NRCWS Perspective Plan

VISION-2025

भाकृअनुप
ICAR

NRCWS

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

CONTENTS

FOREWORD OF DIRECTOR GENERAL

Indian agriculture must continuously evolve to remain ever responsive to manage the change and to meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. In order to capitalize on the opportunities, we at the ICAR attempted to visualize an alternate agricultural scenario from present to twenty years hence. In this endeavor, an in-depth analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) was undertaken to place our research and technology development efforts in perspective so that we succeed in our pursuit of doing better than the best. Accordingly, the researchable issues are identified, strategies drawn and programmes indicated to have commensurate projects and relevant activities coinciding with the launch of the 11th Five Year Plan.

Weeds are a big constraint in crop production and are responsible for heavy yield losses in almost all the crops. Weeds also endanger biodiversity, affect human and cattle health, aquatic ecosystem, grasslands, etc. Out of the losses due to various biotic stresses, weeds are known to account for nearly one third. The problems due to weeds are more evident in the era of modern agriculture due primarily to large-scale use of high doses of fertilizers and irrigation as well as due to the increasing trade. In view of the heavy yield losses inflicted by weeds, the National Research Centre for Weed Science was set up in April, 1989 to act as a nodal center for research and training in the field of weed science in the country.

The major issues being faced in the field of weed management are the threat of invasive alien weeds, development of protocols for weed risk analysis to prevent the entry of alien weeds, herbicide residues and environmental safety, management of herbicide resistant weeds, weed shift in emerging farming situations like organic farming and conservation tillage, biological control of weeds, effect of global climate change on crop weed interaction, exploitation of biotechnological means for development of HRCs, management of problem weeds like parasitic, perennial, aquatic and weeds of non-cropped areas.

It is expected that realizing the Vision embodied in the document would further ensure that the NRC for Weed Science, Jabalpur continues to fulfill its mandate to make Indian agriculture locally, regionally and globally competitive. The efforts and valuable inputs provided by my colleagues at the ICAR Headquarters and by the Director and his team at the Institute level for over an year to develop Vision 2025 deserve appreciation.

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and
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March, 2007

PREFACE

Weeds are plants that are undesirable to human activity at a particular time and place, and therefore, weeds will always be associated with human endeavours. Weeds pose serious problems to agriculture and environment. In agriculture these not only cause huge reductions in crop yields but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect pests, diseases and nematodes. In non-crop areas, they affect aesthetic look of the ecosystem as well as native biodiversity and health and quality of life.

National Research Centre for Weed Science (NRCWS) was set up in April, 1989 to act as a nodal institution in weed science for providing leadership through basic and applied multi-disciplinary research; training; and, national facility for research and information. In fact, it is the only set-up of its kind in the entire world where the problems posed by weeds are addressed in a comprehensive manner using multidisciplinary approach. Despite several constraints of facilities and manpower, during the short period of its existence, the Centre has significantly contributed in the areas of identifying major weeds in different crops and cropping systems of the country, weed dynamics in crops and cropping systems, evaluation of new herbicides and making herbicide recommendations, monitoring of herbicide residues in food chain and environment, non-chemical and biological methods of weed control, management of parasitic, aquatic, perennial and invasive weeds, allelopathic potential of prominent weed species, development of national database of weeds and transfer of improved weed management technologies.

The 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. Some of the challenges that are likely to emerge in future which need scientific redressal on priority basis, include impact of alien invasive weeds, the role of global warming on weed diversification, new weed introductions of quarantine importance etc.

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 already made. To meet these numerous challenges, the Centre strongly needs to be upgraded to the level of an Institute with more manpower, matching facilities and budget. Capacity building of scientists is also very essential in the frontier and emerging fields of weed science.

I sincerely thank Dr. Mangala Rai, Secretary, DARE and Director General, ICAR and Dr. J.S. Samra, Deputy Director General (NRM), ICAR for their unstinted guidance in preparing this document. Thanks are also due to Dr. A.K. Gogoi, Assistant Director General (Agronomy), NRM, ICAR for his keen interest. The valuable suggestions by the members of the Research Advisory Committee and all other eminent weed scientists are also gratefully acknowledged. I also thank the scientists of the Centre for giving their valuable inputs. I appreciate Dr. M.B.B. Prasad Babu, Dr J.S. Mishra, Dr. M.S. Raghuvanshi and Mr. Sandeep Dhagat for their painstaking efforts in preparing this document.

(Jay G. Varshney)
Director, NRCWS

Explanation to abbreviations

AAU	Assam Agricultural University
AICRP-WC	All India Coordinated Research Programme on Weed Control
CABI	Commonwealth Agricultural Bureaux (CABI International)
CABPEST	Commonwealth Agricultural Bureaux on PEST
CABSAC	Commonwealth Agricultural Bureaux for South Asian Countries
CBD	Convention on Biological Diversity
CGIAR	Central Government
CIAE	Central Institute of Agricultural Engineering
CRC	Current Research Contents
CSIR	Centre for Scientific and Industrial Research
CSWCRI	Central Soil Water Conservation Research Institute
DAC	Department of Agriculture and Cooperation
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DST	Department of Science and Technology
GMO	Genetically Modified Organisms
GPS	Global Positioning System
HPLC	High Performance Liquid Chromatography
HRC	Herbicide Resistant Crops
IARI	Indian Agricultural Research Institute
IASRI	Indian Agricultural Statistical Research Institute
ICAR	Indian Council of Agricultural Research
IIBAT	International Institute of Biotechnology and Toxicology
IIT	Indian Institute of Technology
ISRO	Indian Space Research Organization
JNKVV	Jawaharlal Nehru Krishi Vishwa Vidhyalaya
KVK	Krishi Vigyan Kendra
MoEF	Ministry of Environment and Forests
NATP	National Agricultural Technology Project
NBAIM	National Bureaux of Agriculturally Important Microorganisms
NBRI	National Botanical Research Institute
NBSSLUP	National Bureaux of Soil Survey and Land Use Planning
NCAP	National Centre for Agricultural Economics and Policy Research
NRCWS	National Research Centre for Weed Science
NRM	Natural Resource Management
NRSA	National Remote Sensing Agency
PDBC	Project Directorate on Biological Control
PDCSR	Project Directorate for Cropping System Research
QRT	Quinquennial Review Team
RAC	Research Advisory Committee
RDVV	Rani Durgavati Vishwa Vidyalaya
RPF	Research Project Files
RWC	Rice Wheat Consortium
SRC	Staff Research Council
SWOT	Strength, Weakness, Opportunities and Threats
USDA	United States Department of Agriculture
WRA	Weed Risk Analysis
WTO	World Trade Organization
ZSI	Zoological Survey of India

Executive Summary

"Being fore-warned is fore-armed" is the principle behind preparation of perspective plans. Weeds are big constraints in crop production and are responsible for heavy yield losses in all crops. Out of the losses due to various biotic stresses, weeds are known to account for nearly one third. A recent study undertaken at this Centre suggests that proper weed management technologies if adapted can result in an additional production of 103 million tonnes of foodgrains, 15 mt of pulses, 10 mt of oilseeds and 52 mt of commercial crops, per annum, which in few cases are even equivalent to the existing annual production. This amounts to an additional income of Rs. 1,05,036 crores per annum.

The problems due to weeds are more evident in the era of modern agriculture due primarily to large scale adoption of HYVs and hybrids and use of high doses of fertilizers and irrigation. Increased human activity characterized by destruction and disturbance of natural ecosystems have also increased the problem of environmental weeds.

NRC for Weed Science is the nodal centre for research and training in the field of weed science in the country. Infact it is the only centre of its kind in the entire world. Established in 1989, the Centre became fully functional as late as in the year 2000. Since then, it is developing fast and equipping itself with modern tools and instruments needed for quality research. It also has the support of AICRP on Weed Control currently operating of 22 SAUs located at different agro-ecological regions of the country.

This Perspective Plan sets NRCWS' path of scientific research, technology development and transfer and human resources development for achieving enhanced productivity, sustainability, ecological and environmental security and socio-economic equity. During the short span of its existence, the NRCWS has established itself as a Centre of excellence in the field and is all set for providing the much needed leadership in this important area of research.

Weed science research is currently experiencing unprecedented pressures and prospects. At one hand there is pressure on scaling down the emphasis on herbicide use which is otherwise providing solution to many weed problems at an affordable cost. On the other hand there is a growing demand for non-chemical methods whose effectiveness and cost-competitiveness are sometimes questionable. There is a need for judicious mix of both the chemical and non-chemical methods for sustainable weed management.

Some of the significant contributions made by NRCWS have been the development of a national data base on weeds, identification of major weeds in each cropping system under different agro-climatic zones of the country, preparation of district-wise weed atlas and weed maps, developing herbicide recommendations in different crops, development of integrated weed management modules for different crops and cropping systems and management of invasive weeds such as *Parthenium* & Water hyacinth through biocontrol agents etc. The center has undertaken several studies on basic and strategic research, some of the important ones being biology and ecology of major weeds, ecophysioloy of crop-weed interaction, identification of plant phytotoxins with herbicidal properties etc. However, much needs to be done, particularly considering the challenges thrown by the globalization of agriculture.

The technologies developed by the center and the AICRP on Weed Control have made good impact on crop production. In general, they proved more effective, economical, labour-saving and involved less human drudgery. The demonstrations carried out in farmers' fields have shown yield increase in field crops in the range of 5-30 per cent over farmers' method. Technologies such as the herbicide use has increased from less than 1000 MT in 1980s to over

12,000 MT in 2002-03. Herbicide use is the highest in wheat (57 per cent), followed by rice (17 per cent), plantation crops (9 per cent) and soybean (4 per cent). The use in other crops, however, is considerably low because of a variety of reasons.

The impact of biological control of *Parthenium* using Mexican beetle (*Zygogramma bicolorata)* is particularly noteworthy. Due to the Centre's efforts during 2001-2004 in multiplying and distributing insects to all parts of the country, the insect is believed to have been established in about one-quarter of the infested area of 7-8 mha.

Some of the unintended negative impacts of herbicide use are persistence in soil, pollution of ground water, toxic residues in food (contamination), feed and fodder, adverse effect on non-target organisms and development of resistance in weeds. Many of these apprehensions are not supported by scientific findings/ explanations. Large scale monitoring of herbicide residues under AICRP-Weed Control over several years have shown that most herbicides when used at recommended time and method of application did not leave residues in soil and grain samples. The effect on soil productivity and on soil microbes too was only transient. Judicious use of these chemicals has been found to have no adverse effect on environment. This is due to the fact that herbicides are moderately to less toxic and that these are applied during the initial stages of crop growth. Notwithstanding these apprehensions, herbicides would remain as one of the major tools in weed management in view of the huge benefits these offer to the farmers. However, extensive research efforts are needed to allay such fears or apprehensions among the public regarding the use of herbicides.

This document is prepared keeping in mind the key issues such as globalization of agriculture and its implications on competitiveness in world market, possible introduction of exotic weeds and quality (residue-free) parameters; sustainability of agricultural systems, environmental protection and conservation, equity, gender equality, biodiversity, increasing profitability, employment generation etc. The advances made in cutting edge technologies such as biotechnology, information and space technology etc. have been considered in developing the research programmes.

Scenario of weed situation in the coming times (Chapter 6 of this document) highlights the major challenges that are likely to emerge on the basis of which a comprehensive research programme has been drawn. It includes:

- Long-term impact of weed control methods
- Development of integrated weed management strategies
- Biology and eco-physiology of crop-weed interaction
- Judicious use of herbicides
- Weed control through bio-control agents and bio-pesticides
- Design, development of weeding tools and herbicide applicators
- Herbicide residues and environmental quality
- Utilization of weeds
- Weed database and information system
- HRD, transfer of Technology and impact analysis

Weeds in non-crop areas have taken center-stage with some such as *Parthenium*, *Mikania micrantha, Chromolaena odorata,* Water hyacinth, *Ageratum spp.* threatening the biodiversity as well as health of human beings and animals. More alien weeds are expected to gain entry into the country following liberalization of agriculture and trade.

The programmes have been put on a time scale along with the levels of emphasis each one receives in a particular time-frame. Multi-disciplinary and systems approach will be adopted to achieve the objectives. The linkages with national and international institutions and agencies, private sector, NGOs etc., will be sought in R&D and technology transfer.

In order to meet the targeted mandate and all the outlined objectives as enumerated in the Scenario (Chapter 6), it has been proposed to upgrade the Centre to Institute level and create facilities in accordance with the recommendations of the QRT (1996-01). The proposed cadre strength of the new set up would be 41 scientists, 62 technical, 31 administrative and 41 supporting staff. The proposed infrastructural facilities include radio-tracer laboratory, biotechnology laboratory, microbiology laboratory and information and training centers. Setting up of Centres of AICRP-WC in each SAU is also proposed for giving the benefit of research to all regions.

The capacity building of scientists at NRCWS and SAUs would be given priority by organizing training programmes, encouraging participation in seminars and workshops, sabbatical leave etc. The visiting scientist scheme of ICAR will be implemented in some selected areas. Training of foreign nationals from less developed countries is also proposed.

Activities related to technology transfer will receive the highest priority. Weed management technologies, crop-wise and cropping system-wise, both in print and electronic form (CD and online) will be prepared and distributed to all SAUs, state departments of agriculture, selected NGOs with a request translate them in respective local languages and further dissemination amongst other agencies (KVKs, Panchayats etc.). Full advantage of print and electronic media will be taken to reach the masses. Similar technology awareness raising activities will be undertaken regarding invasive weeds in non-crop areas. The other stakeholders such as departments of forest, irrigation, tourism, railways etc. will also be involved.

1. PREAMBLE

Weeds pose serious problems to agriculture and environment. Out of the total 826 weed species reported in the country, 80 are considered as very serious and 198 as serious weeds. 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 yields by 31.5 per cent (22.7 per cent in winter season and 36.5 per cent in summer and *kharif* season). The composition and competition by weeds is dynamic and is 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 is also, very essential in successful management of weeds.

Considering the problem of weeds in crop fields 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 economical weed control. In 1978 the All India Coordinated Research Programme on Weed Control (AICRP-WC) 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 for which facilities were not available at different Centres. In view of this it was decided to set up a nodal centre for basic and applied research in Weed Science in the VII Five Year Plan. Thus, the present National Research Centre for Weed Science came into being in April, 1989.

The Centre, 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 making 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, allelopathic studies, management of perennial weeds and other invasive weeds in non-crop areas and transfer of improved weed management technologies.

Justification for revising the Vision 2020

Weed science is a multidisciplinary and dynamic area of research. The subject is very much advanced in developed countries where weed management is undertaken with minimal role of labour by harnessing the advances made in cutting edge disciplines such as 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 25 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 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. 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 introductions of quarantine importance etc., also necessitated a thorough revision of perspective plan.

The present document is prepared after several rounds of discussions with the scientists of the centre. In addition the opinion of members of RAC and eminent weed scientists of the country were also sought. The suggestions given by the QRTs of the Centre and AICRP-WC have also been considered while finalizing the document. The research activities shown beyond the year 2007 are based on the assumption that the Centre would be upgraded in terms of manpower and facilities as proposed in the document.

2. MANDATE

As weeds are the major yield limiting factors, proper weed management is of utmost importance for realizing increased crop productivity. The weed menace in forestry, pasture, grasslands and aquatic bodies, non-cropped areas like wastelands, public amenity areas etc. is also equally important as they threaten biodiversity and adversely impact health of man and animals as well as quality of the environment.

The Centre was initially established with the mandate "To act as a nodal institution in weed science for providing leadership through basic and applied multi-disciplinary research; training; and, national facility for research and information".

Looking at the importance of weed science in Indian agriculture, the mandate was later expanded which is as under:-

- **To undertake basic and applied 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 on research methodologies in the areas of weed science and weed management;**
- **To collaborate with national and international agencies in achieving the above mentioned goal; and**
- **To provide consultancy on matters related to weed science.**

NRCWS, being a nodal centre has to play a pivotal role in developing integrated weed management strategies for improving the crop yields and to reduce the problems in other ecosystems. But much needs to be done in future to work out effective strategies in the light of the new emerging weed problems and address issues related to globalization and WTO. The Centre will continue to have collaboration with the AICRP-WC Centres located at different regions of the country, which will act as out-reach centres to generate the location specific research recommendations.

3.1. Infrastructural facilities

Though the Centre was established in 1989, it had to work under serious constraints of manpower and space until April, 2001. With the inauguration of the administrative-cum-laboratory building in 2001, the Centre started growing in a systematic manner. Since then, efforts are being made to enrich the different laboratories with state-of-the-art and sophisticated equipments.

Research Farm: The Centre has a well-developed and properly laid-out farm of 61.5 ha with adequate farm machines including zero till seed drill, FIRBS planter and four tractors. The farm has enough irrigation facilities both conventional and sprinkler type. Besides, it has a big threshing yard, silos for storage purposes, and a field laboratory for initial processing of the bulk soil and plant samples. It also has an automatic weather station. The soil of the research farm is medium black (*Typic Haplustert*) and moderately alkaline.

In addition to these, the Centre also has facilities such as net/poly houses to conduct pot culture experiments, controlled environment growth chambers, a quarantine insectory and containment facility, and quarantine net house for research on transgenics. Facilities like aquatic chambers are also available for conducting research on aquatic weeds.

Laboratories: The Centre can boast of having modern equipments such as nitrogen auto analyzer, HPLC, GLC, UV-Visible double beam spectrophotometer, atomic absorption spectrophotometer, multi-probe soil moisture measuring system, canopy analyzer, fluorescence meter, universal research microscope with photographic attachment, stereo zoom research microscope, leaf area meter with colour image analysis system, IRGA, image analyzer (computerized), stereo zoom research microscope, high speed refrigerated centrifuge, Millipore water purification system, GPS, freezing microtome for histo-pathological studies and a lyophilizer for making myco-herbicidal formulations besides other routinely used scientific equipments such as hot air ovens, BOD incubators, high precision electronic balances, and open top chambers for studies on CO_2 enrichment.

The Centre also has a small but modestly well-equipped workshop for designing, fabricating and developing weed control tools and implements.

ARIS Cell: The ARIS cell of the Centre is well equipped with the latest software including specialized ones such as ArcInfo, ERDAS Imagine, a broadband VSAT, LAN and a server. In addition all the scientists are also provided with computers, e-mail and internet facility.

Library: The Centre's library is well enriched with a good collection of literature in the field of weed science besides facilities such as CABPEST and CABSAC CDROMs and Current Contents on Diskette on biological sciences. The library subscribes to about 67

Indian and 17 foreign journals and presently has about 1300 reference books in the area of weed science.

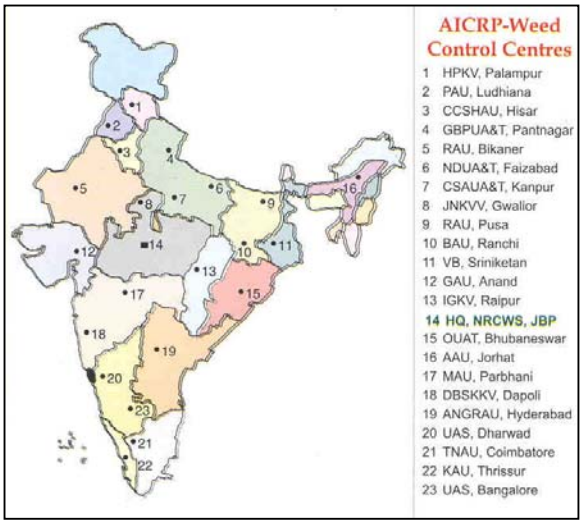
The growth pattern of library expenditure is as follows:

Expenditure pattern *(Rs. in lakhs)*	VII Plan	VIII-Plan	IX-Plan	X-Plan
Library	2.86	13.54	9.39	10.42*

* *Estimates*

Others: Modern facilities like conference/ committee halls equipped with LCD projector and public address system are available for holding scientific conferences, meetings and group discussions. In addition, a small museum is also developed for displaying various weeding implements collected from different places in India. The Centre also has a modest information centre with exhibits depicting significant research results and the technologies developed at the Centre. In addition the laboratories are also provided with uninterrupted power supply by a 33 KV generator set.

Net working and collaboration



NRCWS acts as the Project Coordinating Cell for the AICRP on Weed Control which is currently operating at 22 SAU's located at different agro-climatic zones of the country. The NRCWS also collaborates with several other educational and research institutions. An MoU was signed with Jawaharlal Nehru Krishi Vishva Vidyalaya (JNKVV), Jabalpur enabling better collaboration in the area of research, teaching and extension. It has also been recognized by Rani Durgawati Vishva Vidyalaya (RDVV), Jabalpur as a post-graduate research centre for their students. In addition, the centre is open to several educational institutions all over the country for their research and training activities.

The Centre has active collaboration with several ICAR Institutes and other research organizations like Delhi University and IIT, Delhi, DBT, DST, CSIR, ISRO etc. Besides, a healthy interaction exists between the Centre and the herbicide industry, NGOs and others.

Besides the in-house projects, the Centre also handles a number of externally funded projects on specific themes, the details of which are as under:

S. No	Project title	Duration		Funding agency
		From	To	
1	Biological control of weeds by plant pathogens	1994	1997	DBT
2	Studies on the pest potential by the Mexican Beetle introduced for bio-control of *Parthenium*	1995	1998	ICAR
3	Developing strategies for the management of *Parthenium* weed in India using fungal pathogens	1997	2001	*CABI , UK*
4	Biological control of *Echinochloa crusgalli* in rice and *Phalaris minor* in wheat crop	2000	2003	ICAR
5	Role of insects in suppression of problematic *alligator weed Alternanthera philoxeroides* and testing of herbicides for integrated management	2000	2003	ICAR
6	Phytotoxicity of allelochemicals to aquatic weeds	2000	2003	ICAR
7	Fate and phytotoxicity of applied herbicides and their impact on nutrient cycle in relation to soil factors and management practices	2002	2004	ICAR
8	Evaluation and management of allelopathic influences of crops and weeds of rice-wheat cropping system	2002	2004	ICAR
9	Development of national database on weeds.	2001	2004	NATP
10	Integrated management of *Cuscuta* sp. in field crops.	2002	2004	NATP
11	Molecular characterization and field trials of mustard transgenic for hybrid seed production and resistance to herbicides (In collaboration with Delhi University and IARI, New Delhi)	2002	2005	DBT
12	Organization and management PME (In collaboration with NCAP)	2002	2004	NATP
13	Systematic study on weed seeds of India (In collaboration with AAU, Jorhat)	2002	2005	ICAR

S. No	Project title	Duration		Funding agency
		From	To	
14	Large scale demonstration on management of Parthenium through integrated approach (Net-work project with 7 other centres)	2004	2007	DBT
15	Determination of the role of weeds in epidemic and perpetuation of economically important plant viruses (In collaboration with IARI)	2004	2007	ICAR
16	Effect of elevated atmospheric carbon dioxide (CO_2) on crop-weed interactions	2004	2007	ICAR
17	Detection of Weeds for Precision Crop Management Using Remote Sensing Technique	2004	2007	ISRO
18	Augmentation & activity enhancement of Mexican beetle (*Zygogramma bicolorata*) for biological control of *Parthenium*	2005	2007	ICAR

3.2 **Budget:** Plan-wise budget allocation of NRCWS is as follows.

Rs in Lakhs

Plan	Plan	Non-Plan	Total
IX	612.81	569.22	1182.03
X	823.47	1020.62	1844.09
XI*	1895.00	1954.00	3849.00

* projected

3.3 **Manpower:** The details of sanctioned strength as well as staff in position of NRCWS is as shown in the following table.

Plan Period	Scientists		Technical		Administration		Supporting	
	S	P	S	P	S	P	S	P
VII	27	8	27	17	17	11	25	18
VIII	27	13	27	23	17	11	25	25
IX	27	16	27	24	17	08	25	25
X	27	16	35	25	18	10	25	23

S-Sanctioned P-In position

Despite several constraints of facilities and manpower, during the short period of its existence the Centre has been able to accomplish good achievements. However, with the strengthening of infrastructural facilities since April 2001, the Centre is poised to fulfill the major expectations of undertaking basic and strategic research, providing leadership and coordinating weed science research in the country besides acting as a repository of information in the field of weed science. Following are some of the major achievements:

4.1 NATIONAL DATA BASE ON WEEDS

- From the huge data built-up over years by the AICRP-Weed Control, the Centre has developed a comprehensive 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.

- A weed atlas depicting the weed distribution maps of different agro-ecological regions of the country has also been prepared.

4.2 WEED MANAGEMENT IN CROPS AND CROPPING SYSTEMS

4.2.1 INTEGRATED TECHNIQUES

- In greengram intercropped with rice, pre-emergence application of pendimethalin 1.0 kg/ha with hand weeding at 25 DAS significantly reduced the weed biomass and increased the yield of both the crops.
- In mustard, better weed control and higher total productivity can be obtained by intercropping with berseem and pre-emergence application of pendimethalin 1.0 kg/ha followed by one hand weeding.
- In upland direct-seeded rice, an integrated strategy of growing cowpea or *dhaincha* as an intercrop and pre-emergence application of pendimethalin (1.0 kg/ha) followed by a manual weeding at 20 DAS has been found appropriate for reducing weed competition.

- Summer ploughing followed by glyphosate application (2.0 kg/ha) at 4-6 leaf stage in the month of April or sequential application of glyphosate 2.0 kg/ha and 1.5 kg/ha, have been found effective in controlling *Saccharum spontaneum* (*Kans*).

- In tomato, application of pendimethalin and fluchloralin both at 1.0 kg/ha integrated with earthing-up at 45 days and five hand weedings proved effective.
- In blackgram, pre-emergence application of oxyfluorfen 0.10 kg/ha, pendimethalin 0.75 kg/ha, fluchloralin 0.90 kg/ha and two hoeings at 3 and 5 weeks after sowing were found very effective.
- In okra, pre-sowing application of fluchloralin 0.90 kg/ha, pendimethalin 0.75 kg/ha and metolachlor 1.0 kg/ha (both pre-emergence) followed by hand weeding and hoeing at 6 weeks after sowing proved effective against associated weed growth. Application of pretilachlor 1.0 kg/ha, anilofos 0.40 kg/ha and pendimethalin 1.0 kg/ha proved equally effective in reducing the weed growth.

4.2.2 HERBICIDAL TECHNIQUES

- Application of pendimethalin at 1.0 kg/ha as pre-emergence was found safe and effective against *Cuscuta* in niger, chickpea, linseed and lentil.
- In berseem, imazethapyr application as pre-planting incorporation at 50 and 100 g/ha and post-emergence at 100, 150 and 200 g/ha provided green forage yield at par with that of weed free condition.
- In rice-wheat system, sequential application of butachlor (rice) and isoproturon (wheat) and butachlor fb hand weeding have been found effective against *Echinochloa* sp. and *Fimbristylis* sp. in rice.
- Continuous use of butachlor in rice and isoproturon in wheat has reduced the problem of *Echinochloa colona* in rice and *Phalaris minor*, *Cichorium intybus* and *Chenopodium album* in wheat. The problem of *Commelina communis* and *Cyperus iria* in rice and *Chenopodium ficifolium* in wheat has, however, increased.
- Herbicide recommendations for various crops and cropping systems have been made based on the multi-disciplinary and multi-location trials conducted in different agro- climatic zones. Some of the important herbicide recommendations for different crops as follows:
  - **Rice**: Ethoxysulfuron 0.015 kg\ha post-em, fenoxaprop 0.06 kg\ha post-em, flufenacet 0.12 kg\ha post-em, pretilachlor 0.75 kg\ha pre-em, Butanil 3.0 kg\ha post-em, dithopyr 0.12 kg\ha pre-em, acetachlor 0.15 pre-em, chlorimuron + MSM 0.004 post-em.
  - **Wheat**: Metribuzin 0.25 kg\ha post-em, fenoxaprop 0.09 kg\ha post-em, flufenacet 0.3 kg\ha post-em, Clodinafop 0.06 kg\ha post-em, sulfosulfuron 0.03 kg\ha post-em, metsulfuron 0.004 kg\ha post-em, isoproturon 1.0 kg\ha post-em, chlorosulfuron 0.015 kg\ha pre-em, dicamba 0.5 kg\ha post-em, tralkoxydim 0.3 kg\ha post-em, triasulfuron 0.002 kg\ha post- em .
  - **Soybean**: Alachlor 1.0–1.5 kg\ha pre-em, bentazon 0.75–1.0 kg\ha post-em, butachlor 1.5–2.0 kg\ha pre-em, chlorimuronethyl 0.008–0.012 kg\ha post-em, fluazifop-p-butyl 0.25–0.50 kg\ha post-em, fluchloralin\trifluralin 0.75–1.0 kg\ha ppi, imazethapyr 0.10–0.15 kg\ha post-em, lactofen 0.15-0.20 kg\ha post-em, metolachlor 1.0–1.5 kg\ha pre-em, metribuzin 0.50–0.75 kg\ha pre-em, metsulfuron methyl 0.004–0.006 kg\ha post-em, oxadiazon 0.75–1.0 kg\ha pre-em, oxyfluorfen 0.15–0.20 kg\ha pre-em, pendimethalin 0.75–1.0 kg\ha pre-em, sethoxydim 0.25–0.50 kg\ha post-em,

- **Groundnut**: Alachlor 1.5 kg\ha pre-em, fluchloralin\ trifluralin 0.75–1.0 kg\ha ppi, oxadiazon 0.5-0.75 kg\ha pre-em, pendimethalin 0.75–1.0 kg\ha pre-em,
- **Rapeseed and Mustard**: Fluchloralin 1.0 kg\ha ppi, isoproturon 1.0 kg\ha pre-em, oxadiazon 0.75 kg\ha pre-em, pendimethalin 1.0 kg\ha pre-em,
- **Safflower**: Alachlor 1.0–1.5 kg\ha pre-em, fluchloralin\ trifluralin 0.75–1.0 kg\ha ppi, oxadiazon 0.75–1.0 kg\ha pre-em,
- **Sesame**: Alachlor 1.0–1.5 kg\ha pre-em, fluchloralin\ trifluralin 0.75–1.0 kg\ha ppi, oxadiazon 0.75–1.0 kg\ha pre-em, thiobencarb 1.0–1.5 kg\ha pre-em,
- **Castor**: Fluchloralin 1.0 kg\ha pre-plant incorporation, metolachlor 1.0–1.5 kg\ha pre-em, pendimethalin 1.0 kg\ha pre-em,
- **Sunflower**: Alachlor 1.0–1.5 kg\ha pre-em, fluchloralin\trifluralin 1.0 kg\ha ppi, metolachlor 1.0–1.5 kg\ha pre-em, oxadiazon 0.50–0.75 kg\ha pre-em, pendimethalin 0.75-1.0 kg\ha pre-em.
- **Linseed**: Fluchloralin 1.0 kg/ha ppi, isoproturon 0.75–1.0 kg/ha pre-em, oxadiazon 0.75 kg/ha pre-em, oxyfluorfen 0.15-0.20 kg/ha pre-em, pendimethalin 1.0 kg/ha pre-em.
- **Niger**: Alachlor 1.0 kg/ha pre-em, butachlor 1.0–1.5 kg/ha pre-em, fluchloralin 1.0 kg/ha ppi, oxadiazon 0.75–1.0 kg/ha pre-em, pendimethalin 1.0 kg/ha pre-em.
- **Onion**: sequential application of pendimethalin at 1.0 kg/ha as pre-emergence spray followed by application of pendimethalin at the same rate as sand mix at 30 days after planting has been found to be a cost effective strategy for broad spectrum weed control.

4.2.3 CULTURAL TECHNIQUES

- Soil solarization (covering the soil with transparent polythene films) alone as well as with FYM @ 5 t/ha for a period of 6 weeks has shown excellent control of most of the annual weeds in soybean–wheat and sesame-tomato systems. However, it has no effect on the seed reserves of *Medicago hispida* even at germinating zone.
- In rice–wheat system, zero-tillage in wheat has reduced the population of *Phalaris minor* whereas wild oat population increased.

- A long-term field experiment revealed that *Euphorbia geniculata* (a major weed in soybean) could be managed effectively by rotation with sorghum or maize.
- Long-term field experiments have conclusively shown that soybean could be grown successfully under zero tillage after wheat and linseed.
- Continuous adoption of rice - lentil system has reduced the problem of *P. minor* in lentil. The problem of *Cichorium intybus, M. hispida* and *C. album*, has however, increased in sorghum-chickpea system.

- Soybean –chickpea system has been found to increase the problem of *Euphorbia geniculata*.

4.2.4 COMPETITIVE CROP CULTIVARS

- Upland rice cultivars Vandana, Kalinga-III and RR-151-3 have shown better weed competitive ability and higher yield potential under sub-optimal weed management condition.
- Chickpea cultivars JG16, JG11 and JG315 have been found promising for weed suppression and higher seed yields.
- Wheat cultivars WH147, Raj3765, C306 and HI1077 and DL803 have been found promising with higher yields and weed competitive abilities.
- Quick growing and spreading type pea cultivar JP885 has been quite effective in weed suppression.

4.2.5 MANAGEMENT OF PROBLEM WEEDS

- Oxadiazon (0.5 kg/ha) and pendimethalin (1.0 kg/ha) as pre-emergence reduced the infestation of *Asphodelus tenuifolius* in chickpea.

- Pre-emergence application of pendimethalin (1.0 kg/ha) has effectively controlled parasitic weed *Cuscuta* spp. in niger and urdbean. Post-emergence (2 weeks after sowing) application of pendimethalin (0.5-0.75 kg/ha) has been found safe and effective in lucerne.
- Addition of surfactant (Laffmol DA) to glyphosate alone and glyphosate + sulfonyl urea (chlorimuron ethyl) increased the bioefficacy against *Cyperus rotundus* and metsulfuron methyl for *Oxalis latifolia*.
- *Scirpus grossus,* an anchored aquatic weed of low lying areas was effectively controlled by the application of tank mixture of glyphosate 1.0 kg/ha and 2,4-D Na salt 2.0 kg/ha.

- Metsulfuron-methyl (6-20 g/ha) has been found to give effective control of Alligator weed (*Alternanthera philoxiroides*), one of the problematic weeds in aquatic bodies and low land areas.
- *Cyperus rotundus* can be effectively controlled with two or three split applications of glyphosate (0.5+0.5+0.5 kg/ha) and two splits of glufosinate ammonium (0.45+0.45 kg/ha) applied during July-August
- Metribuzin (0.5 kg/ha) as pre-emergence or chlorimuron ethyl (10 g/ha) and imazethapyr (70 g/ha) as post-emergence at 2-3 weeks after sowing have been found most effective against *Euphorbia geniculata* in soybean.

- Quizalofop 125-150 g/ha has been found effective in managing *Saccharum spontaneum* in mustard, chick pea and pea.
- *Cassia serecea, Cassia tora,* and *Marigold* were found promising in suppressing the growth of *Parthenium* to a great extent.

4.2.6 BIOLOGICAL CONTROL

- Mexican beetle, *Zygogramma bicolorata* has been proved to be an effective bio-agent against the problem weed *Parthenium hysterophorus*. The beetle has been successful in suppressing the weed in several localities in and around Jabalpur.

- *Neochetina* spp., an exotic insect has successfully suppressed water hyacinth in three ponds of Jabalpur. The insect can be used as an effective bioagent against this aquatic weed.
- *Trichoderma viride* and *Gliocladium virens* have been found to control *Phalaris minor* in wheat and *Echinochloa* spp. in rice under laboratory conditions without any adverse affect on the crop.

- An indigenous turtle beetle (*Cassida* sp. nr *enervis*) has been found to be host-specific against alligator weed (*Alternanthera philoxeroides*), thus offering a great promise in keeping the weed under check.

- Turtle beetles *Aspidomorpha miliaris* and *A. sanctuaris* have been identified as potential biocontrol agents against *lpomoea fistulosa*.
- About thirty allelochemicals were screened for their phytotoxicity to six floating and four submerged aquatic weeds for exploring potential of their use as eco-friendly herbicides.

4.2.7 MECHANICAL TOOLS

- Weeding tools collected from different parts of the country have been assessed and their designs improved for better performance. The drawings have been given to AICRP-WC Centres for fabrication and further testing in their respective areas.

- In soybean and maize, twin wheel hoe has been found more promising for effective weed control.
- A wick applicator was developed for application of non-selective herbicides in standing crops like mustard and soybean. A manually operated multi nozzle boom sprayer has also been developed.
- A power-driven aquatic weeder was designed and developed for management of aquatic weeds.

3. IMPACT OF HERBICIDES ON ENVIRONMENT

- The monitoring of herbicide residues in soil, water and food chain, in different crops and cropping systems throughout the country revealed that none of the herbicides used at recommended doses and time of application, persisted at levels above the safety limit in soil and edible plant parts.
- Glyphosate and metribuzin have been found to be relatively safer to Mexican beetles in comparison to 2,4-D. Metsulfuron-methyl (MSM) has been observed to be a safer herbicide followed by glyphosate and 2,4-D to *Cassida* sp. nr *enervis*, a bio-agent on alligator weed. In addition MSM has also been found to be least toxic to fish.

- The residual effect of different herbicides *viz*. fluchloralin, pendimethalin, metolachlor and oxyfluorfen applied in different crops like blackgram, okra and cotton did not disturb the biological balance of soil microflora (bacteria, fungi and actinomycetes).
- 2,4-D, glyphosate, paraquat have shown detrimental effect on earthworms.
- No residual effect was observed of fluchloralin, pendimethalin, metolachlor and oxyfluorfen applied to blackgram; butachlor, anilofos and 2,4-D in rice-rice cropping system; isoproturon and 2,4-D in wheat; fluchloralin and pendimethalin in cumin.
- Atrazine (2.0 kg/ha) did not leave any hazardous residue in cane juice and jaggery of pure sugarcane in major sugarcane growing areas of Tamil Nadu.
- Atrazine (1.0 kg/ha), pendimethalin (1.0 kg/ha) and oxyfluorfen (0.125 kg/ha) did not affect the population of earthworm *Pontoscolex corcthrurus*.
- As bioassay procedures for herbicides are more economical and less difficult to perform as in chemical analytical methods, sensitive plant species for herbicide bioassay like cucumber, sorghum, mustard, soybean, oat, millets, sugar beet, wheat, canola, sunflower, corn, lentils etc. were identified.

4. GLOBAL CLIMATE CHANGE

- Elevated CO_2 (550 ppm) has drastically enhanced the plant growth, shoot and root biomass, production of flowers in *Parthenium hysterophorus* and *Amaranthus viridis*.
- Elevated CO_2 has hastened the maturity in wild oat.
- The mortality of weeds due to herbicide application has been delayed under elevated CO_2.

5. NATIONAL WEED HERBARIUM & WEED CAFETARIA

- A herbarium of about 200 weeds has been developed.
- A weed seed repository of about 150 weed seeds along with a weed seed identification kit has also been developed.
- A weed cafeteria containing germplasm of 100 weeds was developed.

6. WEED UTILIZATION

- Biomass of several weed species i.e. *Parthenium*, *Lantana*, *Mikania*, *Chromolaena*, *Cassia*, *Ipomoea carnea*, *Salvinia*, water hyacinth etc. has been utilized for mulching and in preparation of compost/vermicompost.
- Layering method of composting in which *Parthenium* biomass was placed in pits, treated with urea and later sealed by dung and soil, has given good quality compost. *Parthenium* seeds also were killed by this method.

- The compost prepared from *Parthenium* and water hyacinth has been found to be equivalent to FYM in nutrient content.
- *Parthenium* biomass has also been used for making paper and particle boards.

7. TRANSFER OF TECHNOLOGY

- A large number of field demonstrations and on-farm trials besides various *Kisan Melas/Gosthis*, TV shows, radio talks etc., have been carried out to demonstrate the effectiveness of improved weed management technologies in different crops, cropping systems and in non-crop areas. Regular training programmes for farmers, subject matter specialists and extension personnel are also being conducted.
- A large number of recommendations made by the Centre and AICRP-WC have found place in the package of practices of different SAUs.
- The Centre undertook mass rearing of Mexican beetle, an effective bioagents against *Parthenium* and so far about five lakh beetles were distributed free of cost to different farmers, municipalities, KVKs and NGOs all over the country. The beetle has established well in many released localities in U.P., M.P., H.P., Delhi, Haryana, Uttaranchal, Orissa, Maharashtra, West Bengal and Bihar.
- NRCWS has been actively engaged in creating public awareness on the ill-effects of *Parthenium* and its management, throughout the country, by organizing '*Parthenium* Day' on 6th Sept and '*Parthenium* Awareness Week' in September of each year.

8. PUBLICATIONS

- Besides annual reports of the Centre and the AICRP-WC, a quarterly newsletter "Weed News", a very good number of technical bulletins publications have been brought out.
- In addition, more than thirty extension folders on different weeds and their management both in Hindi and English have also been brought out.

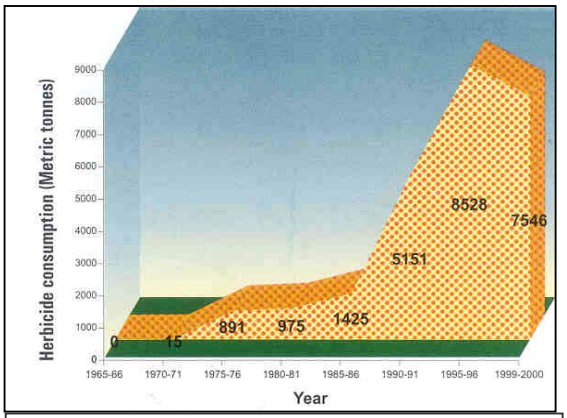
The full potential of high yielding varieties or hybrids could only be realized by adopting the matching production technology. Various biotic and abiotic stresses upset the whole game plan by adversely affecting the crop productivity. Out of the losses due to various biotic stresses, weeds are known to account for nearly one third. A recent study undertaken at this Centre suggests that proper weed management technologies if adapted can result in an additional production of 103 million tonnes of food grains, 15 mt of pulses, 10 mt of oilseeds and 52 mt of commercial crops, per annum, which in few cases are even equivalent to the existing annual production. This amounts to an additional income of Rs. 1,05,036 crores per annum.

The actual yield losses in farmers' fields however would be much lower as they practice some level of weed management. The data obtained from field demonstrations carried out by AICRP-WC shows that the weed management practices followed by farmers are still inadequate and thus there exists a scope for significantly enhancing the crop productivity by adopting improved weed management techniques. Cutting across regions and crops on an average this yield improvement can range from 5-30 per cent.

The biggest impact of the research carried out for over two decades and their demonstration in farmers' field has been the realization that weeds are one of the biggest constraints in crop production. The popular attitude of farmers on weeds has been to ignore the impact of weeds on crop production. This is basically due to the fact that weeds unlike insects and diseases do not damage the crop physically.

SAVING OF LABOUR: The improved weed management technologies involving herbicides and improved weeding tools save labour, easy and convenient to use and enable timely control of weeds. It has come as 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. 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.

Due to the lack of suitable manpower, the centre could not undertake systematic studies to assess the impact of improved weed management technologies. However, 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.



Trend of consumption of herbicides in India

The herbicide use is particularly noteworthy in rice and wheat. The rice herbicides such as butachlor and anilofos

have recorded huge increase in use upto 1650 and 500 MT, respectively. So also herbicide isoproturon, which is solely used for weed control in wheat, whose use has gone up to 2700 MT in 2.7 million hectares. Although data on region-wise consumption of herbicides is difficult to obtain, it is of common knowledge that the herbicides consumption is maximum in Punjab, Haryana, Western U.P. and Uttaranchal. The third field crop, where herbicides are popular is soybean in which the area under herbicides has increased from 4,25,000 ha in 2003 to 8,04,000 ha in 2004. Being a crop grown in *kharif*, weeds are a big problem and they limit the yield substantially. Herbicide industry has responded well with the introduction of a wide range of herbicides to suit different agro-ecological conditions, different times of application (pre-plant, pre-emergence, post-emergence) and for managing different weeds (grasses, broad-leaved weeds, sedges etc.). Herbicides commonly used in soybean include alachlor, triallate, pendimethalin, imazethapyr, metolachlor, chlorimuron, and metribuzin. However, the use pattern of herbicides in soybean is not steady. This is mainly because of the fact that soybean is grown as a rainfed crop besides the unstable market. Tea is another crop where herbicides are extensively used. Being an organized sector manual weeding is cost-prohibitive in tea. Some of the herbicides used are simazine, dalapon, paraquat, glyphosate.

Though, the herbicides are not very popular in other crops, the use however, is picking up in crops like fennel, onion, potato, groundnut, maize, sugarcane, vegetables etc. 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. It is estimated that the consumption would increase by 10 per cent per annum.

MANAGEMENT OF HERBICIDE-RESISTANT *PHALARIS MINOR*: *Phalaris minor* was successfully controlled in Punjab and Haryana with the application of herbicide isoproturon for over two decades. Continuous long-term use, however, resulted in the development of resistance during early 1990s. Large scale yield reductions in wheat were recorded even with the use of isoproturon. In extreme cases of heavy infestation, farmers chose to plough down or pre-maturely harvest the crop for fodder. The herbicide resistance problem was evident in an estimated area of nearly one million hectares. The use of new herbicides clodinafop, fenoxaprop and sulfosulfuron has successfully contained the problem, 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. 900 crores at current prices (2004). The new herbicides are currently (2003-04) used in an area of about 1.6 million hectares.

***PHALARIS MINOR* CONTROL THROUGH ZERO TILLAGE:** The concept of zero tillage (ZT) in wheat in rice-wheat system was introduced for the first time in Haryana primarily to control *P. minor*. Through large-scale trials conducted throughout the IGP, it has been demonstrated that ZT is able to effect *P. minor* control in wheat to the extent of 20-30 per cent. The Australian Council for International Agricultural Research (ACIAR), one of the funding agencies of zero tillage project in Haryana, has estimated the present value of future stream of benefits of ZT adoption to control *P. minor* infestation in the rice-wheat areas of North-western India, over a 30-year horizon, to be around $1800 million in present value terms. Besides controlling *P. minor* the technology would also result in saving on account of land preparation to the extent of Rs. 1500-2000/ha at current prices. From a meager 5000 ha in 1997-98, the area under ZT technology has gone up to 2,00,000 ha in 2002-03.

HUMAN COMFORT AND GENDER EQUALITY: The focus of mechanical weeding has shifted from the use of age old *Kurpis* and hand hoes to wheel hoes, which involve less human drudgery. The Centre has been improving the design of these tools for maximum efficiency and human comfort which are being popularized through AICRP-WC. Although, it is difficult to quantify the impact, these improved weeding tools are believed to result in considerable saving of labour besides offering human comfort. The technology also addresses the issue of gender equality, as manual weeding involves human drudgery, which is primarily carried out by women.

BIOLOGICAL CONTROL OF *PARTHENIUM* AND WATER HYACINTH: The Centre has substantially contributed in developing and popularizing technologies involving the use of Mexican beetle (*Zygogramma biocolarata*) and *Neochetina* spp. for the control of *Parthenium* and Water hyacinth, respectively. *Parthenium* typically being a weed in non-crop areas and waste lands, management by other methods is not practical and cost-effective. The Centre has taken a proactive role in multiplying the beetle and distributing them (free of cost) in different parts of the country. Till date, an estimated 5 lakh beetles have been sent out as culture material. The feedback obtained from different places and the surveys undertaken by NRCWS unambiguously show that the beetle has established in most places and is expected to multiply and spread to newer areas in the next couple of years. Wherever it has established, it is giving satisfactory control of *Parthenium*, slowly making way for natural vegetation to come back to its original status. Of the total area of 7-8 mha, it is estimated that about 3 mha may have been covered by the beetle.

The control of water hyacinth through bio-control agent *Neochetina spp.* is however erratic, giving good control in some areas while not doing well in others. As other methods of control are not practical and cost-effective, *Neochetina spp.* may still be considered as the only viable option. The two weevils *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 North East. Clearing of Loktak lake in Manipur and Humayun Sagar in Hyderabad are particularly noteworthy. Mechanical removal is highly expensive costing anywhere between Rs. 4000-5000/ha. Recently, the famous Ooty lake (18 ha) was cleared at an astronomical value of Rs. 1.74 crores (The Hindu, 12 April, 2002).

The water fern (*Salvinia molesta*) problem is particularly acute in Kerala where the thick mats of the weed on water bodies block sunlight, reduce oxygen levels, threaten biodiversity, making waterways unnavigable and unsuitable for fish culture on which majority of small, marginal and landless rural population is dependent. The rice cultivation either becomes uneconomical or has to be abandoned due to non-availability of timely work force for the removal of the weed mats. The weevil, *Cyrtobagous salviniae* introduced by the PDBC, Bangalore in 1982 has proved highly successful in clearing the *Salvinia* weed mats in Kuttanad, Thrissur and other areas of Kerala.

Once again it is difficult to quantify the impact of these technologies in economic terms. However, it may be appreciated that the control is almost coming at no cost compared to huge investments which otherwise would be required for manual or chemical control of these weeds. It is estimated that the cost of *Parthenium* control through manual/chemical control range from Rs. 1000-2000/ha. The indirect benefits of *Parthenium* control in terms of improved health and productivity of human beings and livestock, on restoration of natural ecosystems and protection of biodiversity are immense and invaluable.

Other cultural methods of weed management developed by the Centre such as use of stale seedbed, intercropping with fast growing, weed suppressing intercrops, crop rotations, nutrient and irrigation management etc., are recommended as individual components in an IWM system. The type and level of integration depend on several factors. The impact is, therefore, difficult to quantify.

Soil solarization technique developed by the Centre 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, high value crops and in organic agriculture.

THE LEADERSHIP ROLE IN WEED SCIENCE:

As a nodal Centre for research and being in the field of weed science in the country, NRCWS is acting as a repository of information on all aspects of weeds and weed management and providing leadership in the field. The work on basic research being carried at the Centre is expected to contribute immensely in better understanding of the weed problem and would form basis for improved control in the future. The work on identifying plant toxins and bio-herbicides involving microbes will help in evolving ecofriendly weed management practices in the future.

5.2 INPUT/OUTPUT ASSESSMENT

The Centre has given several technologies for the management of weeds in agriculture and other ecosystems. From some of the case studies reported in Chapter 5 (Impact Assessment) it is evident that few of the technologies have been adopted by the farmers to a considerable extent resulting in higher crop yields and profits. Assuming very conservative figures of 5 per cent increase in crop production and 10 per cent adoption levels, the net benefit to the country will be to the tune of Rs. 500 crores annually. Similar returns are likely in horticulture and in non-crop areas. The X five year plan budget for NRCWS (including AICRP-WC) is Rs. 25.20 crores. Thus, there would be a minimum benefit of Rs. 100 per every rupee spent on research and development in the field of weed science. In an independent scientific study by the National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, weed management was identified as the third most important area of research in rainfed rice in terms of generating economic surplus.

5.3 LESSONS LEARNT, SUGGESTIONS AND OPTIONS FOR FUTURE

Despite intensive research for over two decades under the aegis of AICRP-WC, the weed problems are not only persisting but also increasing. The reasons are firstly, the modern agriculture characterized by large scale adoption of HYVs and hybrids which are dwarf and respond better to increased use of fertilizers and irrigation, favours weed growth as well. Secondly, the weeds have greater ecological amplitude and are capable of adopting to any weed management system. Thirdly, the work under AICRP-WC was basically to identify local weed problem and develop control measures, mainly through chemicals. There was very little or no research worth the name on biology and ecology of weeds, which otherwise forms the basis for developing sound integrated weed management practices.

Another important reason for the lower impact could be the inadequate awareness among farmers of the new technologies. The Centre is dependent on SAUs and state agricultural

departments for technology transfer process. The set up in many states is very lethargic and inefficient. Because of the wrong mindset, many extension agencies do not give weed management the attention that it deserves. In addition the adoption of herbicides is also skewed. They are more popular in rice, wheat, tea and soybean that too in few states like Punjab, Haryana, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and Gujarat. At some places because of poor demand herbicides are not easily 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.

NRCWS is still at its infancy considering that it has become fully functional only after the year 2000. The leadership role it was supposed to assume is yet to be realized. About one-third of the scientific positions are yet to be filled up and there are no scientists specialized in important disciplines such as microbiology, taxonomy, biotechnology *etc*. The centre needs more support from the ICAR in this regard.

What has progressively emerged during several years of research is recognition of the fact 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 a particular tillage and 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. A weed which is sensitive to a herbicide will make way for a relatively tolerant weed following its continuous use.

The worst scenario of continuous use of a herbicide is the development of herbicide resistance. This was amply demonstrated with the occurrence of resistant populations of *Phalaris minor* in parts of Punjab and Haryana with the continuous use of herbicide isoproturon. 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. 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.

The other major lesson learnt is the growing of crops in the absence of any tillage. This has been demonstrated on a large scale on Indo-Gangetic plains in rice-wheat system. Besides being a resource conservation technology, the zero tillage has shown to record substantially low infestations of *Phalaris minor*, a troublesome weed in wheat. However, the long-term implications of this technology on weed flora shift, weed seed dynamics, etc. need to be investigated.

Based on the experience gained over the years following suggestions are made:

- NRCWS should establish a full-fledged Training Centre to train manpower.

- NRCWS should develop IWM modules for different crops in digital form (CDs) for wide distribution.
- Awareness about invasive weeds such as *Parthenium* be created on a large scale and eradication programme be taken up on a mission basis involving public participation.
- The technology transfer be based on Integrated Crop Management (ICM) approach rather than doing it individually for management of weeds for better impact.
- Involve public sector in technology transfer.

Weeds are plants that are undesirable to human activity at a particular time and place, and therefore, weeds will always be associated with human endeavours. Weeds continue to 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. In non-crop areas, they affect aesthetic look of the ecosystem and health and quality of life. Weeds are highly persistent and adaptable. As they are a part of the ecosystem they can never be eradicated, only efforts can be made to contain them to a level where they do not cause economic losses.

Proper management of weeds is essential to meet the growing demand of foodgrains, pulses, oilseeds and other crops by the ever increasing population. As per the projections of IFPRI, Washington there is a likelihood of shortfall of 41 per cent in the food grain production in the country by 2020. There appears to be only two situations to over come such problems viz., horizontal or vertical increase in the production. While horizontal increase has little possibility as there is very little scope of bringing more area under cropping except by way of increasing cropping intensity, the vertical increase has got tremendous scope which can be achieved with better genotypes and providing farmer-friendly input technology. The improved weed management technologies if adapted could solve the problem of food scarcity in the country. A recent study undertaken at this Centre suggests that proper weed management technologies if adapted can result in an additional production of 103 million tonnes of foodgrains, 15 mt of pulses, 10 mt of oilseeds and 52 mt of commercial crops, per annum, which in few cases are even equivalent to the existing annual production. This amounts to an additional income of Rs. 1,05,036 crores per annum.

The salient features of the possible scenario of weeds in 2025 are as follows:

1. **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, often irreversible to the environment, economy and in some cases to human health.

a) **Management of IAWs that have already entered the country**: Majority of the

> As per Convention on Biological Diversity (CBD, 1992) alien invasive species are the biggest threat to biodiversity next only to human resettlement. A large number of alien invasive weeds have invaded our ecosystems and are threatening their survival and productivity.

important weed species in India have been introduced into the country in the past, either accidentally as contaminants in food or grain imports or deliberately. Especially, a large portion of non-agricultural area has been invaded by a number of unwanted plants, many of which are aliens. *Chromolaena odorata*, *Ageratum haustonianum*, *Mikania micrantha* are creating havoc in plantation crops in Kerala and north-eastern states. *Mimosa rubicaulis* has seriously infested the world famous Kaziranga National Park of Assam and is threatening the food source of several herbivores in the park including the much-endangered single horned Rhinoceros. Water hyacinth has spread over 2.0 lakh hectares of water surface in India covering almost all the states.

Parthenium hysterophorus has invaded an estimated 7-8 mha of non-cropped areas throughout the country. *Lantana camara* is a serious menace in Himachal Pradesh, Madhya Pradesh, North-Eastern states etc. A large number of aquatic weeds such as water hyacinth, *Salvinia molesta*, *Hydrilla*, Alligator weed are a great nuisance to fisheries, navigation, irrigation, hydroelectric projects and in tourism. These weeds are severely affecting human and cattle health, biodiversity, productivity and quality of eco-systems. Hence, management of such IAWs is a great challenge to the weed research scientists in the country.

b) Management of future introductions of AIWs: Increasing trade and globalization coupled with liberalization policies will further increase the risk of invasion by such weeds leading to decrease in native biodiversity, reduced productivity of different ecosystems, reduced input-use efficiency and increased production cost.

It is observed that a record number of major weeds (975), which exist in other countries, are at doorstep awaiting entry into the country. Therefore, we should be careful in preventing their introduction into the country.

Table 1. World's serious or principal weeds, whose introduction to India must be prevented

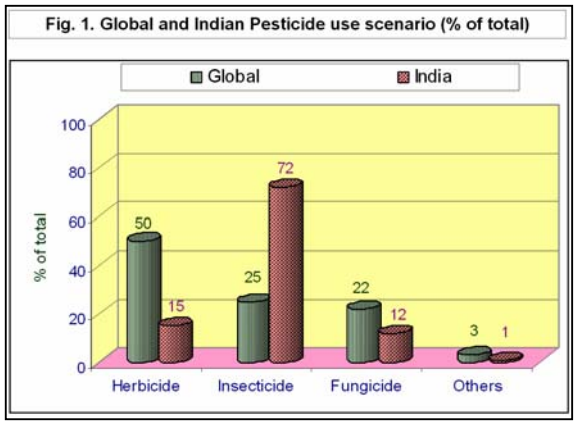
Country	No. of weed species
Australia, New Zealand	195
African countries	181
SE Asia, Far East	150
Middle East	118
South America	102
Europe	90
Central America	86
North America	33
Former Soviet Union	20
Total	**975**

Source: A geographical atlas of world weeds, Holm et al. (1979) John Wiley & Sons.

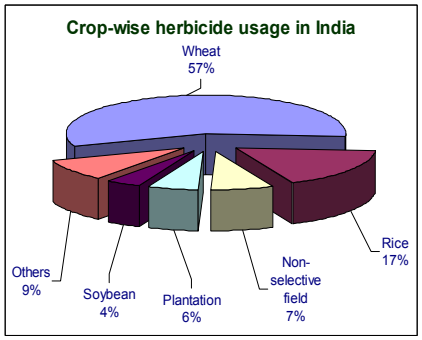
In order to prevent future introductions, more weeds, particularly the ones that are problematic in related countries, need to be subjected to rigorous Weed Risk Analysis (WRA). There is also an urgent need to design safeguards and strengthening of quarantine regulations to lower the risk of their entry. Australia, New Zealand, USA have developed detailed protocols for WRA and for identification of quarantine weeds. NRCWS would foster collaborations with the concerned organizations in these countries to develop protocols for WRA.

2. Enhanced use of herbicides: Herbicides are the most successful weed control technology ever developed as they are selective, cost effective, fairly easy to apply, have persistence that can be managed, and offer flexibility in application time. They are eco-friendly if applied at proper dose, method and time, besides being quite safer in comparison to other pesticides like insecticides. In India, around 96 per cent of the

herbicides are slightly to moderately toxic while more than 70 per cent of the insecticides are highly to extremely toxic. In general, herbicides account for the largest proportion of crop protection chemicals sold on a world-wide scale. Globally, herbicides constitute 50 per cent of the total pesticides sale and in some countries like USA, Germany and Australia, the figure is as high as 60-70 per cent. In India, however, the position is different as herbicides form a meager 15 per cent of total pesticide consumption. But still, the consumption has increased rapidly from 4100 metric tonnes (MT) in 1988-89 to 11,000 MT in 2001-02 and it is likely to further increase in future. It is estimated that the herbicide market would grow at over 10 per cent per annum.



Herbicides have come as 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 57 per cent and 17 per cent of the total herbicide consumption in the country.



The third field crop, where herbicides are popular is soybean in which the area under herbicides has increased from 4,25,000 ha in 2003 to 8,04,000 ha in 2004, accounting for 4 per cent of the total herbicide consumption. Tea is another crop where herbicides are extensively used. Being an organized sector manual weeding is cost-prohibitive in tea. Though, the herbicides are not very popular in other crops at present, their use however, is picking up in crops like fennel, onion, potato, groundnut, maize, sugarcane, vegetables etc. 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.

There is also a lot of regional variation in herbicide consumption. For example, only 17 per cent of the total wheat acreage of 26 mha is being treated mostly in Punjab, Haryana and western Uttar Pradesh. Similarly only about 14 per cent area out of 42

mha under rice is treated with herbicides, almost entirely in transplanted rice. As herbicide use in other crops at present is very low, there exists a very good scope for their use in future. Some of the issues relating to the enhanced herbicide use are discussed below:

a) **Herbicide resistance in weeds:** Continuous long-term use of herbicides can result in the development of resistance in weeds. 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. 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 *Echonochloa 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 in-built mechanisms for their defence, there is every likelihood that herbicide resistance in weeds will continue to be a problem in the forseeable future as well. We need to be watchful of similar problems emerging in other crops and cropping systems.

b) **Herbicidal toxicity to succeeding crop and environment:** Although herbicides are a boon to the agricultural community in substantially increasing crop yields, their use is not without potential problems. Some of the unintended negative impacts of herbicide use are persistence in soil, pollution of ground water, toxic residues in food (contamination), feed and fodder and adverse effect on non-target organisms. The potential of herbicides in 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 such apprehensions, herbicides would remain as one of the major tools in weed management as these offer huge benefits to the farmers and as herbicide use is likely to increase substantially in the future, their judicious use is of utmost importance.

c) **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 very 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 technologies like zero- tillage can cut down the production cost substantially without penalizing productivity. 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 some quantity of herbicides. However, as the country is exporting all these commodities we must ensure that these do not contain any herbicide residues.

d) **Threat to native biodiversity:** It is observed that a large number of indigenous flora possess medicinal and aromatic properties. The increased use of herbicides in the crop fields is likely to pose a serious threat to the existence of such useful native flora, which are existing since time immemorial.

3. **Weed shift:**

a) **Rainfed farming:** Since the availability of water to agriculture will be greatly reduced in future, the importance of rain-fed and dry-land agriculture will result in shift in weed flora, development of problem weeds difficult to control such as *Orobanche*, *Striga* etc., besides reduced efficacy of herbicides due to moisture stress.

b) **Organic farming:** 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, growing intercrops, cover crops and green manure crops) would gain importance.

c) **Resource conservation technologies:** Increased adoption of resource conservation technologies like zero tillage, bed planting etc., will lead to reduced cost of cultivation, better management of problem weeds like *Phalaris minor* in rice-wheat system. In addition it may also result in weed flora shift favoring the perennial weeds besides increasing the herbicide use.

4. **Global climate change:** 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. As weed populations show greater variations, it is possible that with a changed global climate weeds too will achieve a greater competitive fitness against the crop plants and development of new weed types.

5. **Development of super weeds:** Imparting resistance to normally herbicide susceptible crops to produce herbicide-resistant crops (HRCs) has been the most extensively exploited area of plant biotechnology. Resistance genes for several herbicides or herbicide modes of action have been incorporated into the genome of corn, cotton, canola and soybean which are now commercially available. Remarkably, the global biotech crop area increased more than fifty-fold in the first decade of commercialization from a meager 1.7 million hectares in 1996 to 90 million hectares in 2005. Herbicide tolerance has consistently been the dominant trait during all these years. In 2005 alone, herbicide tolerance, deployed in soybean, maize, canola and cotton occupied 71 per cent or 63.7 million hectares of the global biotech area (90.0 million hectares).

Introduction of Herbicide Resistant Crops (HRCs) besides helping in efficient management of problem weeds with minimum risk to the crop and increasing the

yields may also lead to development of 'super weeds'. Their management will be essential in the days ahead.

6. **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.

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.

7. **Biological control of weeds:** Technologies employing natural systems, biological organisms, bio-pesticides would gain importance to overcome or reduce the dependence on herbicides, wherever possible. 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*. Looking to

A Pond heavily infested by Water hyacinth

Same pond cleared by *Neochetina spp*.

the various advantages in this technology, the work on biological control of weeds will intensify 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.

8. **Management of parasitic weeds**: Parasitic weeds are posing problem in the productivity of some of the major crops and cropping systems. *Cuscuta* spp. is a major problem in niger (Orissa, parts of Madhya Pradesh and Chhattisgarh), in lucerne (Gujarat), blackgram/greengram (in rice-fallows of Andhra Pradesh), berseem, lentil, linseed and chickpea (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 more recently in tomato and potato in Karnataka. *Striga* spp. 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* spp., rose wood, *Dalbergia* spp., *Albigizzia* spp., *Terminalia* spp., rain tree, *Pongamia* spp., Gulmohar, *Madhuca* sp., *Ficus* sp., etc. The problem of perennial weeds is increasing enormously. It is necessary to develop the management technology for such weeds.

Orobanche spp.

9. **Aquatic weed management:** 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. However, the area under these aquatic bodies is increasing with the building up of dams, canals and tanks for irrigation and fisheries production. The aquatic weeds have been found to increase the loss of water through transpiration, interfere in navigation, affect fisheries, mar recreational value of water, severely impede the flow of water in canals, thereby reducing availability of water to agriculture. The most prevalent method of managing the menace of aquatic weeds is their physical removal from the water bodies which is highly laborious and expensive, besides the disposal of the harvested material is also a big problem.

   In view of the restricted use of herbicides in aquatic bodies due to the multifaceted use of water for purposes like fish culture, irrigation, domestic use etc., use of biological agents through insects like *Neochetina spp.* and hydrophilic mite *Orthogalumna terebrantis* against water hyacinth, *Cyrtobagous salviniae on Salvinia molesta* (water fern) and herbivore fishes such as a common grass carp (*Ctenopharyngdon idella)* against small floating and submerged weeds would be more prevalent. In depth and more comprehensive eco-friendly research work is required to be carried out on the management of such weeds.

10. **Exploitation of weeds for beneficiary use:** Weeds like water hyacinth, *Chromolaena, Lantana, Parthenium*, *Ipomoea*, etc., are rapidly spreading through out the country at the cost of other useful vegetation. Proper utilization of such biomass through appropriate technologies like vermicompost, mulch, phytoremediation etc., may help in supplementing chemical fertilizers besides adding organic matter to the soil.

Utilization of weeds as a source of ayurvedic medicines, bio-pesticides and bio-fuel also has enough potential. Technology for using weeds for making paper, particle boards, furniture etc., has to be developed ahead. Such activities are expected to raise income and employment opportunities.

6.1 SWOT

6.1.1 STRENGTHS

- Multi-disciplinary human resources competent to handle all problems related to weeds and weed management
- Well laid out experimental farm, green house, poly house, laboratory and other facilities with sophisticated equipment for carrying out basic, strategic and applied research in weed science
- Strong network of 22 coordinating centres under AICRP-Weed Control to carry out the network programme based on agro-ecological regions of the country, for identifying local weed problems and validation of weed management technologies developed by the Centre
- Repository of information (database, library, weed herbarium, weed seed collection etc.) for all matters related to weeds and their management and referral centre
- Training and human resource development activities

6.1.2 WEAKNESSES

- Lack of sufficient number of scientists in view of the large mandate of the Centre which prohibits the carrying out of work in the different target areas of research.
- Lack of certain infrastructural facilities for research and training
- Lack of administrative, technical and supporting staff
- The quality of work in some SAUs (AICRP-WC centres)is rather poor and needs strengthening of scientific manpower and infrastructural facilities
- Herbicides for minor crops and for specific weed problems such as parasitic and perennial weeds are not available
- Dependence on herbicide industry for new molecules
- The adoption of IWM technologies is low as they are knowledge-intensive and difficult to convince farmers
- Long gestation period and low success rates in some programmes such as bio-control research and bio-herbicides (allelo-chemicals)

6.1.3 OPPORTUNITIES

- Weeds are a big constraint in crop production and a big menace to public and animal health
- Farmers and public are keen for their effective management
- Weed management is supported by herbicide industry
- Urbanization is making labour scarce and expensive
- Need for effective, economical and sustainable weed management practices to sustain higher productivity
- Increased threat of alien invasive weeds
- Breakthroughs made in biotechnology and information technology could be taken to advantage
- Concern for human comfort and gender equality

- Concern for safe food, water and clean environment
- Labour saved could be gainfully employed in other more productive farm activities

6.1.4 THREATS

- Increased dependence and use of herbicides
- Non-chemical, eco-friendly systems of weed management (crop rotations, intercropping, etc.) may lose their importance
- Chances of herbicide contaminating the food, feed and water
- Long-term sustainability of agricultural systems may be threatened
- Fear of displacement of labour
- Fear of bio-control agents becoming pests on agriculture crops
- Fear of herbicide resistant crops impacting negatively the food, the environment and the biodiversity
- Possibility of duplication of work by some Crop Directorates of ICAR

7. PERSPECTIVE

The agricultural sector in India, as in many developing countries, continues to occupy the centre stage of the country's over all progress and development. The role of agriculture in generating a broad-based economic growth is well known. Sectoral growth and product diversification have generated employment, enhanced rural incomes and stimulated the industrial growth with a decline in rural poverty. Although in terms of total food production, India ranks high in the world for many crops, its standing in terms of their productivity is rather disappointing. On the other hand, besides having the largest area of cultivated land, farming population, the country also has the highest average rainfall as compared to any other country in the world. The country has the world's second largest irrigation system, fourth largest fertilizer production country and one of the largest national agricultural research systems. Thus, it is obvious that agricultural production in the country has remained rather inefficient in utilizing the natural resources as well as man-made resources. The wide gap in productivity levels between frontline demonstrations and farmers' fields is a reflection of poor technology transfer process in the country.

India is also blessed with rich and varied natural resources because of which it can boast of being home to rich and varied flora and fauna. It is improper to make a judgement on which flora is beneficial and which is not. Hence, notes A.S. Crafts - a noted weed scientist "In the beginning there were no weeds". Weeds are no separate group of plants. Man invented the weeds. Plants have been termed as weeds considering their negative value in a given situation. The definition given by Weed Science Society of America (WSSA) hence appears apt "Any plant that is objectionable or interferes with activities and welfare of man". This is given with the perspective that any plant or vegetation could be included as a weed in the future so long as the plant fits into the above definition.

The agricultural crops are infested with a variety of weeds. Out of over 800 weeds documented in India 80 are considered as serious and nearly 200 as major weeds. A National Database on weeds developed by NRCWS gives information on the major weeds in each crop and cropping system at district level for the entire country which could be used for setting priorities, planning research and developing location-specific weed management practices. The Institute has a huge mandate of dealing with weeds not only in food crops but also in vegetable, fruit and plantation crops. Weeds are not only important in agriculture but are a great nuisance in forestry, grasslands, wastelands, public amenity areas, etc. where they severely impact on biodiversity, environment and health. Prioritization of research activities is therefore very vital to make the best use of limited availability of manpower and facilities. Increased ecosystem disturbance due to urbanization and industrialization would increase the risk of invasion by alien weeds. Considering the increased problem of weeds in all walks of life and the economic losses they inflict, a proposal for upgrading NRCWS into a full-fledged Institute made in this document be seriously considered by the ICAR. We should take pride in the fact that no other country in the world, at present, has a separate Institution to address the problems posed by weeds.

Research, training and technology transfer activities related to weed science need to be intensified in the country in view of the following considerations:

- Weeds are causing huge losses to crop yields
- Losses are likely to further increase with increased use of modern crop production technology
- Weeds are also a great threat to biodiversity and health of humans and animals
- More weeds are expected to be introduced due to globalization of agriculture
- Need to have effective quarantine laws in place to prevent entry of new weeds
- Over 900 species considered as major or serious weeds elsewhere in the world but not yet recorded in India.
- With urbanization and mechanization the labour and animal power would become scarce and expensive.
- Increased concern for human comfort and gender equality.
- Increased use of herbicides as an effective and economical strategy.
- Greater risks of herbicide contamination of food, water and environment
- Greater risk of occurrence of herbicide resistant weeds
- Greater demand for ecofriendly and environmentally benign weed management technologies
- Greater public concern for safe drinking water, food and environment
- Greater demand for organically grown products
- Greater use of resource conservation technologies to cut costs and attain higher profits
- Increased popularity of GMOs including herbicide resistant crops (HRCs)
- Greater risk of HRCs on biodiversity, environment and human safety
- Increasing popularity of contract farming and precision farming
- Greater need for competent manpower and matching facilities
- Harnessing information technology, e-media for dissemination of technology
- Better co-ordination and complementarity with other research partners in both private and public sector
- Reducing the load of herbicides in the environment by improving their performance and integrating with other methods of control
- Stricter evaluation of herbicides on their environmental impact
- Need for policy guidelines in registration, regulation and marketing of herbicides

The Perspective Plan is prepared taking a holistic view of the weed problems in all ecosystems, and the research and technology developments made in other developed countries to solve them. The impact of WTO, globalization of agriculture, advances made in biotechnology, information technology, gender equality and other issues have been perused critically with respect to weed management. The SWOT analysis of the Centre and the need for synergy, cooperation, collaboration, networking with other related national and international institutes have been taken into account while developing the

research programems with a view to avoid duplication and to bring complementarity in research, training and technology transfer.

Based on the various analyses as presented above, the NRCWS should be able to not only generate necessary knowledge and technologies but also to provide guidance to the development of appropriate policies in the field of weed management.

Approach: Weed science is more advanced in several developed countries such as USA, Canada, Countries of European Union, Australia, New Zealand, Japan, etc. However, as most of these countries depend on herbicides for weed management, the herbicide market accounts for 60-70 per cent of the total pesticide market. However, heightened concern for environmental and consumer safety has led not only to stricter guidelines of herbicide registration and use, but also tried to put greater emphasis on non-chemical strategies such as physical, mechanical and biological methods of weed management. Investigations on use of microbes, microbial toxins are receiving priority. Several mycoherbicides have been commercialized but their adoption is still limited. India can learn from their experience and revert back to sustainable methods of weed management before taking the full circle. As outlined in the scenario, the future weed problems will be multi-pronged and a narrow strategy cannot work. Therefore, a holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative.

Human resource development: For undertaking new and strategic research, human resource development is very crucial. Research tools are becoming very sophisticated as well as costly necessitating the need for training in emerging areas. The quality and quantity of human resources to meet the new challenges and opportunities posed by technological revolution, sustainability considerations and globalization are far from satisfactory. The status of AICRP-WC being operated at different SAUs is still worse. Frequent transfers of scientists and lack of administrative control by NRCWS is leading to deterioration in the output, which many a time is below standard. On the other hand the existing scientific as well as technical manpower also require training in emerging areas. The scientists need specialized training on conceptualizing, planning and resource management. With the liberalization, the incentives to scientists, technicians and other personnel have to be progressively revised in order to attract and retain good talent and keep them motivated.

Need for upgradation of facilities: Considering the importance of the subject, wide mandate and numerous objectives to be met, there is a strong need for upgrading the Centre to the level of an Institute with more manpower, matching facilities and budget. The QRT of the Centre (1996-2001) has also strongly recommended the upgradation. Further, the NRCWS is unique in that it is the only organization of its kind in the entire world, where a multidisciplinary team of scientists are working on various aspects of weed management. The upgraded institution, besides catering to the entire nation will also be able to act as a lead Centre for training scientists from less developed countries in Asia, Africa and Lain America.

The facilities such as radio-tracer laboratory, GIS laboratory, environmental quality laboratory, biotechnology laboratory, quarantine laboratory for plant pathogens, training and communication facilities etc. are required. The Centre badly requires a designated lecture/training hall, space for sports and recreation facilities etc. A small training facility comprising a training hall, an information centre and a trainee hostel adequately equipped with modern gadgets and tools is a dire necessity. The farm (62 ha) has not undergone a

systematic layout and development since its taking over. A budget of Rs. 150 lakh (at 2004 prices) would be required for its systematic development as recommended by CSWCRI, Dehradun. Extension of the present laboratory-cum-administrative building by adding two more wings as per the approved master plan will provide sufficient space for the proposed new laboratories.

The cadre strength of the scientific staff of the Centre has been fixed at 27 out of which only 16 are in position as on date. The scientists in critical disciplines like microbiology, biotechnology and additional posts in entomology and pathology are required on priority. As recommended by the QRT of the Centre (1996-2001), the cadre strength of scientists be raised to 40 with proportionate increase in other categories.

The manpower position in the proposed setup would be as under.

Scientific	Technical	Administrative	Supporting
41	62	31	41

Similarly the AICRP-Weed Control also needs to be expanded and upgraded. Each SAU must have a centre. Systematic work by multi-disciplinary group of scientists can only be done under AICRP-WC. Financial and technical support need to be provided by the ICAR in other SAUs where AICRP-WC is not operating currently, so that the area under their jurisdiction will also be benefited by advances made in this field. The ICAR Institutes where duplication of research is suspected could be included as voluntary centres of AICRP-Weed Control.

The future weed problems will be multi-pronged and hence, narrow strategy can not work. Therefore, a holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative. The main issues concerning weeds and weed management in India, that require scientific research and technological redressal for which NRCWS must be sensitive and responsive are highlighted below:

1. Invasive Alien Weeds: Majority of the important weeds in India have been introduced into the country in the past either accidentally or deliberately. Some of the major alien invasive weeds include *Lantana camara, Eichhornia crassipes*, *Savlinia molesta, Parthenium hysterophorus, Chomolaena odorata, Mikania micrantha, Mimosa spp.* etc. These weeds (except aquatic ones) have invaded vast areas of forest, grassland, wastelands, and in some areas orchards and plantation crops too. *Lantana* was introduced into the country in the year 1908 and since then it has invaded almost all parts of the country. Due to its hybridization, there exists a wide genetic diversity. This is probably the main reason for the poor control with many bio-agents introduced for biological control of *Lantana camara*.

Chromolaena odorata, earlier restricted to NE region and Western Ghats is now fast spreading to other areas. Besides wastelands, grasslands and cleared forests, it is proving to be major weed in orchards and plantation crops. In non-crop areas of Western Ghats it has almost replaced *Lantana camara*. It can be considered as more serious weed than *Lantana camara* because of its copious reproductive capacity by way of high production of seeds, which are light in weight and can be carried away by wind to vast 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. Similarly, *Parthenium hysterophorus* is a serious weed which has spread throughout the country in a big way. Management of such weeds is of utmost importance as that are not only adversely affecting the human and cattle health but some of these have now also entered the crop fields, thus reducing crop yields. These weeds are a serious threat to the biodiversity or native flora. Hence, their effective management in all situations i.e., both crop and non-crop lands is essential.

2. Weed Risk Analysis: 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 need to 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 factor 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 & Storage, Government of India has strengthened the system by deploying 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.

3. 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 may affect certain sensitive crops grown in rotation. The indiscriminate use of pesticides leaves behind residues in food chain and environment. Widespread and increasing 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 has to be developed.

The facilities for herbicide residue monitoring are made available at 8 Centres of AICRP-Weed Control, of which four are to be strengthened still further. The work will be undertaken in close 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 will have to be stepped up to meet the challenges arising out 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.

4. Herbicide resistance in weeds: Continuous use of herbicides can lead to the development of resistance in weeds to herbicides, which is a global phenomenon. Recent instances of herbicide resistance in *Phalaris minor*, an important weed in wheat in parts of Punjab and Haryana is a case in point which has posed a serious threat to the sustainability of rice-wheat system over an area of one million hectares in this productive belt. This will continue to be a problem in the forseeable future as well. We need to be watchful of similar problems emerging in other crops and cropping systems.

5. Weed shift: 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, 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.

6. Biological control of weeds: There is sufficient scope for managing weeds especially in non-cropped areas through the use of biocontrol agents like 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. This approach is inexpensive and self-perpetuating besides being user-friendly and environmentally benign. NRCWS 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 seed setting, 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 been reported to feed on any crop plant or weed sp. Several competitive plants such as *Cassia tora, Cassia serecia, Tagetus* spp. etc., have also been reported to suppress *Parthenium* effectively. Spreading these 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.

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

Chlorotic spots on the upper & lower side of *Mikania* leaf caused by *Puccinia spegazzinii*

A mature stem gall caused by the gallfly

7. Global climate change: 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. As weed populations show greater variations, it is possible that with a changed climate weeds too will achieve a greater competitive fitness against the crop plants. 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. Therefore, it is very essential to undertake such type of research.

8. Biotechnology and GMOs: Resistance genes for several herbicides or herbicide modes of action have been incorporated into the genome of corn, cotton, canola and soybean which are now commercially available. During the last decade (1996 to 2005), global adoption rates for transgenic crops have been unprecedented. The acreage has increased from 1.7 million hectares in 1996 to 90 million hectares in 2005, of which, 71 per cent (63.7 m. ha) were planted with crops tolerant to herbicides.

Transgenic mustard resistant to herbicide under trial at NRCWS

As far as the transgenic crops are concerned, not many laboratories in India are undertaking the work related to the development of HRCs. NRCWS does not have the manpower and facilities for such research. Therefore, proposals for funding projects on the subject may be considered. Alternatively, the technology available with MNCs be allowed to be commercialized in the country as its overall benefits seem to outweigh the shortfalls. Exploitation of HRCs at least in crops such as maize and soybean where there is little danger of pollen flow to wild relatives and creation of 'super weeds' may be considered on priority. Biotechnology also has application in development of bio-herbicides and myco-herbicides which needs to be harnessed adequately.

9. 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 very 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 adopting 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 technologies like zero-tillage can cut down the production cost substantially without penalizing productivity.

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 some quantity of herbicides. However, as the country is exporting all these commodities we must ensure that these do not contain any herbicide residues.

10. Human comfort and gender equality: Manual weeding, which is widely practiced in the country, is time-consuming and backbreaking. An estimated 5 to 6 billion man-days are spent in this operation each year, which is mostly performed by women. Adoption of ergonomically developed tools and use of chemicals would reduce the drudgery to a greater extent. The labour thus saved (20-40 man days per hectare) could be positively employed in more remunerative enterprises like livestock rearing, poultry, sericulture, mushroom cultivation, bee-keeping etc. This will also raise the esteem of women and free

them for giving more time for sanitation, health care, etc. Use of chemicals should not be viewed as a technology displacing labour. It in fact, aims at human comfort besides providing more time for remunerative activities to earn additional farm income.

11. Enhancing farmers' income and employment generation: It is one of the important policy decisions of the Government of India. Improved weed management practices have been found to significantly increase the crop yields. 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 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.

12. Awareness raising 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 these are 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. Therefore, there is a need to popularize the cost-effective weed management technologies through field demonstrations, electronic mass media, trainings and participation in *kisan melas*, etc. It is also 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 Centre would intensify technology awareness and transfer activities by bringing out technology capsules both in printed and electronic versions and distributing them to all the stakeholders i.e., KVKs, SAUs, NGOs etc. AICRP-WC Centres would translate them into the respective local languages and take up further dissemination. 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 manner should be developed.

13. Utilization of weeds: Weeds like Water hyacinth, *Chromolaena, Lantana, Parthenium*, *Ipomoea*, etc., are rapidly spreading through out the country at the cost of other useful vegetation. Proper utilization of such biomass through appropriate technology may help in supplementing chemical fertilizers besides adding organic matter to the soil. The tender and succulent portion of many weeds with wider C:N ratio may also be utilized for vermicomposting which has enough potential for use in the production of organic tea as well as for vegetable farming. Utilization of weeds as a source of ayurvedic medicines, bio-pesticides and bio-fuel is another potential area of research.

Most of the issues listed in this Chapter require multi-disciplinary and multi-sectoral approach for finding solutions. The scientists belonging to different disciplines will be encouraged to work as a team with time bound targets. Scientists will also be encouraged to take up on-farm trials in farmers' fields and also involve farmers 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. The details of linkages, programme-wise have been given in Chapter 9. Efforts will be made to attract funding for research proposals from

external agencies in specific research areas requiring immediate attention. 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 also be explored.

9.1 Programmes

The main programmes to be taken up to address the issues raised in the previous chapter are as under:

1. Integrated weed management	• Develop guidelines for incorporating the non-chemical methods (cultural/mechanical and agronomic manipulation) with chemical methods • Study the impact of crop establishment techniques on weed management • Reduce herbicide use by employing non-chemical methods and techniques to improve herbicide use efficiency. • Identify competitive crop cultivars and their traits • Identify suitable cover crops, intercrops and green manure crops • Use of plant and weed residues for mulching, composting, phytoremediation etc.
2. Weed management through 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. Biological weed management	• Explore the potential pathogens, insects, fish, allelochemicals for utilization as biotic agents in weed management (in India and abroad) • Study the host (weed)-biotic agent inter-relationship and interaction with environment and human beings • Assess the commercial feasibility of biotic agents for mass production, host specificity and possible adverse effect on non-target flora and fauna • Supply of biological agents to various stakeholders like SAUs, AICRP-WC Centres, KVKs, NGOs etc.

4. Herbicide residues and environmental quality	• Quantify herbicide residues in soil, water and plant parts and their consequent entry in the food chain • Assess the possible risk of herbicide hazards on environment • Develop management techniques to mitigate the negative impact of herbicide residues • Develop policy guidelines on herbicide residue limits in food products
5. Aquatic weed management	• Understand biology 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. 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 limits (ETLs) of weeds in different crops • Understand biology and ecology of major weeds
8. Application of biotechnology	• 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 • Study the impact of HRCs on biodiversity
9. Weed risk analysis (WRA)	• Generate data on biology and ecology of important weeds and their damage potential • Optimize and standardize the procedure and protocols for WRA • Identification of weeds of quarantine significance
10. Parasitic weed management	• Develop integrated management practices for *Striga, Cuscuta, Orobanche* and *Loranthus* • Explore the potential of native and exotic biocontrol agents
11. Weed utilization	• Utilize weed biomass as a source of nutrients, bio-gas, bio-fuel, etc • Phyto-remediation of industrial and municipal wastes • Develop production technology for weeds with medicinal properties
12. Management of invasive alien weeds (IAWs)	• Assess the extent and level of infestation of IAWs in different eco-systems • Impact of IAWs on biodiversity • Develop management strategies especially through bio-control
13. Weed management in precision agriculture	• Detect weeds by remote sensing technique • Forecast infestations and crop yield losses • Development of variable rate technology for site-specific application of herbicides by integrating GPS and GIS
14. Database and information systems	• Update National database on weeds • Strengthen library and information system • Develop decision support systems (DSSs), simulation models and information retrieval systems on weed management • Development of databases for on-line dissemination of information on weed management
15. HRD and technology transfer	• Capacity building of scientists in cutting-edge technologies

	• Training programmes, HRD activities for different stakeholders • Increased interaction with farmers and stakeholders through innovative approaches • Socio-economic survey and impact analysis.

9.2 Programmes on Time frame

A) Long-term impact of weed control methods

Sl No	Research Programme	2007-12	2012-17	2017-25
1	Continuous use of herbicides on floristic distribution of weed flora, soil weed seed bank, herbicides residues, soil microflora status and soil fertility under rice-wheat cropping systems (PHT)	♦♦♦♦	♦♦♦♦	♦♦♦♦
2	Long term impact of soil solarization on weed seed bank, soil health and productivity of crops	♦♦	-	-
3	Long term studies on effect of cropping sequence on weed dynamics and soil weed seed bank	♦♦♦♦	♦♦♦♦	♦♦♦♦
4	Long-term impact of tillage on weed dynamics and crop productivity in dominant cropping systems	♦♦♦♦	♦♦♦♦	♦♦♦♦

B) Development of integrated weed management strategies

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Development of sustainable IWM modules for dominant cropping systems	♦♦♦♦	♦♦♦♦	♦♦♦♦
2	Evaluation of competitive crop cultivars and identifying traits for weed suppression in major crops	♦♦	♦♦	♦♦
3	Evaluation of tillage and weed management practices in important cropping systems	♦♦	♦♦	♦♦
4	Evaluation of intercrops/cover crops, live mulches for weed smothering in field crops/orchards	♦♦	♦♦	♦♦
5	Study the impact of nutrient and	♦♦	♦♦	-

	plant residue management on weed dynamics in cropping systems			
6	Evaluation of green manuring on weed dynamics in different cropping systems.	♦♦	-	-
7	Development of IWM practices for the control of parasitic weeds in different crops	♦♦♦	♦♦	♦♦

C) Biology and eco-physiology of crop-weed interaction

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Response of weeds to global climate change.	♦♦♦	♦♦	♦♦
2	Impact of transgenics resistant to herbicides on the diversity of crops and vegetation	♦♦♦	♦♦♦	♦♦♦
3	Screening and development of important cultivars for high allelopathic suppression of problem weeds	♦♦	♦♦	♦♦
4	Quantification, prediction and development of simulated models for crop yield loss estimation and setting up economic threshold limits	♦♦♦	♦♦	♦♦
5	Understanding weed seed dormancy and developing technology to break dormancy	♦♦♦	♦♦♦	♦♦
6	Weed seed bank and seed production potential of major weeds under different management conditions	♦♦	♦♦	♦♦

D) Judicious use of herbicides

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Evaluation of new herbicides for weed control in different crops	♦♦♦♦	♦♦♦♦	♦♦♦♦
2	Efficient weed management through herbicides in cropped and non-cropped situation	♦♦♦	♦♦♦	♦♦♦
3	Increasing herbicidal efficacy through herbicide mixtures, surfactants and adjuvants	♦♦	♦♦	♦♦
4	Improving performance of herbicides through better application techniques	♦♦	♦♦	♦♦

5	Investigations on uptake, translocation, mechanism of action of herbicides with a view to improve herbicide efficiency, understand herbicide resistance etc.	♦♦	♦♦	♦♦

E) Weed control through bio-control agents and bio-pesticides

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Survey and identification of native bio-agents (insect pests), studies on their biology and pest potential against important invasive weeds	♦♦♦♦	♦♦♦♦	♦♦♦♦
2	Importation, evaluation and release of bio-control agents against major invasive weeds (*Parthenium*, Water hyacinth, water fern, alligator weed, *Mikania micrantha, Chromolaena odorata, Mimosa* spp., *Hydrilla* etc).	♦♦♦♦	♦♦♦♦	♦♦♦♦
3	Development of cheap and effective mass production technology of effective bio-agents like *Z. bicolorata, Neochetina* spp. *Cyrtobagous salviniae* and other bio-agents, which will be imported in future.	♦♦♦♦	♦♦♦	♦♦♦
4	Development of biological based integrated management for the control of major invasive weeds	♦♦♦♦	♦♦♦♦	♦♦♦♦
5	Identification, evaluation and commercialization of plant pathogens for biological control of major weeds	♦♦♦♦	♦♦♦♦	♦♦♦♦
6	Identification and evaluation of phytotoxins and allelochemicals for management of weeds	♦♦♦♦	♦♦	♦♦

F) Design, development of weeding tools and herbicide applicators

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Development of technology for precision spraying, location specific spraying, variable rate sprayers etc.	♦♦	♦♦♦♦	♦♦
2	Design, fabrication and evaluation	♦♦	♦♦	♦♦

	of mechanical weeding tools.			

G) Herbicide residues and environmental quality

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Monitoring of herbicide residues and setting residue limits in soil, water and food chain	♦♦♦♦	♦♦♦♦	♦♦♦♦
2	Development of simulation models for predicting herbicide persistence in soil	♦♦	♦♦♦♦	♦♦
3	Effect of herbicides on soil flora and fauna.	♦♦♦♦	♦♦	♦♦

H) Collection, Conservation and Utilization of weeds

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Collection, identification and maintenance of weed herbarium and weed seeds	♦♦	♦♦	♦♦
2	Evaluation and utilization of weed biomass as a source of plant nutrients and other industrial uses	♦♦♦♦	♦♦	♦♦
3	Developing production technology for weeds of medicinal value	♦♦	♦♦	♦♦

I) Weed database and information system

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Detection of weeds by remote sensing technique	♦♦	♦♦	♦♦
2	Development of decision support systems for weed management in cropped and non-crop situations	♦♦	♦♦	♦♦
3	Development and updation of national database on weeds	♦♦	♦♦	♦
4	Development of protocol for weed risk analysis and identifying quarantine weeds	♦♦♦♦	♦♦	♦♦

J) Transfer of Technology and HRD

Sl	Research Programmes	2007-12	2012-17	2017-25
1	Testing and refinement of weed management technologies	♦♦♦♦	♦♦♦♦	♦♦♦♦

2	Technology transfer and impact analysis of weed management technologies	♦♦♦♦	♦♦♦♦	♦♦♦♦
3	Capacity building of scientists	♦♦	♦♦	♦♦

9.3 Funds

The major share of funds needed for execution of the programmes envisaged in the perspective plan will be borne by the Indian Council of Agricultural Research.

Funding will also be sought from outside funding agencies such as DBT, DST, CSIR, MoEF, ISRO and other international agencies such as ACIAR, CABI, etc. for short term projects. In addition, funds will also be raised through farm income, contract research, contract service, consultancy training, etc.

Sl	Heads	2007-12	2012-17	2017-25
A	**Recurring**			
	Pay and allowances	320.00	480.00	720.00
	TA	25.00	37.50	56.25
	HRD	15.00	22.50	33.75
	Res. Contingencies	350.00	525.00	787.50
	Total (A)	710.00	1065.00	1597.50
B	**Non-Recurring**			
	Equipments	336.80	505.20	757.80
	Works	742.00	1113.00	1669.50
	Library	50.00	75.00	112.50
	Land	-		
	Vehicles	20.00	30.00	45.00
	IT share	36.20	1777.50	4263.75
	Total (B)	1185.00	1777.50	2666.25
	Grand Total (A+B)	1895.00	2842.50	4263.75

10 Linkage, Coordination and Execution Arrangement

The overall programme of NRCWS and AICRP on Weed Control will be coordinated and monitored by the Director, NRCWS. The programme-wise linkages with other partners and collaborators and their role are given below

Sl. No	Programme	Agency	Role
1	Long-term impact of weed management methods	SAUs	Data generation, technology dissemination and impact analysis.
2	Development of integrated weed management strategies	SAUs	Data generation, technology dissemination and impact analysis.
		ICAR Institutes; CGIAR Institutes	Supply of genetic material.
3	Biology and eco-physiology of crop-weed interaction	IARI, New Delhi	Technical guidance, consultancy
		Delhi University, Delhi; NRCBT, New Delhi, Herbicide Industry	Development/supply of transgenics resistant to herbicides.
		Institutes of ICAR & CGIAR	Supply of genetic material.
		PDCSR, Modipuram	Joint research, data sharing
		IASRI, New Delhi	Consultancy
		SAUs	Data generation, technology dissemination and impact analysis.
4	Judicious use of herbicides	Herbicide Industry, IARI, New Delhi	Supply of herbicides formulations, adjuvants, herbicide standards, radio labeled herbicides, etc.
		ITPFT, Gurgaon; CIAE, Bhopal	Collaborative research
		SAUs	Data generation, technology dissemination and impact analysis.
5	Weed control through bio-agents and bio-pesticides	CABI, CRC for Tropical Pest Management, and Univ. of Queensland, Australia	Sharing database, facilitation, consultancy & HRD.
		PDBC, Bangalore	Facilitation, data sharing, joint research.
		SAUs	Data generation, technology dissemination and impact analysis.
		IARI, New Delhi, ZSI, NBAIM, RDVV, Jabalpur	Identification of insect pests and pathogens.

Sl. No	Programme	Agency	Role
6	Design and development of weeding tools and herbicide applicators	CIAE, Bhopal	Supply of weeding tools, joint research, data sharing.
		SAUs	Data generation, technology dissemination and impact analysis.
7	Herbicide residues and environmental quality	Herbicide Industry	Supply of standards, radio labeled herbicides and metabolites, HRD.
		ANPPR, New Delhi	Supply of standards, metabolites, joint research, data/facility sharing, HRD.
		IIBTT, Chennai	Joint research, data sharing, HRD.
		IARI, New Delhi	HRD, Joint research and data sharing.
		IASRI, CASS, IARI, New Delhi	Consultancy on modelling.
		IPFT, Gurgaon	Collaborative research
		SAUs	Data generation, technology dissemination and impact analysis.
8	Collection, conservation and utilization of weeds	BSI, Kolkata, NBRI, Lucknow	Identification of weed herbarium.
		Pharmaceutical Industry	Information sharing and marketing
		SAUs	Collection of herbarium and weed seeds.
9	Weed database and information system	NBSSLUP, Nagpur	Data base sharing and mapping.
		NRSA, Hyderabad	Data sharing, consultancy, collaborative research.
		IASRI; CASS, IARI, New Delhi	Consultancy on modelling, DSS etc.
		SAUs	Data generation, technology dissemination and impact analysis.
10	Transfer of Technology and Human Resource Development (HRD)	SAUs, KVKs and State Departments of Agriculture	All activities related to technology transfer.
		Herbicide Industry; DAC, MoA, GOI	Sponsoring training programmes.
		JNKVV & RDVV, Jabalpur	HRD

The critical inputs in the research and other aspects will be through regular projects, externally funded projects, contract research, visiting scientists, and training of our own scientists abroad. For the approved programmes in the different agro-ecological regions, working arrangements will be made with national and international institutions and universities. Linkages will be developed with all the agencies working on weed management.

11.1 FUNDS

Adequate funding and the human resources (both in terms of number and quality) are the two most critical inputs for carrying out the programme. The requirement of funds for execution of the programmes will be met as outlined in 9.3.

11.2 MANPOWER

Manpower in all categories is a serious limitation. More than one-third of the sanctioned scientific strength is not in position at present. Filling up of positions in disciplines such as microbiology, biotechnology either through redesignation or redeployment should be considered on priority. The requirement of manpower to carry out the programmes envisaged in this document will be as follows:

Scientific	Technical	Administration	Auxiliary/ supporting
41	62	31	41

11.3 Infrastructure

The present infrastructure and other facilities available with the centre are inadequate for fulfilling the envisaged objectives effectively. Therefore, additional infrastructure, equipments and manpower would be required. The facilities such as radio-tracer laboratory, GIS laboratory, environmental quality laboratory, biotechnology laboratory, quarantine laboratory for plant pathogens, training and communication facilities etc. are required. The Centre badly requires a designated lecture/training hall, space for sports and recreation facilities etc. A small training facility comprising a training hall, an information centre and a trainee hostel adequately equipped with modern gadgets and tools is a dire necessity. The farm (62 ha) has not undergone a systematic layout and development since its taking over. A budget of Rs. 150 lakh (at 2004 prices) would be required for its systematic development as recommended by CSWCRI, Dehradun. Extension of the present laboratory-cum-administrative building by adding two more wings as per the approved master plan will provide sufficient space for the proposed new laboratories. The Centre would put up a detailed proposal for approval during the XI Five Year Plan.

11.4 HRD and Training

For NRCWS to play the leadership role in weed science in the country, it is very essential to undertake capacity building of scientists, in the frontier and emerging fields of weed science. Further all the scientists need to be encouraged to interact with peers and experts in their respective fields on a regular basis. Participation in international conferences and workshops, those held particularly on foreign soil would make a huge difference in their thinking and attitude as they will be able to assess their strengths and weaknesses in a more objective way. The budget meant for HRD activities be allowed to be used for this purpose. The advantages of Sabbatical leave facility and the visiting scientist scheme of the ICAR could also be made use of in meeting this objective.

The areas where intensive training is required along with the institutions that can offer expertise are as under:

Area	Institute / Organization
Management of weeds through bio-control agents	CABI Bioscience, UK; CRC for Tropical Pest Management, Brisbane; University of Queensland, Australia; PDBC, Bangalore
Tillage and Weed Management	University of California, Davis, USA; RWC
Herbicidal activity of plant constituents	Instituto de Exolgia, Universidad Nacional Autonoma de Mexico, Mexico DF, Mexico; IARI and CSIR, New Delhi
Environmental monitoring and modeling of crop-weed competition	Department of Theoretical Production Ecology, Wageningen Agricultural University, Netherlands
Herbicide resistance in crops and weeds	Natural Resources Institute and University of Reading, UK
Weed management in precision agriculture	ISRO, Bangalore and NRSA, Hyderabad
Weed Risk Analysis	University of California, Davis, USA; AQIS (now Biosecurity Australia) and CRC for Australian Weed Management, University of Adelaide, Australia,
Global climate change and its impact on crop-weed interactions	University of Queensland, Australia; University of Illinois, USA

The overall possible risks that the weed management technology may encounter in the near future are described below.

Although, herbicide consumption in India has risen manifold from a meager 15 MT in the year 1970 to about 11, 000 MT in 2001-02, they are used only in approximately 20 million hectares amounting to about 10 per cent of the present total cropped area. In India, the consumption of herbicides is a meager 60 g/ha at present and accounts for only 16 per cent of the total pesticide consumption in India in contrast to the global trend wherein herbicides account for about 50 per cent of the total pesticide consumption. Although herbicides have benefited the agricultural community by substantially increasing crop yields, their use is not without potential problems. Some of the unintended negative impacts of herbicide use are persistence in soil, pollution of ground water, toxic residues in food (contamination), feed and fodder, adverse effect on non-target organisms, development of resistance in weeds and displacement of labour. These issues can be adequately addressed for the benefit of the farmers and the nation as discussed elsewhere in the document.

Unlike other pesticides, most herbicides do not persist or carryover, particularly in a tropical country like India with high temperatures and rainfall, which enhance the potential losses of applied herbicides various means such as leaching, microbial degradation, hydrolysis and even surface runoff. Several experiments conducted with different crops and herbicides in India, revealed that most of the herbicides applied at recommended doses are non-toxic to the succeeding crops except some sensitive crops like cucumber, pea and mungbean. However, choosing less persistent products, using the appropriate rates and accurate timing and proper application methods, selective tillage, herbicide combinations, and tolerant crops and varieties can help to avoid any possible carryover effects on the subsequent crop.

Generally herbicides have relatively high water solubility and a low soil sorption coefficients in comparison to insecticides, and to a lesser extent, fungicides, and thus have higher leaching capability. The problem of groundwater pollution is more with herbicides which are relatively more mobile in soil as well as in light soils in comparison to heavy soils. Worldwide, among all the herbicides, atrazine followed by alachlor is reported to be a frequent contaminant in ground water and therefore its use has been restricted or banned in some European countries like Italy, as early as in 1990. However, in USA, the largest consumer of atrazine (about 22,000 MT/annum), it is still being used in corn, for the reason that its ban could result in substantial loss in producer income and societal net benefit. The current level of herbicide use in India is too low to result in groundwater contamination. Recent studies initiated under AICRP-Weed Control have indicated no traces of isoproturon in water samples drawn from tube wells in Punjab, the state with the largest consumption of this herbicide.

Herbicides are invariably applied during early stages of crop growth (many a time before planting or emergence of the crop) and never directly onto the flowers and/or fruits. Thus the extended time lag (waiting period) between application and crop harvest will result in dilution of the chemical in the plant system and greater degradation of the toxic molecule, eventually resulting in the non-accumulation of residues in the harvested produce.

Herbicides can also affect other life forms in the environment, such as fish, animals, birds, invertebrates, microorganisms and humans. In contrast to other pesticides like insecticides,

rodenticides, and nematicides, most of which are extremely hazardous to highly hazardous, many of the herbicides are potentially less toxic. This is primarily due to the fact that herbicides are chemicals meant to inhibit biochemical processes in plants which are distinctly different from those occurring in animals.

The risk of developing herbicide resistance in weeds can be overcome to a greater extent by avoiding the continuous use of a particular herbicide coupled with judicious herbicide rotations and mixtures and also by integrating with non-chemical or cultural methods such as crop rotation, tillage, inter-cultivation, intercropping etc.

Another risk that the herbicides may confront is the apprehension that the rural workforce will be rendered jobless and deprived of earning their livelihood. But this myth is unfounded in that with the increasing urbanization, manual labour is not only becoming scarce but also costly and uneconomical. Moreover, manual weeding is highly laborious, back-breaking, and inefficient involving human drudgery. Improved weed management practices liberate the rural women and youth from this human drudgery, who can be diverted to more productive means of livelihood like dairying, poultry, bee-keeping, silviculture, piggery etc. In addition the rural womenfolk who does most of the manual weeding would be left with more free time which can be spent for the welfare of their families, especially children and household nutrition needs. Such developments are expected to eventually result in better standard and quality of living. Herbicides should, therefore, be considered not only as a labour saving technology, but also as a progressive and modern tool which address gender equality besides improving farm profits.

Risks of biological weed control through the introduction of new species of biological control agents are related primarily to potential ill-effects on non-target crops and organisms. Utmost care is exercised while testing the host-range of the bio-control agent prior to release to minimize the likelihood of such occurrences. The effectiveness of established protocols for such testing is underscored by the lengthy record of introductions of phytophagous natural enemies without any permanent harm to any non-target system. Unforeseen negative impacts on non-target organisms through the release of natural enemies appear to be rare and are usually outweighed by their role in conserving biodiversity and improvement in environmental quality.

The adoption of herbicide resistant, genetically manipulated crops in the future may face the risk of development of “super weeds” and contamination of non-GM crops. This is a problem particularly in crops like rice and mustard which have wild relatives existing in India. But this technology can be safely adapted in crops like soybean and maize which do not have any wild relatives existing in the country. The benefits once again far outweigh the risks associated with HRCs. For the reason alone, this technology has unprecedented adoption by farmers with area under HRCs exceeding 70 per cent of total area under GM crops.

It is difficult to change the attitude and mindset of scientists and other partners to accept the inter-disciplinary and participatory mode of operation. A change is therefore, necessary for the desired success. The present promotional policy unfortunately disregards output both in terms of quality and quantity. The situation in AICRP-WC (SAUs) is still worse. Lack of administrative control with NRCWS has made AICRP projects a ‘dumping yard’ for unwanted scientists.

13. REVIEW, REPORTING AND EVALUATION ARRANGEMENT

The Centre's research bodies such as Research Advisory Committee (RAC) and Institute Research Council (IRC) will be reviewing the programme annually. Peer reviews and external reviews are also proposed to be organized on the lines as generally done by the Institutes under CGIAR. Quinquennial Review Teams (QRT) will be reviewing the mandate and research achievements at the end of each 5-year period.

In addition to these organized monitoring procedures, reviews of programmes by Principal Investigators, involving the concerned scientists from the group should be a frequent activity. Each scientist will prepare a critical time-targeted progress report on a six-monthly basis which is critically examined keeping in mind the goals and time-frame. The Director of the Centre will be monitoring and assessing the research activities through regular field/laboratory visits, discussion and review of implementation through seminars and group meetings.

Terms of reference of RAC

- To suggest research programmes based on the national and global context of research in the thrust areas.
- To review the research achievements of the Institute and to see that these are consistent with the mandate of the Institute.
- Any other function that may be specifically assigned by the Director-General

Terms of reference of Institute Research Council (IRC)

- Consideration and evaluation of the research projects (RPF I). The Principal Investigator will make the presentation of the research project to the IRC. The IRC will recommend/reject the research projects along with its duration.
- Consideration and evaluation of the on-going projects (RPF-II: Annual Research Progress Reports), after these have been assessed by an expert. The IRC will make specific recommendations/comments about the achievements and shortcomings of the projects.
- Advise on the fostering of linkages between the Groups/Divisions/Institutes in respect of multi-disciplinary projects.
- Monitor the follow-up action on the recommendations of QRTs with respect to technical programmes of the Institute.
- Any other function as may be assigned to it by the Director of the Institute or ICAR.

14. RESOURCE GENERATION

The main source of finances will continue to be the ICAR which will be ensuring the regular allocation of funds. Besides, the Centre will also be generating additional resources through revenue returns, sale of farm products, consultancy, contractual services, contract research, training, technologies, sponsored projects etc., the details of which are mentioned in the following table.

(Rs. in lakhs)

Sl. No.	Source	IX-Plan*	X-Plan*	XI-Plan**
1	Consultancy	-	-	02.00
2	Royalties	-	-	-
3	Testing fees (for herbicides)	20.32	46.32	60.00
4	Training charges foreseen	-	-	01.00
5	Other items (Sponsored research projects etc.)	-	-	10.00
	a) Sale of farm produce	38.83	55.43	70.00
	b) Miscellaneous	-	-	02.00
Total		59.15	100.95	145.00

* Actual, ** Projection

ICAR guidelines and the recommendations of the high level committees like Johl Committee will be followed in this regard. The Centre would increase income generation by taking up of nucleus and breeders seed production in collaboration with JNKVV, Jabalpur.

15 OUTPUT AND EXPECTED SITUATION

The results of the research programme as envisaged in this document are anticipated to yield the following output:

- Basic and strategic knowledge in the area of weed science.
- Publications of international repute as well as patents on new concepts, methodologies, guidelines, techniques and technologies on different aspects in the field of weed science.
- Improved crop yields and farm income.
- Improved national agricultural productivity resulting in increased GDP.
- Better quality of agricultural produce.
- Saving of human labour which can resort to better and more remunerative works.
- Brings about gender equality and human comfort.
- Improved human and animal health by controlling the obnoxious and poisonous weeds.
- Better understanding of the crop-weed interactions under a changed global climate and development of technologies to overcome the negative impact, if any, of climate change on crop productivity
- Efficient use of costly inputs like fertilizers and irrigation.
- Technologies for better utilization of water for irrigation, fisheries, navigation and recreation.
- Conservation of native biodiversity besides recovering the lands meant for grasslands, forestry etc.
- Improved recreational and aesthetic value of parks, residential colonies and other public places and water bodies.
- Comprehensive databases and information systems.
- Development of expertise and training facilities of international standard to provide training on weed management.
- Technologies for effective utilization of weeds for beneficial purposes.

16. OUTCOME

The proposed research activities in the field of weed science are expected to result in the improved management of weeds in crop as well as non-crop situations, forestry, 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 steep decline in the share of agriculture in India's GDP from about 38 per cent in 1980-81 to 18.5 per cent in 2005-06 is quite alarming. A recent study undertaken at this Centre suggests that proper weed management technologies if adapted can result in an additional production of 103 million tonnes of foodgrains, 15 mt of pulses, 10 mt of oilseeds and 52 mt of commercial crops, per annum, which in few cases are even equivalent to the existing annual production. This amounts to an additional income of Rs. 1,05,036 crores per annum, which shows that weed management technologies have the potential of significantly enhancing the share of agriculture in India's GDP by about 15 per cent. Thus, the agricultural productivity will increase which will eventually result in significantly increasing the country's overall GDP and its growth rate. The socio-economic status of the farming community especially the rural poor 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 like sericulture, bee keeping etc. Our environment will be clean and native biodiversity will be preserved.