information on five major weeds along with their degree of infestation and vernacular names, in each of these districts. In addition it also provides the status and distribution of invasive weeds in the country. Altogether weed maps of 19 states are available. Two volumes of District-wise distribution pattern of weed flora in prominent crops covering different states have been brought out. In addition to this, an Interactive e-module on weed management in crops has also been developed. There is need to continuously upgrade this data base to include non-crop and aquatic areas, weed shift, introduction of new alien weeds, etc. Such up-to-date information would be of immense use for policy planners, researchers and local administrators.



Invasive Alien Weeds: *As per Convention on Biological Diversity (CBD 1992) alien invasive species are the biggest threat to biodiversity next only to human* resettlement. A perusal of publication 'Geographical Atlas of World Weeds' by Holm *et. al*. (1979) indicates that there are 975 weeds in different parts of the world which have not yet been recorded or reported in India. Increasing trade and globalization coupled with liberalization policies will further increase the risk of invasion by such IAWs.

Hence, there is an urgent necessity for the development of a national strategy/action plan for meeting the challenges posed by these weeds. In order to prevent future introductions, more weeds, particularly the ones that are problematic in related countries, need to be subjected to rigorous Weed Risk Analysis (WRA).

Weed Risk Analysis: The weed risk assessment (WRA) process is a science-based quarantine risk analysis tool for determining the weed potential of proposed new plant imports. WRAs are usually done at the species level but sub-specific taxa or hybrids are also occasionally assessed. Weed risk management systems play an increasingly important role in informing and guiding the development of invasive plant species policy and guiding management responses (Pheloung *et al.* 1999, Groves *et al.* 2001, Keller *et al.* 2007, Buddenhagen *et al.* 2009, Setterfield *et al.* 2010). Increased exchange of grains and seeds following globalization of agriculture is bound to result in further introductions. The sanitary and phytosanitary (SPS) agreement of WTO suggests that the countries not only update their quarantine laws, but also incorporate the elements of pest risk analysis for making regulatory decisions for both import and export. Therefore, there is an urgent need to analyze the risk factors associated with different exotic weeds to design safeguards and to lower the risk of their entry. This entails generating data on weed biology, list of quarantine weeds to facilitate trade etc. The department of Plant Protection, Quarantine and Storage, Government of India has strengthened the system by deployment of weed scientists at selected entry points to intercept consignments containing weed seeds. It has also notified through the gazette, the weeds of quarantine significance. Australia, New Zealand, USA have

developed protocols for weed risk analysis and for identification of quarantine weeds. We may use their expertise in this matter.

Herbicide residues and environmental safety: Agriculture has gone through major changes during the last century. It has developed from a more or less extensive subsistence farming to a highly intensive, often mechanized production system relying heavily on inputs both energy as well as other resources. Thus, production has become dependent on chemical inputs like pesticides and fertilizers. A change from a high-input and chemically-intensive agriculture to a more sustainable form is not only desirable, but also has become a necessity.

As herbicide use is likely to increase substantially in the future, their judicious use is of utmost importance to avoid the build up of toxic residues in soil which will affect certain sensitive crops grown in rotation. The indiscriminate use of pesticides leaves behind residues in food chain and environment. Widespread and increased use of herbicides is likely to cause greater concern about potential ecological effects. There is danger of herbicides contaminating the soil and the ground water. Their effect on non-target organisms (microbes, earthworms etc) is also of equal interest. To avoid the potential ill effects, strict registration and regulatory mechanism be developed.

The work should be undertaken in collaboration with Network Project on Pesticide Residues of ICAR which is currently putting greater emphasis on other pesticides, particularly insecticides, as they form bulk of the pesticide market and are also the main culprits implicated for contaminating the food.

Research efforts have to be stepped up to meet the challenges of increased use of herbicides. Educating farmers on the safe use of herbicides and integrating chemicals with other methods of weed management are considered to be important. Monitoring herbicide residues in environment and food chain should continue to be an important activity as new chemicals are expected to be introduced into the market. Permanent herbicide trials (PHTs) have been planned in major cropping systems under different agro-ecological regions of the country under AICRP-WC which would yield a wealth of information on

the long-term implications of herbicide use, including effect on crop productivity, weed flora shifts, resistance of weeds, etc.

Herbicide resistance in weeds: Continuous use of herbicides can lead to the development of resistance in weeds to herbicides *viz*. isoproturon resistance in *Phalaris minor* in some parts of the country. This was a costly lesson learnt as the weed devastated the crop and threatened the sustainability of the rice-wheat system for nearly a decade until the new alternate herbicides were introduced. This kind of phenomenon will continue to be a problem in the foreseeable future as well. Emerging similar problem in other crops and cropping systems are to be monitored based on long term findings. Now it is widely agreed not to depend on one particular method of weed management but to combine them suitably. With respect to the use of chemicals, there is greater wisdom in rotating the herbicides, using herbicide mixtures and integrate with time tested management practices such as crop rotation, tillage etc. The wheel has come full circle. Now the challenge is how to make these practices effective and economical.

Non-chemical weed management: The growing concern for human health and sustainability of agricultural production is giving way for organic farming in some parts of the world. In view of this, integrated weed management practices involving non-chemical methods such as mechanical and cultural (zero tillage, conservation tillage, plant residue management, soil solarization, growing intercrops, cover crops and green manure crops) be given due emphasis. However, it is a big challenge to make these non-chemical methods of weed management effective and economical. Soil solarization technique developed by this Directorate is a novel one, capable of controlling not only weeds, but also some soil-borne diseases and nematodes for at least two seasons. Notwithstanding the high cost, soil solarization considering its wide impact, may become very popular in future at least in nurseries and in high value crops and in organic agriculture.

The success achieved in controlling *Phalaris minor* using zero tillage technology in Indo=-Gangetic plain may be explored in other wheat growing regions. Through large-scale trials conducted throughout the Indo-gangetic plain, it has

been demonstrated that ZT is able to effect *P. minor* control in wheat to the extent of 20-30 per cent. Besides controlling *P. minor* this technology would also result in saving on account of land preparation.

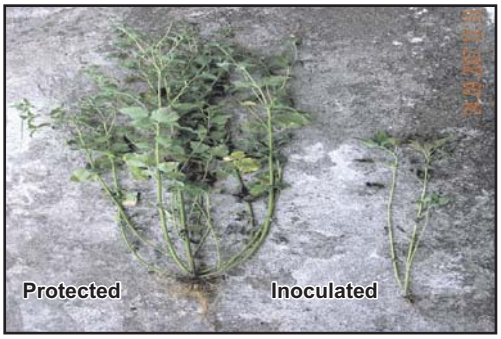
In maize, growing cowpea as an intercrop for fodder or green manure was found to suppress the weeds quite significantly. Where as in mustard, better weed control and higher total productivity can be obtained by intercropping with berseem. Incorporation of *Sesbania* grown as intercrop may be incorporated in upland direct-seeded rice can be adopted for managing weeds and obtaining higher grain yield.

Biology and ecology of weeds: It was evident from several years of research that there is considerable variation in the floristic composition of weeds not only from different regions but also from field to field in the same eco-region. This highlights the role of crop management practices in general and weed management practices in particular, adopted by the farmers. Every single agronomic operation has a direct or indirect bearing on weeds. Weeds are not static but respond positively to management practices. Particular rotation with, particular tillage and a particular weed management practice followed for few years will lead to the preponderance of some weeds. A minor weed may emerge as a major one after a couple of years under a set regime. The impact of herbicides on weed flora shift is also very conspicuous. Herbicides exhibit varied effect on weeds depending upon their morphological, physiological and biochemical characteristics. However, little or no research worth the name on biology and ecology of weeds, which otherwise form the basis for developing sound integrated weed management practices.

Biological control of weeds: There is sufficient scope for managing weeds at least in non-cropped areas through the use of exotic insect pests as has been successfully proved in the management of *Parthenium* by the Mexican beetle (*Zygrogramma bicolorata*), water hyacinth by *Neochetina* spp. and *Salvinia* by *Cyrtobagous salviniae* (Gangavisalakshi and Sushilkumar 2007). Looking to the various advantages of this technology, the work on biological control of weeds has to be further intensified in the future. However, any biocontrol agent has an

associated risk to change its behaviour and host specificity which may have to be looked into with great depth and vision.

Biocontrol of water hyacinth



Reduced growth of Lagascea mollis due to *Puccinia* sp. (isolate NRCWSR-3) infection

Global climate change: It is expected that the growth of C_3 plants would be enhanced by CO_2 enrichment as compared to C_4 plants. The differential effect of CO_2 enrichment on C_3 and C_4 plants may have significant implications for crop weed interaction since majority of crops belongs to C_3 where as large number of weeds belongs to C_4 category. Therefore, it is very essential to undertake basic and strategic research including physiological, biochemical and molecular aspects to evolve fitting weed management technology.

Elevated CO_2 favored parthenium root growth

Herbicide tolerant crops and development of super weeds: Imparting resistance to normally herbicide susceptible crops to produce herbicide-tolerant crops (HTCs) has been the extensively exploited area of plant biotechnology. HTCs make efficient management of problem weeds easy with minimum risk to the crop. Resistance genes for several herbicides or herbicide modes of action have been incorporated into the genome of various crops, *viz*. corn, cotton, canola and soybean, and have been commercialized. Consequently, worldwide the area under HTCs is increasing rapidly with every passing year since their commercialization in the late nineties of twentieth century. However, apprehension is being raised regarding the possibility of development of 'super

weeds' due to introduction of Herbicide Tolerant Crops. The country should be ready with the package of technologies to address such situation. Biotechnology also has application in development of bio-herbicides and myco-herbicides which needs to be harnessed adequately.

Utilization of weeds: Proper utilization of the huge biomass being produced by the problematic weeds, like water hyacinth, *Chromolaena, Lantana, Parthenium*, *Ipomoea*, etc., through appropriate technologies, like vermicompost, mulch, phytoremediation, etc., may help in supplementing chemical fertilizers besides adding organic matter to the soil. Some weeds having high nutritional value, like alligator weed *Alternanthera philoxeroides*, can be used as fodder for animals. Utilization of weeds as a source of ayurvedic medicines, bio-pesticides and bio-fuel also has enough potential. Attempts may be made to develop technologies for making paper, particle boards, furniture etc. by using weed biomass. Such activities are expected to raise income and employment opportunities. As the basic research in relation to weed management is badly neglected, possibilities of forging collaboration with non-agricultural universities in the areas of taxonomy, ecology, biosystematics, etc. will be explored.

Water hyacinth mulch in potato

Awareness creation and technology transfer: The weed management technologies have not reached the farmers at the same pace as happened in case of varieties, fertilizers and insecticides. One of the main reasons could be that unlike other pests, the losses caused by weeds are invisible and many a time is ignored by the farmers in spite of the fact that they cause maximum losses. Lack of awareness regarding losses caused by weeds and ways to control them are still the major reasons for poor adoption of weed management technologies. Another important reason for the lower impact could be the inadequate awareness among farmers of the new technologies. The set up in many states is lethargic and inefficient. Many extension agencies do not give much attention

on weed management that it deserves. As a result of which the adoption of herbicides is also skewed. As they are more popular in rice, wheat, tea and soybean only that too in few states like Punjab, Haryana, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and Gujarat. In some places because of poor demand of herbicides that are not commercially available to those interested in using them. Therefore, there is a strong need to work in collaboration with herbicide industry/ private sector to correct this imbalance and on the other hand, the cost-effective weed management technologies through field demonstrations, electronic media, trainings and participation in *kisan melas*, etc need to be popularized. It is important to involve farmers in testing and refinement of the technologies. Efforts should also be made to study the impact analysis of weed management technologies. The Directorate would intensify technology awareness and transfer activities by bringing out technology capsules both in printed and electronic versions and distributing them to all KVKs, SAUs, NGOs etc. AICRP-WC Directorate would translate them into the respective local languages and take up further dissemination for the benefit of all stakeholders. Since private sector is emerging as a strong force in technology generation, acquisition and transfer, suitable mechanism of linkage between public and private sector in assessing and transferring appropriate technologies in a complementary fashion should be enforced. Therefore, there is a great need to popularize the cost-effective weed management technologies. Although the increased number of herbicides introduced into the Indian market is a reflection of the popularity of the herbicides as a tool for weed management, systematic studies to assess the impact of improved weed management technologies is required.

Strategy and Framework

The future weed problems will be multi-pronged and narrow strategy can not work. Therefore, a holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative. Scientists will also be encouraged to involve in on-farm trials in farmers' fields and take part in technology development, refinement and transfer. Effective linkages in research and technology development with SAUs and related ICAR/other institutions will be strengthened not only to avoid duplication of work but also for effective utilization of resources and to bring complementarily in research output. Efforts will be made to attract funding research proposals from external agencies in specific research areas requiring immediate attention. The following strategies would be adopted to accomplish the vision and goals of the Directorate of Weed Science Research (see ***Annexure I***).

1. Development of integrated weed management practices	Develop guidelines for incorporating the non-chemical methods (cultural/mechanical and agronomic manipulation) with chemical methods Impact of crop establishment techniques on weed management Reduce herbicide use by employing non chemical methods and techniques to improve herbicide use efficiency. Develop organic weed management practices in major field and vegetable crops. Use of plant and weed residues as mulch material
2. Managing weeds through judicious use of herbicides	Evaluate new herbicides and facilitate their registration for commercial availability Optimizing their time and dose of application and elucidating factors affecting their efficiency Integrate with other methods to reduce dose and increase efficiency
3. Developing bio-control measures for managing weeds	Explore the potential pathogens, insects, fish, allelochemicals for utilization as biotic agents for weed management (in India and abroad) Study the host (weed)-biotic agent inter-relationships and interaction with environment and human beings

	Assess the commercial feasibility for mass production of biotic agents; Host specificity and possible adverse effect on non-target flora and fauna Supply of biological agents to SAU's and AICRP-WC Directorates
4. Monitoring environmental quality	Quantify herbicide residue in soil, water and plant parts and consequent entry in thefood chain Assess the possible risk of herbicide hazards on environment Management techniques to mitigate the negative impact of herbicide residues Develop policy guidelines on herbicide residue limits in food products
5. Aquatic weed management	Understandbiology and ecology of major aquatic weeds Explore the potential native and exotic biocontrol agents against major aquatic weeds Develop techniques for enhancing the efficiency of recommended biocontrol agents Develop integrated weed management practices involving biological, mechanical and chemical methods Develop guidelines for safe use of herbicides
6. Herbicide residue management	Understand the absorption, translocation and metabolism of herbicides in crop plants and weeds Understand the antagonistic, synergistic and additive response of herbicide mixtures Monitor and quantify herbicide resistance in important weeds Interaction of other pesticides and agrochemicals-on the efficiency of herbicides Develop protocol for judicious use of herbicides Develop agronomic techniques for herbicide residue management

7. Understanding the biology and eco-physiology of crop weed interaction	Understand mechanism of weed seed dormancy and methods to overcome dormancy Long-term impact of tillage, cropping system and management practices on weed seed bank Develop weed density-crop yield models Set economic threshold limit (ETLs) of weeds in different crops Understand biology and ecology of major weeds
8. Using biotechnological tools for managing weeds	Develop and evaluate herbicide resistant crops (HRCs) Explore and develop myco-herbicides and bio-pesticides Understand the concept of genetic engineering and its feasibility in weed management Impact of herbicide resistant crops on biodiversity
9. Weed risk analysis (WRA)	Generate data on biology and ecology of important weeds and their damage potential Optimize and standard the procedure and protocols for WRA Identification of weeds of quarantine significance
10. Parasitic weeds management	Develop integrated management practices for *Striga, Cuscuta, Orobanche, Loranthus* etc.
11. Utilization of weeds for economic and social benefits	Utilize weed bio-mass as source of nutrients, bio-gas, bio-fuel, etc Phyto-remediation of industrial and municipal wastes Develop production technology for weeds with medicinal properties.
12. Monitoring dien invasive weeds (AIW) and developing control measures	Assess extent and level of infestation of AIW in different eco-systems Impact of AIW on Biodiversity Develop management strategies especially through bio-control.

13. Developing techniques for managing weeds in precision agriculture	Detect weeds by remote sensing technique Forecasting weed infestations and crop yield losses Development of variable rate technology for site-specific application of herbicides by integrating GPS and GIS
14. Developing weed database	Update National database on weeds Database on weed seed atlas. Database of weeds of medicinal importance. Strengthen library and information system Development of Decision Support Systems (DSS), simulation models and information retrieval systems on weed management Development of databases for online dissemination of information on weed management
15. Facilitating dissemination of weed management technologies, knowledge and information	Capacity building of scientist/ Subject Matter Specialists (SMS) Training programmes, HRD activities for different stakeholders Increased interaction with farmers and stakeholders through innovative approaches Socio-economic survey and impact analysis

Epilogue

DWSR is committed to play a pivotal role in developing integrated weed management strategies for improving the crop yield and to reduce the problems in other ecosystems. We envision that research activities in the field of weed science would result in the improved management of weeds in crop as well as non-crop situations, grasslands, etc. The aquatic bodies will be freed from the weed menace, thereby enhancing their aesthetic value and making them more suitable for navigation purposes. The development in weed management would augment farmers' income and will contribute towards agricultural growth. The socio-economic status of the farming community especially the small-holders will improve. Human drudgery involved in manual weeding will decrease and more gender equality will prevail, providing more time for rural women and youth to take up other subsidiary and more remunerative activities. Our environment will be clean and native biodiversity will be preserved.

Concerted efforts would be made to become more sensitive to the needs of the farming community especially that of the rainfed and dry land areas where the modern chemical methods could not make much head way and weed management is still being followed in traditional manual manner. The Directorate will develop mechanism to regularly monitor the changes in weed scenario at national level, and will develop the strategies to respond to the changes for the benefit of the farmers.

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Annexure-I : Strategic framework

Goal	Approaches	Performance measure
Weed biology and eco-physiology	Collection, identification and maintenance of weed herbarium and weed seeds	National repository of information on weed identification Improved abiotie and biotic resistance, enhanced nutrient uptake and assimilation, etc.
	Gene mining of weeds for important traits and their transfer into candidate crop plants by genetic engineering	
	Impact of transgenics resistant to herbicides on the diversity of crops and vegetation	
	Screening and development of important cultivars for high allelopathic suppression of problem weeds	
	Quantification, prediction and development of simulated models and crop yield loss estimation for setting up economic threshold limits	
	Understanding weed seed dormancy in relation to weed menace and weed management	Standardized procedures for breaking weed seed dormancy for planned management of weeds
	Weed seed bank and seed production potential of major weeds under different management conditions	
	Investigating naturally existing molecules including those in toxic plants for use as herbicides in natural and agro ecosystems.	Understating of allelopathy and invention of natural herbiddes.
	Understanding the basic mechanism(s) underlying the competitive adaptation amongst weeds over crops in context of climate change especially elevated CO_2	Strategic plan for weed management under changing environment
	In vitro maintenance of weeds, contained seed production and their cryopreservation	Collection of pure germplasm and improved access to weed genetic resources
Weed management techniques	Development of organic weed management techniques in crops and cropping systems	Developed weed management technologies and IWM modules
	Development of weed management techniques in vegetables and orchards	

Goal	Approaches	Performance measure
	Development of sustainable IWM modules for dominant cropping systems	
	Evaluation of tillage and weed management practices in important cropping systems	
	Nutrient and plant residue management on weed dynamics in cropping systems	
	Development of IWM practices for the control of parasitic weeds in different crops	
	Design, development and evaluation of wick applicator and also spray techniques for weed management in crops.	Developed design and tools for weed management
	Developing technology for precision spraying, location specific spraying, variable rate sprayers etc.	
	Design, fabrication and evaluation of mechanical weeding tools.	
Herbicide as a tool in weed management	Long term effect of herbicides on weed dynamics, soil microflora, non-targeted organisms and herbicide residues in different crops and cropping systems	Monitoring, documentation and further refinement in IWM modules
	Evaluation of new molecules	Developed recommendations and established public-private partnership in weed science
	Efficient weed management through herbicides in cropped and non-cropped situations	
	Monitoring of herbicide residue, persistence and their accumulation in soil, water and food chain	Research and development contribution in detection of herbicide residues in soil and food chain
	Examination of microbial diversity implicatedin biodegradation of herbicides	Developed database on herbicides based on the persistence
	Detection and nano-encapsulation of priority herbicide for slow delivery	Developed Nano-encapsulated formulation detection tool
	Degradation (Photochemical and microbial) of herbicides in the environment	Developed database on the loss of herbicide due to degradation and their metabolites formed in the environment
	Effect of herbicides on soil flora and fauna.	

Goal	Approaches	Performance measure
	Increasing herbicidal efficacy through herbicide mixtures, surfactants and adjuvants	Contribution towards increasing herbicide use efficiency
	Improving performance of herbicides through better application techniques	
	Investigation on uptake, translocation, mechanism of action of herbicides with a view to improve herbicide efficiency, understand herbicide resistance	
Weed database and information system	Detection, quantification and estimation of yield loss due to weeds by remote sensing technique	Developed net based database of decision support systems for major cropped and non cropped weeds
	Decision support system for weed management in cropped and non-crop situations	
	Development and updating of national database on weeds	
	Weed risk analysis (WRA) and identifying quarantine weeds	Satellite maps of major cropped and non cropped weeds
Bio-pesticides and bio-control of weeds	Constant vigil, Survey, identification biology and antagonistic potential of native bio-agents (insect pests and microbial pathogens) against important invasive weeds	Commercially available effective bio-agents and bio-compounds
	Importation, evaluation and release of potential new bio-control agents against major invasive weeds.	
	Development of cheap and effective mass production technology and delivery methods of effective bio-agents.	
	Development of biological based integrated management for the control of major invasive and aquatic weeds	
	Identification, evaluation and commercialization of plant/ soil pathogen/ microbes for biological control of major weeds	
	Identification and evaluation of phytotoxins/ secondary metabolites and allelochemicals for management of weeds	

Goal	Approaches	Performance measure
Weed utilization	Evaluation and utilization of weed biomass as source of plant nutrient and other industrial uses	Developed techniques and processed products and establish publieprivate partnership.
	Identification and evaluation of weedy plants for phytoremediation of heavy metal contaminated drain water	Establishedmodel for phytoremediation
Transfer of technology and impact assessment	Demonstrations on weed management technology in crop and non crop situations and their impact assessment.	Effective weed management technologies disseminated on the basis of extent/level of adoption.
	Testing and refinement of weed management technologies	
	Capacity building of scientists	Qualified manpower in weed management

NOTES

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