खरपतवार विज्ञान अनुसंधान निदेशालय

DIRECTORATE OF WEED SCIENCE RESEARCH

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DWSR ANNUAL REPORT 2011-12

ICAR

Agrisearch with a human touch

वार्षिक प्रतिवेदन
Annual Report
2011-12

खरपतवार विज्ञान अनुसंधान निदेशालय

Directorate of Weed Science Research

जबलपुर (मध्य प्रदेश) भारत

Jabalpur (Madhya Pradesh) India

वार्षिक प्रतिवेदन
Annual Report
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भाकृअनुप
ICAR

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DIRECTORATE OF WEED SCIENCE RESEARCH
जबलपुर - 482 004 (मप्र) भारत
JABALPUR - 482 004 (M.P.) INDIA

Directorate of Weed Science Research
Jabalpur (M.P.)

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Cover & back page (Photo of weedy rice infestation)

Weedy rice is derived from either spontaneous mutations from domesticated rice or hybridization with wild *Oryza* species. It infests all major rice-growing areas in the tropics, and is particularly a problem in the direct-seeded rice in South and Southeast Asia. Weedy rices are very similar to cultivated rice in the vegetative growth stages, and these are not affected by selective herbicides used in rice.

From Director's Desk

Weeds pose a never-ending threat to agricultural production. Besides reducing crop yield and quality, weeds are a serious problem in many non-cropped areas including water bodies, affecting human and animal health, biodiversity and environmental security. Appropriate weed management in cropped areas can substantially contribute to enhancing productivity and resource-use efficiency. The DWSR is a unique institution of its kind in India which is fast progressing to solve the problems posed by weeds by adopting a multi-disciplinary approach in collaboration with other ICAR institutes and SAUs.

I have great pleasure in presenting the accomplishments of the Directorate during 2011-12 in diversified fields, viz. research, teaching, extension, contract and consultancy services. Research achievements have been grouped under 6 major themes, viz. (i) weed biology and eco-physiology, (ii) weed management techniques, (iii) herbicide as a tool in weed management, (iv) bio-pesticides and bio-control of weeds, (v) weed utilization, and (vi) transfer of technology and impact assessment. In addition, the findings of two service projects on supply and monitoring of Mexican beetles, and vermicompost from weed biomass and agricultural waste are also presented. The Directorate undertook five contract research projects in collaboration with herbicide industries, and one consultancy project on *Zygogramma bicolorata* for the control of *Parthenium* in Nagpur region. The findings have been documented in the form of various publications including research papers in reputed journals. Two important manuals on 'Hand Book on Weed Identification' and 'A Guide to Weed Seedling Identification' have been brought out.

Research and development programmes of the Directorate have been strengthened to meet the emerging challenges posed by globalization and growing threat of alien invasive weeds, herbicide resistance development in weeds, climate change, herbicide residues, and lack of technology transfer. There is a need to develop focused, multi-disciplinary and collaborative research and extension programmes for tackling location-specific problems in different parts of the country. During 2011-12, the Quinquennial Review Team under the Chairmanship of Dr. S.C. Modgal conducted a thorough review of the work done at this Directorate and AICRP-Weed Control, and made important recommendations on various aspects, the implementation of which, will lead to raising the quality and visibility of our research in coming years.

I wish to place on record my sincere thanks to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for his personal attention to strengthen various activities and providing unstinted support for the development of this Directorate. Thanks are due to Dr. A.K. Singh, Deputy Director General (NRM) and Dr. J.C Dagar, Assistant Director General (Agronomy & Agroforestry) for their valuable advice and guidance. The information compiled in this report was generated during the tenure of Dr. J.G. Varshney, former Director and Dr. A.R.G. Ranganatha, Acting Director, whose contributions are duly acknowledged. My sincere appreciation is due to all the scientists for their untiring enthusiasm in conducting the research and supplying the material for this report. I owe my heartfelt gratitude to the editorial committee comprising of Drs. V.P. Singh, K.K. Barman, Shobha Sondhia, P.P. Choudhury and M.S. Raghuvanshi for their painstaking and commendable effort in compiling and editing the report.

It is hoped that the information contained in this report will be useful to the researchers, extension workers, policy makers and administrators involved in weed management programmes in the country. Comments and suggestions for further improvement are welcome.

14 August, 2012

(A.R. Sharma)

CONTENTS

ABBREVIATIONS

AAS	:	Atomic Absorption Spectrophotometer
AAU	:	Anand Agricultural University
AAU	:	Assam Agricultural University
AICRP	:	All India Coordinated Research Project
ANGRAU	:	Acharya NG Ranga Agricultural University
APX	:	Ascorbate peroxidase
ARIS	:	Agriculture Research Information System
BAU	:	Birsa Agricultural University
BSKV	:	Baba Saheb Ambedkar Krishi Vidhya Peeth
CAC	:	Consortium Advisory Committee
CAU	:	Central Agricultural University
CAZRI	:	Central Arid Zone Research Institute
CCOD	:	Current Contents on Diskette
CCSHAU	:	Choudhary Charan Singh Haryana Agricultural University
CD-ROM	:	Compact Disc, read-only-memory
CeRA	:	Consortium for e-Resources in Agriculture
CIAE	:	Central Institute of Agricultural Engineering
CIC	:	Consortium Implementation Committee
CIFE	:	Central Institute of Fisheries Education
CRRI	:	Central Rice Research Institute
CSAUAT	:	Chandra Shekher Azad University of Agriculture and Technology
CSKHPKV	:	Choudhary Shravan Kumar Himachal Pradesh Krishi Vishwa Vidhyalaya
CTRI	:	Central Tobacco Research Institute
DAA	:	Days after application
DARE	:	Department of Agricultural Research and Education
DAS	:	Days after sowing
DAT	:	Days after transplanting
DBT	:	Department of Biotechnology
DOR	:	Directorate of Oilseed Research
DRDO	:	Defense Research and Development Organization
DRMR	:	Directorate of Rapeseed-Mustard Research
DSR	:	Direct-seeded rice
DST	:	Department of Science and Technology
EC	:	Emulsifiable Concentrate
FACE	:	Free Air CO_2 Enrichment
GBPUAT	:	Govind Ballabh Pant University of Agriculture and Technology
GC	:	Gas Chromatograph
GLC	:	Gas Liquid Chromatograph
GPOX	:	Guaiacol peroxidase
GPX	:	Glutathione peroxidase
GR	:	Glutathione reductase
HPLC	:	High-performance liquid chromatography
HRD	:	Human resource development
HW	:	Hand weeding
IARI	:	Indian Agricultural Research Institute
ICAR	:	Indian Council of Agricultural Research
IGKV	:	Indira Gandhi Krishi Vishwa Vishyalaya
IJSC	:	Institute Joint Staff Council

IMC	:	Institute Management Committee
IRC	:	Institute Research Council
IRGA	:	Infra Red Gas Analyzer
ISWS	:	Indian Society of Weed Science
ITMU	:	Institute Technology Management Unit
JNKVV	:	Jawaharlal Nehru Krishi Vishwa Vidhyalaya
KAU	:	Kerala Agricultural University
KVK	:	Krishi Vigyan Kendra
LAN	:	Local Area Network
LD	:	Lethal dose
LSD	:	Least significant difference
MAU	:	Marathwada Agricultural University
MPBT	:	Madhya Pradesh Biotechnology
NAIP	:	National Agricultural Innovation Project
NBAII	:	National Bureau of Agriculturally Important Insects
NDUAT	:	Narendra Deo University of Agriculture and Technology
NGO	:	Non-Governmental Organization
NRM	:	Natural Resource Management
OUAT	:	Orissa University of Agriculture and Technology
PAGE	:	Isoenzymes activity profile
PAU	:	Punjab Agricultural University
PBSR	:	Puddled broadcasting with sprouted seeds
PE	:	Pre-emergence
PME	:	Prioritization, Monitoring and Evaluation
PO	:	Post-emergence
QRT	:	Quinquennial Review Team
RAC	:	Research Advisory Committee
RAU	:	Rajendra Agricultural University
RDVV	:	Rani Durgavati Vishwa Vidhyalaya
RFD	:	Results Framework Documents
RVSKVV	:	Rajmata Vijayaraje Sindhia Krishi Vishwa Vidhyalaya
SAU	:	State Agricultural University
SKRAU	:	Swami Keshwanand Rajasthan Agricultural University
SKUAST	:	Sher-e-Kashmir University of Agricultural Science and Technology
SOD	:	Superoxide dismutase
SRI	:	System of rice intensification
SSR	:	Simple sequence repeat
TNAU	:	Tamil Nadu Agricultural University
TP	:	Transplanted rice
TSP	:	Tribal sub plan
UAS	:	University of Agricultural Sciences
VB	:	Vishwa Bharti
VSAT	:	Very small aperture terminal
WAS	:	Weeks after sowing
WCE	:	Weed control efficiency
WP	:	Wettable Powder

Executive Summary

The Directorate has made significant achievements during 2011-12 in research and transfer of technology. The major research areas were: cultural methods of weed management, use of herbicides, phytoremediation, climatic change vis-à-vis crop-weed competition, herbicide residues and biological control of weeds through insects and plant pathogens. The Directorate has continued its excellent track record of popularizing the biocontrol of *Parthenium* by Mexican beetle (*Zygogramma bicolorata)* throughout the country. The Directorate has also taken up several on-farm trials and field demonstrations on proven weed management technologies, awareness campaigns, trainings, and *Kisan Mela* to educate farmers and other end users.

The major research achievements are summarized below:

Weed biology and eco-physiology

- Elevated CO_2 in atmosphere increased nodule biomass of mungbean and decreased nodule senescence as compared to ambient CO_2, suggesting that the exposure of plants to high CO_2 sustained the functionality of nodules for a longer time. Stomatal conductance and transpiration rate decreased in mungbean and *Commelina diffusa*, but increased in *Euphorbia geniculata* at high CO_2. Both carbonic anhydrase activity and photosynthetic rate increased in all the species under study. Differential response of crop and weed species to high atmospheric CO_2 concentration altered crop-weed competition in favour of weeds. In addition, enrichment of atmospheric CO_2 potentially lowered the quality of mungbean seed with diminished protein and enhanced carbohydrate content.
- Problem of weedy rice has emerged as a potential threat with the popularization of direct seeding in rice cultivation. Being a biosimilar of rice, it goes undetected at vegetative stage. By the time panicle emerges and it is detected, the harm is already done. Early and asynchronous maturity and early shattering of grains aid to problem by increasing its seed bank. For genetic make up and biology of weedy rice in India, 83 accessions were collected across 8 states of India through AICRP centres and maintained at DWSR. Immense variation in seed morphology was observed in these accessions in respect to hull colour, presence and length of awns.

Weed management techniques

- Application of FYM @ 10 t/ha + 2 HWs in rice, and 50% FYM + 50% NPK + clodinafop @ 60 g/ha *fb* 1 HW in wheat resulted in the lowest density and dry biomass of weeds at 60 DAS in rice-wheat system.
- Application of 50% NPK + 50% FYM + recommended herbicide *fb* 1 HW to both soybean and wheat recorded the lowest density and dry biomass of weeds in soybean-wheat system.
- In okra–tomato system, FYM @ 10 t/ha + black polythene mulch recorded the lowest density and dry biomass of weeds and highest fruit yield of both the crops (15.1 t/ha of okra and 23.9 t/ha of tomato as compared to 5.59 t/ha and 2.59 t/ha in control, respectively).
- A DWSR herbicide wick applicator has been designed and developed for applying non-selective herbicides in between rows of soybean and mustard.
- In mango and citrus orchards, adoption of legume-based cropping systems, viz. cowpea-pea-cowpea and blackgram-pea-greengram as intercropping during rainy-winter-summer seasons, respectively, in combination with pendimethalin (1.25 kg/ha as PE) was effective in reducing weed growth. These treatments were at par with application of metribuzin (0.5 kg/ha/season) and glyphosate (2.0 kg/ha/season), but significantly superior to intercropping alone. Intercropping treatments were better than sole chemical and mechanical treatments of weed control in terms of soil health.
- Application of glyphosate (2.0 kg/ha/season) provided season-long control of almost all the weeds in both the orchards. However, metribuzin

caused shifting of weed flora towards perennial weeds, viz. *Cynodon dactylon* and *Cyperus rotundus.* It significantly increased the density of *Cynodon dactylon* by 97, 76 and 21% in mango, and 128, 65 and 35% in citrus during summer, rainy and winter seasons, respectively, over that recorded in the base year, i.e. 2008.

- Among crop establishment techniques, puddle broadcasting with sprouted seeds performed better as compared to system of rice intensification, direct-seeded rice and transplanted rice. The puddle broadcasting with sprouted seeds recorded higher grain yield of rice (4.43 t/ha) and was comparable to 2 HWs (4.39 t/ha) and bispyribac-sodium *fb* HW (4.23 t/ha). Weedy plots under system of rice intensification produced the lowest yield (2.51 t/ha).

Herbicides as a tool in weed management

- Application of bispyribac-sodium (25 g/ha) in direct-seeded rice significantly reduced the population of *Echinochloa colona* (50%), *Cyperus iria* (87.6%), *Alternanthera sessilis* (81%), *Commelina communis* (74%), and *Physalis minima* (31%), and increased grain yield over cyhalofop-butyl (90 g/ha).
- In wheat, application of clodinafop (60 g/ha) + 2,4-D (500 g/ha) caused significant reduction in *Avena sterilis, Phalaris minor* and *Physalis minima*.
- In chickpea, application of quizalofop (60 g/ha) was very effective in reducing the infestation of *Avena sterilis.* However, it failed to check the growth of *Medicago hispida*, *Chenopodium album* and *Cichorium intybus* compared to pendimethalin (1250 g/ha) and oxyfluorfen (200 g/ha). Pendimethalin, however, was toxic to chickpea nodulation.
- Application of penoxsulum + cyhalofop @ 150 g/ha PO, pyrazolsulfuron + pretilachlor @ 1.0 kg/ha at 3-7 DAS, penoxsulum @ 22.5 g/ha at 8-12 DAT, fenoxaprop + almix @ 60 + 20 g/ha PO, oxyflourfen + 2,4-D @ 300 + 500 g/ha at 3-7 DAS, azimsulfuron @ 35 g/ha at 10-12 DAS, trifamon + ethoxysulfuron @ 45 + 25 g/ha at 10-15 DAS was recommended for control of grassy and broad-leaved weeds in rice.
- Application of clodinafop + metsulfuron-methyl @ 60 + 4 g/ha PO, metsulfuron-methyl + carfentrazon + NIS @ 30 g/ha PO, carfentrazone + sulfosulfuron + S @ 20+25+45 g/ha PO was recommended for control of grassy and broad-leaved weeds in wheat.
- In soybean, fluzifopbutyl + fomasofen @ 313 g/ha as PO and saflufenacil + imazethapyr at 136 g/ha as PO was recommended for control of grassy and broad-leaved weeds.
- Application of pendimethalin at 1.0 kg/ha PE showed adverse impact on nodulation in black gram.
- Post-emergence application of quizalofop at 50 g/ha, imazethapyr at 100 g/ha and fenoxaprop at 100 g/ha were safe in terms of nodule count and nodule dry biomass production in soybean.
- Application of oxyflorfen at 200 g/ha PE and quizalafop at 60 g/ha PO were safe in terms of nodule count and nodule dry biomass production in chickpea.
- At harvest of wheat, the residues of isoproturon were detected in soil, grain and straw at the level of 0.016, 0.008 and 0.007 µg/g, respectively. However, residues of sulfosulfuron were below <0.001 µg/g.
- The residues of pendimethalin at harvest of chickpea were 0.505, 0.020 and 0.024 µg/g, and that of quizalofop were 0.002, <0.001 and <0.001 µg/g in soil, seed and straw, respectively. Fishes being cultivated in the runoff collecting ponds showed no mortality due to application of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in the adjacent wheat fields. There were no residues of these herbicides in fish at 90 DAS of wheat.
- During photodegradation of 2,4-D-ethyl ester on *Echinochloa* cutin surface, photoproducts, viz. *o*-chlorophenol, o,p-dichlorophenol, 2,4-dichlorophenoxyacetic acid, butyric acid were formed.
- The photoproducts of propaquizafop were 2-isopropylidene amino oxy ethyl ethanoate, and isopropylidene amino oxy phenolate on soil; isopropylidene amino oxy ethane, isopropylidene amino oxy phenolate, 2-[1-methylidene] amino] oxy] ethyl 2-ethoxy propanoate in aqueous phase, and that of sulfosulfuron on soil surface were 2-amino-4,6-dimethoxypyrimidine, 2-ethylsulfonyl imidazo {1,2-a}pyridine-3-sulfonamide, and *N*-(4,6-dimethoxypyrimidin-2-yl) urea.
- *Aspergillus niger* was identified as chlorimuron-ethyl degrading fungi and the degradation products were ethyl-2-aminosulphonyl benzoate, 4-methoxy-6-chloro-2-amino-pyrimidine, *N*-(4-methoxy-6-chloropyrimidin-2-yl) urea, saccharin and *N*-methyl saccharin.

Biopesticides and biocontrol of weeds

- Terpenoids isolated from neem seed were lethal to floating and submerged aquatic weeds at 20-100 ppm.
- Glycoalkaloid fractions isolated from tropical soda apple (*Solanum viarum*) were lethal to coontail at 100 ppm.
- A potential herbicidal molecule with molecular mass of 262 was isolated from *Parthenium* leaf (lethal to aquatic weeds at 12.5 ppm).
- Leaf and stem extracts of *ban tulsi* (*Croton bonplandianum*) were phytotoxic to water hyacinth.
- Adults of gallfly (*Cecidocharus connexa*), collected from the infested area of Bangalore, were released in *Chromolaena odorata* infested area in Jagdalpur.
- Integrated application of fungal bio-agents, *Alternaria alternata* (IMI No. 501353) and *Alternaria eichhorniae* along with insect *Neochetina bruchii* killed water hyacinth more effectively than when beetles were released alone.
- *Cuscuta* was able to germinate in the absence of host; the germinated seedlings moved up to 15 cm distance towards the host for attachment, but could not survive more than 8-12 days without host. Treatment of host seeds with salicylic acid and *Pseudomonas fluorescence* delayed the attachment of *Cuscuta* seedlings and there was 40% reduction in host recognition.

Weed utilization

- *Arundo*-based phyto-remediation wetland system installed in the farm was operated to reduce the pollutant (Ni, Cu, Zn, Mn) concentration in waste water.

Transfer of technology and impact assessment

- Thirty seven field demonstrations on integrated weed management in rice, soybean maize, and blackgram were conducted in *kharif,* while 45 demonstrations were conducted during *rabi* in wheat, chickpea, mustard. In addition, Kisan Mela-cum-Kisam Goshthi and stakeholders' meet were successfully organized to 23.01.2012. Field visits to farmers' fields, trainings, and *Parthenium* awareness week were oganized.
- Directorate supplied about 22.5 lakh Mexican beetles for biological control of *Parthenium* in large area in different Talukas of Nagpur and monitored their establishment.

1 INTRODUCTION

Directorate of Weed Science Research (DWSR) is engaged in developing and disseminating improved weed management technologies in India. The DWSR is unique institution of its own kind where all the aspects of weed management are taken care of in a holistic manner using multidisciplinary approach. The Directorate, since its inception as National Research Centre for Weed Science in the year 1989, has contributed significantly in identifying major weeds in different crops and non-cropped situations; weed competitive crop cultivars and weed smothering intercrops; developing national database on weeds; evaluating new herbicides and making herbicide recommendations; assessing impact of herbicides and its residues in environment; improving non-chemical methods of weed control; and transferring improved weed management technologies to the end users. The future challenges of the Directorate are to address the issues relating to management of weeds in rainfed, dryland and conservation agriculture, and in aquatic bodies.

Vision

Developing innovative, economic and eco-friendly weed management technologies to contain challenges ahead for sustainable agriculture and other societal benefits

Mission

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

Mandate

- To undertake basic, applied and strategic researches for developing efficient weed management strategies in different agro-ecological zones
- To provide leadership and coordinate 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 area of weed science and weed management
- To collaborate with national and international agencies in achieving the above-mentioned goals
- To provide consultancy on matters related to weed science.

Organization and Management

The Directorate receives guidance from Quinquennial Review Team (QRT), Research Advisory Committee (RAC), Institute Management Committee (IMC), and Institute Research Council (IRC).

Laboratories

The Directorate has well-equipped laboratories with sophisticated scientific instruments like LC-MS/MS System, GC, HPLC, IRGA, AAS, universal research microscope with photographic attachment, stereo zoom research microscope, nitrogen auto-analyzer, leaf area meter, UV-visible double beam spectrophotometer, high speed refrigerated centrifuge, HPLC grade water purification assembly, multi-probe soil moisture meter, lab-ware washer, root length measuring system, line quantum sensors with data-logger, etc.

The Directorate has a containment facility and controlled environmental chambers to facilitate research under controlled environmental conditions. Free Air CO_2 Enrichment (FACE) facility and three open-top chambers are available for studies on crop-weed competition vis-à-vis climate change. The research outcome of these facilities provides information about the possible impact of anticipated global warming on weed menace in crops.

The Directorate has a well-developed agricultural engineering workshop with facilities for fabrication, designing and development of weed control tools and implements. Quarantine insectory is there to carry out research using bioagents.

ARIS Cell and Library

The ARIS cell is well equipped with computers, VSAT and LAN facilities, colour photocopier-cum-printer and A-0 plotter. Specialized softwares for GIS analysis, satellite image analysis and routine data analysis are available. All the scientists are provided with internet facility.

The library is having a total collection of 2838 books pertaining to weed science and related subjects, modern facilities, such as CAB-PEST and CAB-SAC CD-ROMs and Current Contents on Diskette (CCOD) on biological sciences. The library subscribes 70 Indian and 20 foreign journals. The DWSR library is also a member of Consortium for e-Resources in Agriculture (CeRA) under NAIP (ICAR). All the scientists have online access to more than 2000 e-journals in various fields of science. Reprographic and documentation facilities have been created for the preparation of documents and reports.

Networking and Collaboration

The Directorate carries out various network programmes through All India Coordinated Research Project on Weed Control (AICRP-WC), which has 22 centres at SAUs located in different agro-climatic zones of the country. There are 9 additional centres in other SAUs participating voluntarily in the network programme. The research activities for the network programme are finalized in the annual group meeting and biennial workshop of AICRP-WC. The Directorate also collaborates with local educational and research institutions, viz. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, and Rani Durgawati Vishwa Vidyalaya, Jabalpur in the area of research, teaching and extension. It has active collaboration with several ICAR Institutes and other research organizations like MPBT. Besides, a healthy interaction exists with herbicide industries, NGOs and KVKs.

Staff

Particulars	Sanctioned strength	Filled
RMP	1	1
Scientist	27	18
Technical	24	23
Administrative	12	09
Supporting	23	23

Details of resource generation (` in lakhs)

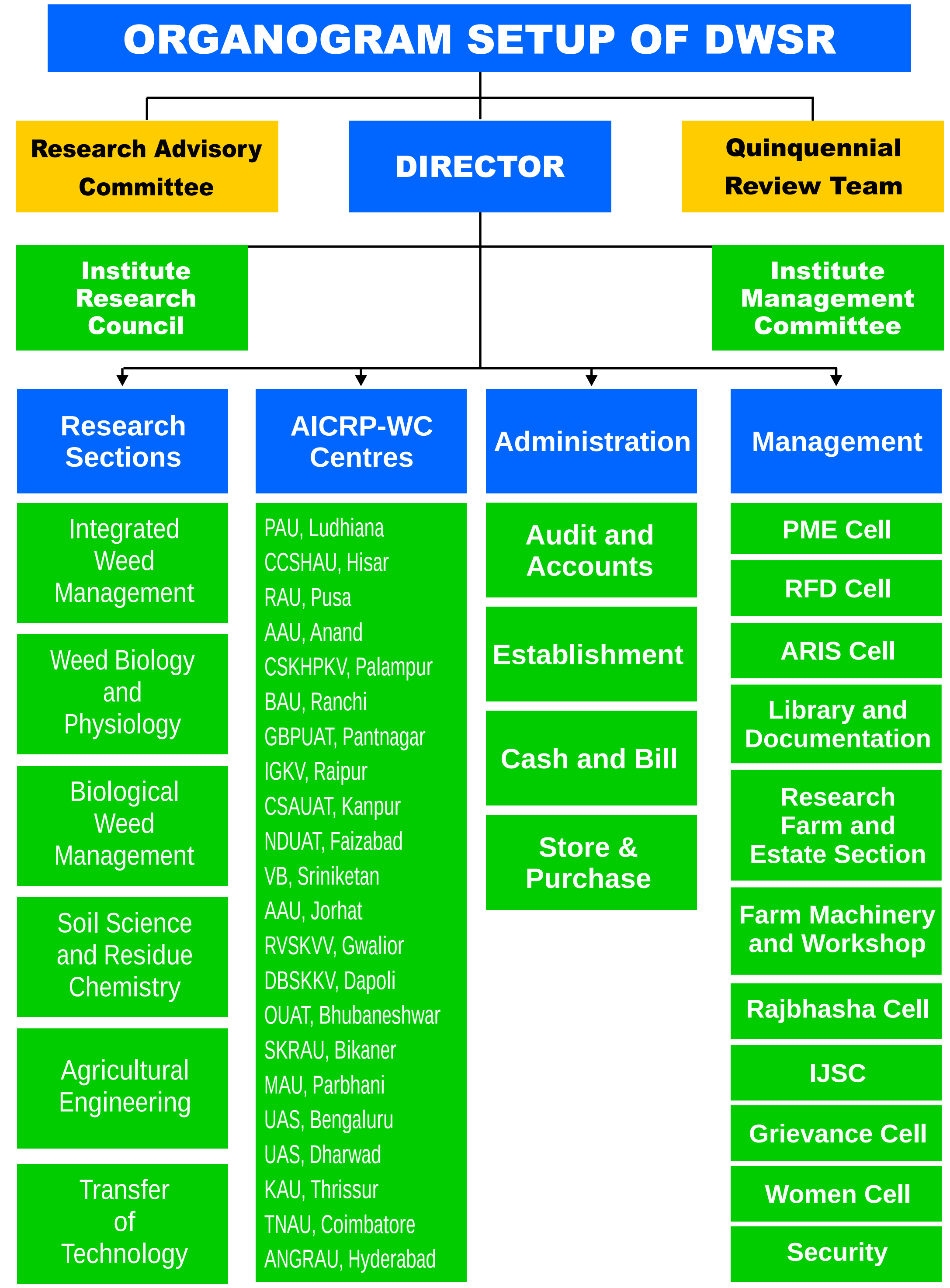
Particulars	Generated
Contract research (testing fees)	21.97
Consultancy	22.50
Resource generation through sale of farm produce, dissertation fees, auction, etc.	24.18
Total	68.65

Research Farm

The Directorate possesses 61.5 ha of well developed research farm with roads and drainage systems, threshing floor, godown and water harvesting ponds.

DWSR Research farm

Containment facility



Budget (2011–12)

(` in lakhs)

Particulars	Plan		Non Plan		Network project	
	Receipt	Expenditure	Receipt	Expenditure	Receipt	Expenditure
(A) Recurring						
Establishment expenses	30.00	30.00	380.00	380.13	472.35	674.50
Pension	0.00	0.00	1.50	1.44	0.00	0.00
P-Loan & Adv.	0.00	0.00	8.00	7.80	0.00	0.00
Travelling allowances	3.40	3.39	3.00	2.97	11.64	14.00
HRD/IT	3.00	2.98	0.00	0.00	0.00	7.57
Research and operational expenses	15.00	15.00	199.50	192.46	54.63	21.78
Tribal Sub-plan	4.25	4.25	0.00	0.00	0.00	36.42
VI Pay commission arrears	-	-	-	-	0.00	615.89
Total (A)	55.65	55.62	592.00	584.80	538.62	1370.16
(B) Non-Recurring						
Equipments	10.65	9.84	0.00	0.00	0.00	0.00
Works	0.00	0.00	0.00	0.00	0.00	0.00
Library	1.35	1.33	0.00	0.00	0.00	0.00
Land	0.00	0.00	0.00	0.00	0.00	0.00
Vehicle	0.00	0.00	0.00	0.00	0.00	0.00
Livestock	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00
Total (B)	12.00	11.17	0.00	0.00	0.00	0.00
Grand Total (A+B)	67.65	66.79	592.00	584.80	538.62	1370.16

2 RESEARCH ACHIEVEMENTS

Theme 1: Weed biology and eco-physiology

Effect of elevated CO_2 on mungbean and associated weeds

Bhumesh Kumar and Meenal Rathore

Effect of elevated CO_2 was studied in summer mungbean and associated weeds (*Euphorbia geniculata* and *Commelina diffusa*) using Free Air CO_2 Enrichment (FACE) facility. Plants were exposed to ambient CO_2 (385 ± 5 ppm) and elevated CO_2 (550 ± 50 ppm) throughout the growing season.

Elevated CO_2 had a positive effect on overall growth of all the plants tested (Fig. 1A and 1B), and resulted in increased biomass and size of mungbean nodules. Both carbonic anhydrase activity (Fig. 1C), and photosynthetic rate (Fig. 1D) increased in all the species under study. Compared to ambient CO_2, nodule senescence decreased at elevated CO_2 (Fig. 1E), suggesting that exposure of plants to high CO_2 sustains the functionality of nodules for a longer time. Stomatal conductance (Fig. 1F) and transpiration rate (Fig. 1G) decreased in mungbean *and C. diffusa* but increased in *E. geniculata* at high CO_2, suggesting its unique adaptive potential to elevated CO_2.

CO_2 enrichment caused transition of ascorbate (Fig. 2A) and glutathione (Fig. 2B) from reduced to oxidized state in mungbean and *C. diffusa.* On the other hand, *E. geniculata* showed the potential to maintain redox homeostasis in its original state at enriched CO_2 level, which could have provided it an advantage over other species in adaptation to climate change condition.

In situ staining of leaves indicated that reactive oxygen species (hydrogen peroxide and superoxide radicals) accumulated only in mungbean, indicating the presence of stronger antioxidant defence mechanism in weed species (Fig 3A). Isoenzymes activity profile (native PAGE) of antioxidant enzymes [superoxide dismutase (SOD), ascorbate peroxidase (APX), guaiacol peroxidase (GPOX), glutathione peroxidase (GPX) and glutathione reductase (GR)] depicted differential regulation as well as induction of new iso-forms in response to elevated CO_2 (Fig. 3B). Stronger antioxidant defence as observed in *E. geniculata* as compared to mungbean *was responsible for the adaption of the former to climate change.* Expression of genes (primer specific) involved in antioxidant defence pathway was altered in mungbean at elevated CO_2 (Fig. 3C).

Differential response of crop and weed species to high atmospheric CO_2 concentration altered crop-weed competition in favour of weeds, and decreased seed yield (Fig. 4A). In addition, enrichment of atmospheric CO_2 potentially lowered the quality of mungbean seed with diminished protein content and enhanced carbohydrate content (Fig. 4B).

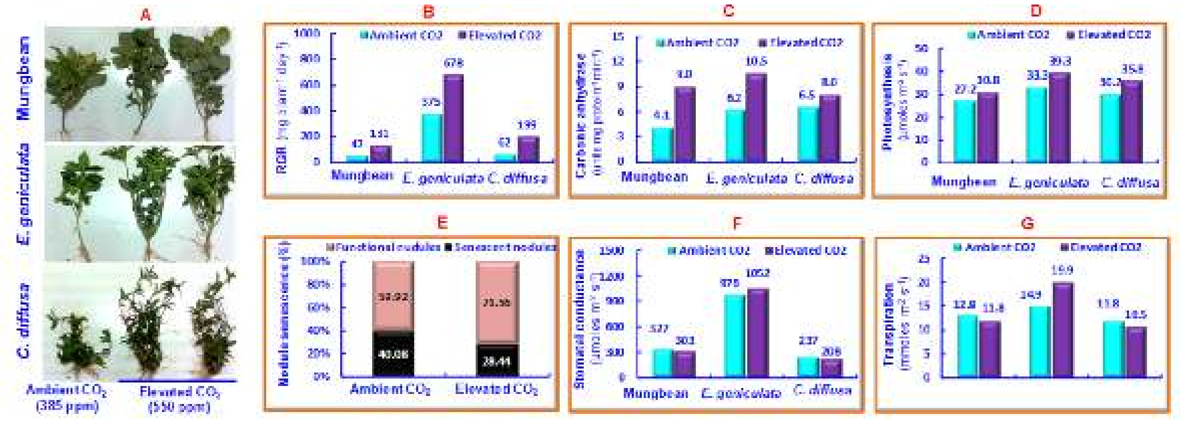


Fig. 1: Effect of elevated CO_2 on growth and development (A), relative growth rate (B), carbonic anhydrase (C), photosynthesis (D), nodule senescence (E), stomatal conductance (F) and transpiration (G) in mungbean and associated weeds at 21 days after treatment

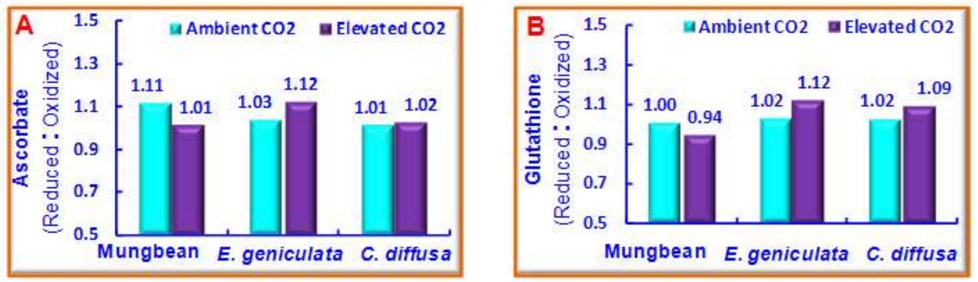


Fig. 2: Effect of elevated CO_2 on ratio of reduced and oxidized ascorbate (A) and ratio of reduced and oxidized glutathione (B) in mungbean and associated weeds at 21 days after treatment

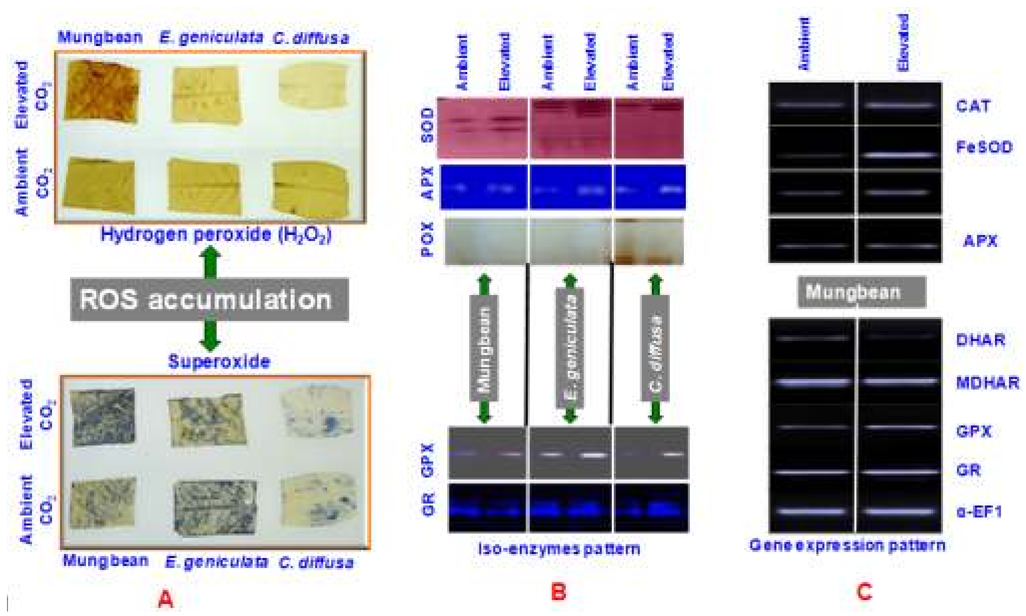


Fig. 3 : Effect of elevated CO_2 on accumulation of reactive oxygen species (A) profile of isoenzymes involved in antioxidant defence pathway in mungbean and associated weeds (B) gene expression pattern of antioxidant defence pathway in mungbean (C) at 21 days after treatment

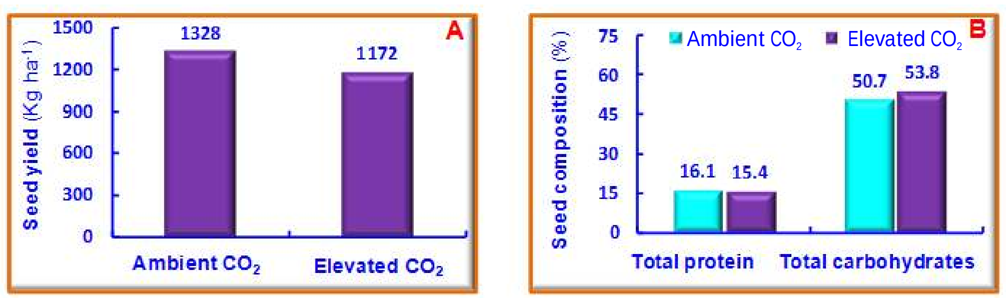


Fig. 4 : Effect of elevated CO_2 on seed yield (A) and seed composition (B) of mungbean

Characterization of weedy rice biosimilars

Meenal Rathore

Weedy rice infestation in India has increased rapidly in recent past. In view of this, Khinni, Mahegawa and Bhadra Paradiya villages of Panagar block of Jabalpur were surveyed to observe and discuss with farmers regarding status of weedy rice infestation under direct-seeded and puddle-broadcast rice. Percent infestation varied from 5% in well managed fields to 50% in poorly managed ones. Farmers stated inability to recognize these biosimilars in early vegetative stages because of their morphological similarity with rice. They were able to assess the presence of weedy rice only after appearance of panicle. It was also observed that these rice biosimilars possessed traits like early maturity, early shattering and asynchronous maturity along with varied hull colour (Table 1 & 2).

Control of weedy rice is difficult as cultural practices for rice also favour weedy rice. Hence, weedy rice biosimilars accessions were collected from the villages surveyed, DWSR farm, and also from other locations of the country for studying their biology with interventions at molecular level to understand and figure out the origin of weedy rice in India by comparing genetic backgrounds of different accessions and to detect probable target sites for its control. Phenotypic variations were observed in the weedy rice accessions collected from the surveyed areas. So far, 79 accessions of weedy rice biosimilars and 7 lines of wild rice germplasm have been collected. To cover all 12 chromosomes of rice, 56 SSR primers against 28 markers for microsatellite analysis of weedy rice biosimilars were selected and synthesized (Table 3).

Table 1. Morphological characters of weedy rice samples collected from Farmers fields

S.No	Characters of awn	Colour of hull	Plant height (cm)	Internodal length (cm)	Presence of ligule	Asynchronous maturity	Remarks
S/1	Black, long	Brownish black	121.9	25	Yes	Yes	DSR over many years
S/2	Brown, long	Dark brown with stripes	134.6	27	Yes	Yes	DSR, in hybrid Khajana sown first time
S/3	Red, short	Grey brown	152.4	24	Yes	No	Variety-Khushboo
S/4	Black, long	Brown black	121.9	28	Nd	Yes	PBSR
S/5	No	Brown	142.2	23	Nd	No	PBSR
S/6	Red, long	Grey brown	142.0	33	Yes	Yes	Transplanted, DSR
S/7	No	Brown	157.5	33	Yes	No	Transplanted, DSR
S/8	No	Brown	152.4	28	Yes	Yes	DSR
S/9	Brown, long	Blackish	134.6	27	Yes	Yes	PBSR, lowland,
S/10	No	Dark brown with stripes	106.7	23	Yes	Yes	PBSR
S/11	Brown, small	Brown	86.4	27	Yes	Yes	PBSR, Lowland
S/12	Brown, long	Dark brown with stripes	111.8	30	Yes	No	PBSR since last two years
S/13	Brown, long	Brown black	142.2	27	Yes	Yes	Transplanted, last year DSR

Weedy rice at DWSR Farm

Variation in hull color and awn length of weedy rice

Table 2. Morphological characters of weedy rice samples collected from DWSR farm

S. No	Characters of awn	Colour of hull	Plant height (cm)	Internodal length	Presence of ligule	Asynchronous maturity
F1	--	Brown	147.3	29	Yes	Yes
F2	Brown	Dark brown with stripes	149.8	27	Yes	Yes
F3	Black	Grey brown	71.1	22	Yes	Yes
F4	Black	Blackish	76.2	22	Yes	Yes
F5	Brown	Brown	116.8	28	Yes	Yes
F6	--	Black	111.7	21	Yes	Yes
F7	--	Brown black	116.8	19	No	Yes
F8	--	Blackish	Nd	Nd	No	Yes
F9	--	Brown black	142.2	29	No	Yes
F10	Brown, short	Blackish	11.5	25	Yes	No
F11	--	Brown with stripes	91.4	21	Yes	No
F12	Reddish-black	Blackish	144.8	30	No	Yes

Table 3. SSR primers designed against 28 markers for SSR analysis of weedy rice biosimilars in comparison to cultivated and wild rice

Marker	Chromosome	Forward primer (F)	Reverse primer (R)
RM220	1	GGAAGGTAACTGTTTCCAAC	GAAATGCTTCCCACATGTCT
RM212	1	CCACTTTCAGCTACTACCAG	CACCCATTTGTCTCTCATTATG
RM53	2	ACGTCTCGACGCATCAATGG	CACAAGAACTTCCTCGGTAC
RM211	2	CCGATCTCATCAACCAACTG	CTTCACGAGGATCTCAAAGG
RM251	3	GAATGGCAATGGCGCTAG	ATGCGGTTCAAGATTCGATC
OSR13	3	CATTTGTGCGTCACGGAGTA	AGCCACAGCGCCCATCTCTC
RM1261	4	GTCCATGCCCAAGACACAAC	GTTACATCATGGGTGACCCC
RM241	4	GAGCCAAATAAGATCGCTGA	TGCAAGCAGCAGATTTAGTG
RM13	5	TCCAACATGGCAAGAGAGAG	GGTGGCATTCGATTCCAG
RM26	5	GAGTCGACGAGCGGCAGA	CTGCGAGCGACGGTAACA
RM413	5	GGCGATTCTTGGATGAAGAG	TCCCCACCAATCTTGTCTTC
RM253	6	TCCTTCAAGAGTGCAAAACC	GCATTGTCATGTCGAAGCC
OSR21	6	ATTTCTTTGGCCACAGGCGA	CCCAGATTCGGAACAAGAAGAAC
RM276	6	CTCAACGTTGACACCTCGTG	TCCTCCATCGAGCAGTATCA
RM11	7	TCTCCTCTTCCCCCGATC	ATAGCGGGCGAGGCTTAG
RM234	7	ACAGTATCCAAGGCCCTGG	CACGTGAGACAAAGACGGAG
RM118	7	CCAATCGGAGCCACCGGAGAGC	CACATCCTCCAGCGACGCCGAG
RM230	8	GCCAGACCGTGGATGTTC	CACCGCAGTCACTTTTCAAG
RM44	8	ACGG GCAATCCGAACAACC	TCGGGAAAACCTACCCTACC
RM215	9	CAAAATGGAGCAGCAAGAGC	TGAGCACCTCCTTCTCTGTAG
RM219	9	CGTCGGATGATGTAAAGCCT	CATATCGGCATTCGCCTG
RM258	10	TGCTGTATGTAGCTCGCACC	TGGCCTTTAAAGCTGTCGC
RM271	10	TCAGATCTACAATTCCATCC	TCGGTGAGACCTAGAGAGCC
RM167	11	GATCC AGCGTGAGGAACACGT	AGTCCGACCACAAGGTGCGTTGTC
RM206	11	CCCATGCGTTTAACTATTCT	CGTTCCATCGATCCGTATGG
RM235	12	AGAAGCTAGGGCTAACGAAC	TCACCTGGTCAGCCTCTTTC
RM277	12	CGGTCAAATCATCACCTGAC	CAAGGCTTGCAAGGGAAG
RM19	12	CAAAAACAGAGCAGATGAC	CTCAAGATGGACGCCAAGA

Identification characters of important weed seeds

V.S.G.R. Naidu

Identifying weed seeds is difficult due to smaller size of many seeds, loss of certain parts, differences in maturity, changes in surface appearance, etc. Identification of weed seeds with the support of colour illustrations and description of seed morphological features is an easy method of weed seed identification. Some of the weed seed characters along with the seed and plant images are given below:

Mukia maderaspantan

Fruits ovoid, globose, green with white bands, turning red at maturity. Seeds 3-4 mm long, ovoid-oblong, grey with shallowly pitted surface.

Mukia maderaspantan and seeds

Stachytarpeta indica

Fruit (drupe) pear shaped, ribbed, 3-5 mm long, enclosed in the calyx, breaking into two oblong pyrenes. Seed long 3-5 mm, black, longitudinally ribbed on one side and flat on the other side.

Stachytarpeta indica and seeds

Trichodesma zeylanicum

Fruits ellipsoid, nutlets ovoid-oblong, smooth, obscurely margined, 4-5 mm long, grey-brown when ripe.

Trichodesma zeylanicum and seeds

Polygonum plebeium

Nutlets 1.0-1.5 mm long, trigonous, with persistent style, shining black.

Polygonum plebeium and seeds

Spilanthes acmella

Achenes 2.0-2.5 mm long, obolong-ovoid, compressed, scabrid, pappus bristles 2-3 minute.

Spilanthes acmella and seeds

Volutarella ramosa

Achene 4-5 mm long, acutely angled, pitted in the grooves, dull brown, pappus hairs many, 5-16 mm long, unequal, shining brown.

Volutarella ramosa and seeds

Cleome chelidonii

Fruit a slender, erect, glandular pubescent cylindrical capsule, 4-8 cm long; seeds about 1 mm in diameter, granular, black or dark brown, transversely and irregularly grooved.

Cleome chelidonii and seeds

Theme 2: Weed management techniques

Organic weed management techniques in diversified cropping systems

Field experiments initiated in 2010 to evaluate organic weed management practices in direct-seeded rice-wheat, soybean-wheat, okra-tomato cropping systems were continued during 2011-12.

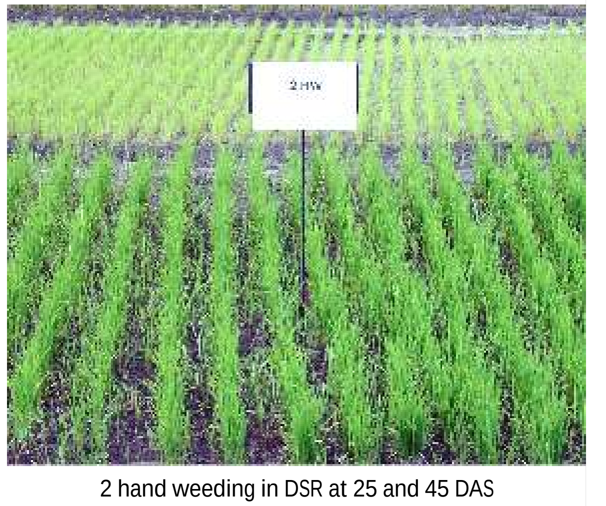
Direct-seeded rice (DSR)–wheat cropping system

A field experiment was conducted in DSR-wheat cropping system with eight treatments in RBD with four replications (Table 4).

Table 4.Treatment details of direct-seeded rice-wheat cropping system under organic weed management

Treatment	Rice	Wheat
T_1	10 t FYM/ha + stale seedbed fb HW at 25 DAS	10 t FYM/ha + stale seedbed fb HW at 25 DAS
T_2	10 t FYM/ha + stale seedbed fb reduced spacing (30 cm)	10 t FYM/ha + stale seedbed fb reduced spacing (15 cm)
T_3	10 t FYM/ha + *Sesbania* incorporation at 30 DAS	10 t FYM/ha + berseem intercropping
T_4	10 t FYM/ha + mechanical weeding at 25 and 45 DAS	10 t FYM/ha+ mechanical weeding at 25 and 45 DAS
T_5	10 t FYM/ha+ 2 HW at 25 and 45 DAS	10 t FYM/ha + 2 HW at 25 and 45 DAS
T_6	Recommended NPK (30-40-20 kg/ha) + herbicide	Recommended NPK (120-60-40 kg/ha) + herbicide
T_7	50% FYM + 50% NPK+ herbicide fb HW at 25 DAS	50% FYM + 50% NPK+ herbicide fb HW at 25 DAS
T_8	Control	Control

Sesbania incorporation in DSR at 30 DAS



2 hand weeding in DSR at 25 and 45 DAS

The major weed flora in rice was *Echinochloa colona, Cyperus iria, Commelina benghalensis* and *Caesulia axillaris*. The lowest weed density (9/m^2) and biomass (4 g/m^2) at 60 DAS were recorded with 10 t FYM/ ha + 2 HWs, which were at par to 10 t FYM/ ha with stale seedbed + HW. The weed density and dry biomass in the control treatments were 155 and 117 g/m^2, respectively. Highest grain yield of rice (4.10 t/ha) was recorded with 50% NPK + 50% FYM + herbicide + HW, which was at par with T_6 and T_3 (Table 5).

The major weed flora in wheat was *Phalaris minor, Medicago denticulata, Chenopodium album, Cichorium intybus, Vicia sativa* and *Physalis minima*. Application of 50% FYM + 50% NPK along with clodinafop @ 60 g/ha fb HW in wheat significantly reduced the weed density and weed dry biomass at 60 DAS. The wheat grain yield was significantly higher (4.84 t/ha) under recommended NPK + herbicide (T_6) than others. Treatments T_5, T_7 and T_3 resulted in grain yield at par, and higher than T_1, T_2, T_4 and control (Table 6).

Table 5. Effect of organic weed management on density and dry biomass of weeds, and yield of direct-seeded rice

Treatment	Weed density /m^2*	Weed dry biomass (g/m^2)*	Plant height at maturity (cm)	Panicles /m^2	Panicle length (cm)	Grain yield (t/ha)
T_1	3.1 (9)	2.8 (9)	64.9	693	14.8	2.40
T_2	4.6 (21)	4.4 (19)	58.7	745	10.0	1.86
T_3	6.9 (47)	6.2 (39)	90.8	540	20.1	3.87
T_4	7.8 (62)	8.3 (70)	77.7	436	17.5	2.15
T_5	2.9 (9)	2.1 (4)	83.0	466	18.7	3.85
T_6	5.7 (32)	5.5 (30)	83.0	415	19.0	3.91
T_7	6.2 (39)	5.0 (26)	90.1	482	19.6	4.10
T_8	12.2 (155)	10.5 (117)	58.1	445	13.8	1.35
LSD (0.05)	1.7	1.8	14.9	104	2.0	0.29

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Table 6. Effect of organic weed management on density and dry biomass of weeds, and grain yield of wheat

Treatment	Weed density /m^2 *	Weed dry biomass (g/m^2)*	Plant height at maturity (cm)	Spikes /m^2	Grain yield (t/ha)
T_1	6.7 (45)	3.5 (12)	68.3	385	2.03
T_2	7.1 (51)	4.6 (21)	62.3	769	2.34
T_3	4.8 (24)	1.8 (3)	90.2	492	4.08
T_4	5.7 (32)	2.8 (8)	77.5	440	2.56
T_5	3.7 (13)	1.5 (2)	77.4	451	4.19
T_6	5.1 (25)	1.9 (3)	96.4	475	4.84
T_7	1.4 (3)	0.7 (0)	89.5	492	4.09
T_8	7.9 (64)	4.1 (16)	76.8	380	1.74
LSD (0.05)	1.6	0.8	8.2	104	0.49

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Soybean – wheat cropping system

A field experiment was conducted in soybean-wheat cropping system with eight treatments in RBD with four replications (Table 7).

The major weed flora in soybean were: *Echinochloa colona, Cyperus iria, Commelina benghalensis, Dinebra* sp, *Physalis minima, Phyllanthus niruri, Caesulia axillaris* and others. The lowest weed density (10.0) and dry biomass (8 g/m²) at 60 DAS was recorded under the treatment 50% NPK + 50% FYM and herbicide + HW as compared to control (45 and 140.6 g/m²). The highest seed yield of soybean was also recorded with the same treatment (2.24 t/ha) as compared to control (0.90 t/ha) (Table 8).

Table 7. Treatment details of soybean-wheat cropping system under organic weed management

Treatment	Soybean	Wheat
T_1	10 t FYM/ha + stale seed bed fb HW at 25 DAS	10 t FYM/ ha + stale seedbed fb HW at 25 DAS
T_2	10 t FYM/ha + stale seedbed fb reduced spacing (30 cm)	10 t FYM/ ha + stale seedbed fb reduced spacing (15 cm)
T_3	10 t FYM/ha + *Sesbania* incorporation at 30 DAS	10 t FYM/ ha + berseem intercropping
T_4	10 t FYM/ha + mechanical weeding at 25 and 45 DAS	10 t FYM/ ha + mechanical weeding at 25 and 45 DAS
T_5	10 t FYM/ha + 2 HW at 25 and 45 DAS	10 t FYM/ ha + 2 HW at 25 and 45 DAS
T_6	Recommended NPK (30-40-20 kg/ha) + herbicide	Recommended NPK (120-60-40 kg/ha) + herbicide
T_7	50% FYM + 50% NPK+ herbicide fb HW at 25 DAS	50% FYM + 50% NPK+ herbicide fb HW at 25 DAS
T_8	Control	Control

Table 8. Effect of organic weed management on density and dry biomass of weeds, and seed yield of soybean

Treatment	Weed density /m²*	Weed dry biomass (g/m²)*	Plant height at maturity (cm)	Pods /plant	Seed yield (t/ha)
T_1	3.9 (15)	5.1 (26)	66.5	44.4	1.67
T_2	5.8 (46)	8.1 (64)	72.9	39.9	1.47
T_3	4.4 (19)	6.2 (39)	72.0	49.1	2.10
T_4	4.7 (21)	6.6 (45)	84.6	42.2	1.44
T_5	4.0 (16)	3.9 (15)	75.1	53.5	2.19
T_6	3.3 (10)	3.9 (16)	75.6	65.3	2.21
T_7	3.2 (10)	2.9 (8)	77.0	62.5	2.24
T_8	6.7 (45)	11.8 (140)	74.4	23.0	0.90
LSD (0.05)	0.9	1.5	10.6	17.1	0.27

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

The major weed flora in wheat were: *Medicago denticulata, Cichorium intybus, Chenopodium album, Vicia sativa, Phalaris minor, Rumex dentatus* and *Lathyrus sativa*. The lowest weed population was recorded under 50% NPK + 50% FYM and herbicide + HW (35/m²) fb 10t FYM/ha + stale seed-bed and HW (39/m²) as compared to control (365/m²). The grain yield of wheat was significantly higher (6.20 t/ha) under recommended NPK + herbicide (T_6) than others (Table 9).

Table 9. Effect of organic weed management on density and dry biomass of weeds and grain yield of wheat

Treatment	Weed density /m²*	Weed dry biomass (g/m²)*	Plant height at matuirty (cm)	Spikes /m²	Grain yield (t/ha)
T_1	6.2 (39)	1.6 (2)	93.9	553	2.69
T_2	7.9 (63)	2.7 (7)	88.5	798	2.83
T_3	7.5 (58)	4.8 (25)	93.2	477	5.02
T_4	10.7 (114)	6.7 (48)	89.7	432	3.21
T_5	8.9 (80)	2.4 (5)	86.8	488	5.32
T_6	8.9 (79)	3.5 (14)	96.7	509	6.18
T_7	5.8 (35)	2.5 (6)	91.2	505	5.25
T_8	18.5 (365)	10.0 (108)	91.0	421	2.04
LSD (0.05)	3.0	1.9	8.1	108	0.74

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

kharif okra- tomato cropping system

A field experiment was conducted in *kharif* okra- tomato cropping system with eight treatments in RBD with four replications (Table 10).

In okra, the major weed flora were: *Phyllanthus niruri, Echinochloa colona, Cyperus iria, Dinebra reflexa, Commelina benghalensi, Physalis minima* and others. Under the treatment FYM + black polythene mulch there was no weed growth fb 10 t FYM /ha + 2 HWs (8.0 and 9.0 g/m²) at 60 DAS, whereas highest population (145/m²) and dry biomass (70 g/m²) of weed was recorded in control. The highest fruit yield of okra was recorded with the 10 t FYM/ha + black polythene (15.1 t/ha) as compared to control (5.59 t/ha) (Table 11).

Table 10. Treatment details of okra-tomato cropping system under organic weed management

Treatment	Okra	Tomato
T_1	10 t FYM/ha + stale seedbed	10 t FYM/ha + stale seed bed
T_2	10 t FYM/ha+black polythene mulch	10 t FYM/ha + black polythene mulch
T_3	10 t FYM/ha + straw mulch	10 t FYM/ha + straw mulch
T_4	10 t FYM/ha + *Sesbania* intercrop *in situ* mulch at 30 DA S	10 t FYM/ha + radish intercrop
T_5	10 t FYM/ha + 2 HW at 25 and 45 DAS	10 t FYM/ha + 2 HW at 25 & 45 DAS
T_6	Recommended NPK (120-60-40 kg/ha) + fluchloralin @ 1.0 kg/ha	Recommended NPK (120-60-40 kg/ha) + fluchloralin @ 1.0 kg/ha
T_7	50% FYM + 50% NPK+ fluchloralin @ 1.0 kg/ha *fb* HW at 45 DAS	50% FYM + 50% NPK + fluchloralin 1.0 kg/ha *fb* HW at 45 DAS
T_8	Control	Control

Table 11. Effect of organic weed management on density and dry biomass of weeds, and okra yield

Treatment	Weed density /m²*	Weed dry biomass (g/m²)*	Yield (t/ha)
T_1	10.9 (121)	9.0 (80)	7.0
T_2	0.7 (0)	0.7 (0)	15.1
T_3	9.4 (87)	8.3 (69)	9.6
T_4	7.2 (52)	7.5 (56)	11.5
T_5	2.9 (8)	3.0 (9)	11.7
T_6	8.4 (70)	6.1 (36)	10.3
T_7	7.2 (51)	5.2 (27)	11.9
T_8	12.0 (145)	8.3 (70)	5.6
LSD (0.05)	1.6	1.2	1.2

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

The major weed flora in tomato was *Medicago denticulata, Cichorium intybus, Physalis minima, Chenopodium album, Paspaladium paspaloides, Vicia sativa* and others. Lowest weed density and weed dry biomass at 60 DAS and highest tomato yield was recorded under 10 t FYM /ha + black polythene mulch (23.9 t/ha), it was at par with T_7 (22.7 t/ha) (Table 12).

Table 12. Effect of organic weed management on density and dry biomass of weeds, and tomato yield

Treatments	Weed density /m²*	Weed dry biomass (g/m²)*	Yield (t/ha)
T_1	11.2 (127)	4.9 (25)	6.8
T_2	0.7 (0)	0.7 (0)	23.9
T_3	10.3 (106)	3.7 (14)	6.6
T_4	11.9 (145)	7.9 (71)	4.5
T_5	9.4 (89)	4.5 (21)	19.1
T_6	9.9 (102)	5.2 (27)	14.3
T_7	9.1 (84)	2.4 (5)	22.7
T_8	16.8 (290)	12.3 (153)	2.6
LSD (0.05)	3.2	2.8	3.3

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Design, development and evaluation of wick applicator for weed management

H.S. Bisen

A DWSR herbicide wick applicator has been designed and developed for applying non-selective herbicides in between crop rows. It consists of cylindrical roller pad, frame, ground wheels, solution tank, cut-off valve and handle. The concentrated herbicide solution stored in chemical tank flows over to cylindrical roller pad through cut-off valve. The cylindrical roller is covered with fibrous clothed pad which gets wet by herbicide solution. When the unit is operated, in wide spaced crop rows, the wet roller pad/cloth comes in contact with the grown-up weeds plants and herbicide solution gets contacted with weeds. Further improvement has been made to enhance the stability during operation of this applicator by reducing the overall weight of the machine, reducing the size of tank, compact arrangement of fixing herbicide tank at lower height and incorporating bearings in rotor wheels.

Application herbicide by herbicide wick applicator

The DWSR herbicide wick applicator was evaluated in soybean and mustard and compared with high volume Knapsack sprayer for application of herbicides. Experiments consisting of six treatments with four replications were carried out in randomized block design.

The weed control efficiency achieved on weed dry biomass basis with DWSR herbicide wick applicator was 58.0 as compared to 70.9% WCE with knapsack sprayer (HV spraying) for imazethapyr. For the application of chlorimuron ethyl + quizalofop-ethyl through wick applicator and knapsack sprayer, the weed control efficiency were 62.3 and 73.1%, respectively in soybean (Table 13).

Table 13. Weed control efficiency achieved by wick applicator and H.V. knapsack sprayer in soybean

Treatment	Weed control efficiency (%) Weed count basis	Weed control efficiency (%) Weed dry weight basis	Seed yield (t/ha)
Imazethapyr by wick applicator	62.3	58.0	1.52
Chlorimuron + quizalofop by wick applicator	60.1	62.3	1.55
Imazethapyr by H.V. Knapsack sprayer	60.6	70.9	1.56
Chlorimuron + quizalofop by H.V. Knapsack sprayer	64.1	73.1	1.55
Weed free by mechanical twin wheel hoe weeder	71.1	60.5	1.57
Weedy check	0.0	0.0	1.08

The field performance of the modified wick applicator was carried out in mustard during *rabi* 2011-12 and compared with HV Knapsack sprayer using nozzle hood for application of imazethapyr and glyphosate. The weed control efficiency on dry-weight basis was 67.7 with herbicide wick applicator as compared to 72.1% under HV knapsack sprayer. In the case of glyphosate, both the application techniques were at par in respect to weed control efficiency (Table 14).

Application of herbicide by knapsack sprayer with nozzle hood

Table 14. Weed control efficiency of DWSR herbicide wick applicator and HV knapsack sprayer with nozzle hood in mustard

Treatment	Weed control efficiency (%) Weed count	Weed control efficiency (%) Dry biomass	Seed yield (t/ha)
Imazethapyr by wick applicator	57.6	67.8	1.13
Glyphosate by wick applicator	57.0	74.0	1.17
Imazethapyr by HV knapsack sprayer with nozzle hood	54.6	72.1	1.17
Glyphosate by HV knapsack sprayer with nozzle hood	53.9	75.2	1.17
Weed free by mechanical twin wheel hoe weeder	57.7	90.7	1.24
Weedy check	0	0	1.00

Results indicated that the DWSR herbicide wick applicator satisfactorily controlled weeds growing between crop rows and its efficiency was close to that of HV knapsack sprayer with nozzle hood.

Integrated weed management in newly-planted mango and *citrus* orchard

V.P. Singh, K.K. Barman and M.S. Raghuvanshi

Field experiments were conducted in mango and citrus orchards to evaluate the economically viable integrated weed control measures. The treatments were: cowpea-pea-cowpea and blackgram-pea-greengram intercropping sequences with and without pendimethalin 1.25 kg/ha PE to each intercrop; metribuzin 0.5 kg/ha, glyphosate 2.0 kg/ha and mechanical weeding (rotavator) twice in each of *kharif-rabi*-summer seasons along with weedy check. The experiment was laid out in RBD with four replications.

Weed population

The experimental fields of mango and citrus orchards were mainly infested with *Cynodon dactylon*, *Paspaladium paspaloides, Cyperus rotundus, Physalis minima, Dinebra* sp. and *Euphorbia geniculata* throughout the year. *Echionochloa colona* during rainy and summer seasons, *Chenopodium album, Vicia sativa* and *Medicago hispida* during winter season were dominant among weed flora.

All the weed control measures influenced the distribution of weed flora. Cowpea-pea-cowpea and

Table 15. Effect of IWM practices on weed density/m² production in mango and citrus orchard

Treatment	Cropping seasons					
	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*
	Mango orchard			Citrus orchard		
T_1: Intercropping of cowpea-pea - cowpea	12.88 (165.4)	13.34 (177.5)	10.93 (119.0)	13.08 (170.6)	9.30 (86.0)	10.14 (102.3)
T_2: Intercropping of blackgram - pea-greengram	13.23 (175.0)	6.95 (47.8)	10.89 (118.0)	14.99 (224.0)	7.80 (60.3)	7.01 (48.6)
T_1 + fluchloralin/pendimethalin	13.69 (187.0)	11.78 (138.3)	9.86 (97.0)	6.23 (38.3)	2.94 (8.0)	5.26 (27.2)
T_2 + fluchloralin/pendimethalin	10.29 (105.4)	3.96 (15.2)	7.73 (59.3)	8.92 (79.0)	2.60 (6.3)	5.54 (30.2)
Metribuzin 0.5 kg/ha in each season	16.77 (280.7)	15.31 (234.0)	17.43 (303.3)	10.38 (107.0)	9.66 (92.8)	10.87 (117.6)
Glyphosate 2.0 kg/ha in each season	8.48 (71.4)	5.95 (34.9)	0.70 (0)	7.75 (59.6)	5.86 (33.8)	2.19 (4.3)
2 mechanical weedings in each season	7.08 (49.6)	8.60 (73.5)	0.70 (0)	6.85 (46.4)	6.51 (41.9)	4.08 (16.2)
Weedy check	15.87 (251.4)	18.86 (355.2)	26.38 (695.0)	12.18 (147.6)	14.53 (210.6)	13.75 (188.6)
LSD (0.05)	2.77	3.11	3.60	3.33	2.37	3.66

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

blackgram-pea-greengram intercropping combined with pendimethalin being at par with the application of metribuzin and glyphosate gave lower density of *E. colona* over intercrops alone. However, *E. colona* population was decreased in metribuzin and glyphosate treated plots by 9 and 20% in mango orchard, and 28 and 36% in citrus orchard, respectively, during 2011-12 of experimentation over the population of base year (2008-09). Highest population of *Cynodon dactylon* was recorded with metribuzin 0.5 kg/ha, which was significantly higher over rest of the treatments. This also caused an increase in density of *Cynodon dactylon* by 97, 76 and 21% in mango and 128, 65 and 35% in citrus during summer, rainy and winter seasons, respectively, over the base year. Growing of intercrops with pendimethalin also caused higher density of *C. dactylon* during fourth cycle of experimentation over the base year. Similar trend was also observed with respect to *Cyperus rotundus*. Highest population of *C. rotundus* was noted in metribuzin treated plots and it was significantly higher over rest of the treatments. Intercropping with and without herbicide also had higher density of *C. rotundus* than weedy check. The higher population of *Physalis minima* was recorded under intercropping with and without herbicidal treatment, which was significantly higher over the rest of the treatments including weedy check. However, highest population of *E. geniculata* was recorded with metribuzin in both the orchard crops. Application of glyphosate provided season-long control of almost all the weeds in both the orchards. So far as the weed shift is concerned, application of metribuzin caused shifting of weed flora towards perennial weeds, viz. *C. dactylon* and *C. rotundus*. Similarly, under weedy check, higher population of *C. dactylon, C. rotundus, A. sessilis and Sida* sp. were observed. Increasing infestation of *C. dactylon* and *C. rotundus* during fourth cycle of experimentation over base year was also observed with the adoption of cropping systems, viz. cowpea-

pea-cowpea and blackgram-pea-greengram in both with and without herbicide. All the weed control treatments were also effective in reducing the population of *Paspaladium* sp., *Dinebra* and *A. sessilis* over weedy check in each season.

All the weed control measures were effective in reducing total weed population and weed dry matter production over weedy check. Among weed control treatments, application of glyphosate 2.0 kg/ha and two mechanical weeding in each season produced the lowest weed growth and this was followed by adoption of intercropping systems (cowpea-pea-cowpea and blackgram-pea-greengram) in combination with pendimethalin (Table 15 & 16).

Tree growth

Weed control measures also influenced the plant growth of mango as compared to weedy check. Both the intercropping systems in combination with pendimethalin showed the highest per cent increase in height (141-146%) over the base year (2008-09), followed by metribuzin (98%). However, the highest per cent increase in girth (345%) was recorded in the treatment of two mechanical weeding in each season, which was at par with the rest of the treatments except metribuzin 0.5 kg/ha. The permanently weedy plots showed the lowest per cent increase in both height (86%) and girth (234%) during fourth cycle of experimentation over base year. In case of citrus, all the weed control treatments being at par with each other produced higher per cent increase in plant height and girth over weedy check (Table 17).

Yield of intercrops

The intercropped plots gave the bonus yield of cowpea (0.18-0.36 t/ha) and greengram (0.23-0.32 t/ha) during summer, cowpea (0.32–0.66 t/ha) and blackgram (0.65-0.77 t/ha) during rainy season, and pea (0.30-0.36 t/ha) during winter season in these orchards. It is obvious from the results that growing intercrops like cowpea and greengram/blackgram during *kharif* and summer seasons and pea during *rabi* season with herbicide application could be utilized as effective integrated weed management package for controlling weeds, reducing soil weed seed bank and getting additional income during non-fruiting period of orchard crops (Table 18).

Table 16. Effect of IWM practices on weed dry biomass (g/m²) production in mango and citrus orchard

Treatment	Cropping seasons					
	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*
	Mango orchard			Citrus orchard		
T_1: Intercropping of cowpea -pea-cowpea	11.37 (129.0)	11.35 (128.3)	4.51 (19.8)	11.20 (125.0)	10.10 (101.5)	4.93 (23.8)
T_2: Intercropping of blakgram-pea-greengram	12.45 (154.5)	11.77 (138.0)	4.47 (19.5)	14.65 (214.0)	10.38 (107.2)	3.70 (13.2)
T_1 + fluchloralin/pendimethalin	11.03 (121.2)	6.18 (37.4)	3.77 (13.7)	7.62 (57.6)	4.25 (17.6)	3.44 (11.3)
T_2 + fluchloralin/pendimethalin	8.17 (66.3)	5.73 (32.3)	3.22 (9.9)	9.64 (92.4)	3.11 (9.2)	2.11 (4.0)
Metribuzin 0.5 kg/ha in each season	11.74 (137.3)	11.83 (139.4)	7.79 (60.2)	14.62 (213.0)	12.10 (145.9)	8.36 (69.4)
Glyphosate 2.0 kg/ha in each season	6.86 (46.6)	3.05 (8.8)	0.70 (0)	5.54 (30.2)	3.63 (12.7)	1.67 (2.3)
2 mechanical weedings in each season	5.16 (26.1)	7.30 (52.8)	0.70 (0)	5.74 (32.4)	4.57 (20.4)	2.37 (5.1)
Weedy check	13.97 (194.7)	13.17 (173.0)	11.09 (122.5)	14.00 (195.5)	12.37 (152.5)	9.25 (85.0)
LSD (0.05)	2.89	2.91	1.14	2.60	3.35	2.77

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Table 17. Effect of IWM practices on growth parameters of mango and citrus plants (% increase over the base year 2008-09)

Treatment	Height		Girth	
	Mango	Citrus	Mango	Citrus
T_1 : Intercropping of cowpea-pea-cowpea	120	73	270	116
T_2 : Intercropping of blackgram-pea-greengram	111	75	296	177
T_1 + fluchloralin/pendimethalin	141	79	340	148
T_2 + fluchloralin/pendimethalin	146	111	333	165
Metribuzin 0.5 kg/ha in each season	98	117	257	147
Glyphosate 2.0 kg/ha in each season	133	119	331	169
2 mechanical weedings in each season	136	120	345	173
Weedy check	86	66	234	86

Table 18. Effect of IWM practices on seed yield (t/ha) of intercrops grown in mango and citrus orchard

Treatment	Cropping seasons					
	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*
	Mango orchard			Citrus orchard		
T_1 : Intercropping of cowpea-pea-cowpea	0.14	0.10	0.82	0.18	0.32	0.36
T_2: Intercropping of blackgram-pea-greengram	0.47	0.59	0.85	0.23	0.65	0.30
T_1 + fluchloralin/pendimethalin	0.06	0.09	0.92	0.36	0.66	0.36
T_2 + fluchloralin/pendimethalin	0.47	0.62	1.05	0.33	0.77	0.30

Table 19. Impact of different weed management practices on soil physico-chemical parameters in mango orchard

Treatment	PF (kg/cm^2)	IR (mm/h)	Org. C (%)	SMBC (µg/g)	Available nutrients (kg/ha)		
					Mineral N	P	K
T_1 : Intercropping of cowpea-pea-cowpea	3.84	15.8	0.72	358	73.5	29.0	334
T_2: Intercropping of blackgram	3.63	14.3	0.66	347	76.9	29.0	343
T_1 + fluchloralin/pendimethalin	3.80	14.3	0.65	297	77.6	29.8	340
T_2 + fluchloralin/pendimethalin	3.75	15.3	0.67	241	77.4	29.8	354
Metribuzin 0.5 kg/ha in each season	3.66	4.5	0.66	230	76.0	23.8	402
Glyphosate 2.0 kg/ha in each season	3.51	4.0	0.64	139	78.0	23.5	411
2 mechanical weedings in each season	3.40	4.3	0.67	369	78.2	23.5	402
Weedy check	4.68	11.0	0.94	348	87.3	23.1	402
LSD (0.05)	0.48	4.6	0.07	38	4.9	1.3	15

PF: Penetration force; IR: Infiltration rate

Soil parameters

The observation on penetration resistance and infiltration rate under the different floor management practices were recorded during *rabi* 2011-12 in the mango orchard. The intercropping treatments, both with and without herbicides, showed significantly higher infiltration rate over the remaining treatments. The penetration resistance under saturated moisture condition was significantly highest in the weedy check treatment, which was densely infested by *C. dactylon*. The resistance provided by the thick root system of the grass could be the probable reason for this observation. There was no significant variation among the remaining treatments in this respect. The data thus indicated that the intercropping treatments were superior to non-intercropping treatments in terms of soil physical quality indices in mango orchard (Table 19).

The soil samples were collected at the beginning, mid and end of both *kharif* 2011 and *rabi* 2011-12 and analysed for chemical parameters, viz. pH, EC, organic carbon, available mineral nitrogen and available- P and -K content. The data thus collected were pooled prior to analysis. The available K content of the soil was relatively lower in the intercropped plots compared to that in weedy and non-intercropped plots. This indicated that the recommended dose of K should be applied to the legumes if these are to be grown as intercrop to manage the orchard floor. Contrary to available K content, available P content was relatively higher in the intercropped plots as compared to sole chemical and mechanical weeding treatments. It could be due to the fact that the intercropped plots received only N and P through DAP thrice in a year, since the inception of the experiment, leading to depleting trend in K but a built up of P in these treatments. No definitive trend in respect to the remaining chemical parameters was noticed among the given weed control measures, except that the organic carbon content of the soil was significantly higher in the weedy than in the remaining plots. This could be due to the benefit of no tillage operation in the weedy plots, resulting in higher carbon sequestration.

Soil samples collected during mid-*rabi* season 2011-12 were also analysed for soil microbial biomass carbon (SMBC) content. Among all the treatments, the SMBC content was much lower in the metribuzin and glyphosate treated plots. The intercropped plots without herbicide application (T_1, T_2) showed significantly higher SMBC than the intercropping with pendimethalin treatments (T_3, T_4). Similar to SMBC, application of pendimethalin also decreased the nodulation in the intercrops (Fig. 5). It was concluded that intercropping of legume crops along with the recommended doses of N, P and K could be a better option of managing weeds in mango orchard. However, an alternative herbicide with no or relatively lower side effect on soil microbial population, compared to pendimethalin, may be evaluated in due course of research for managing weeds in the intercrops.

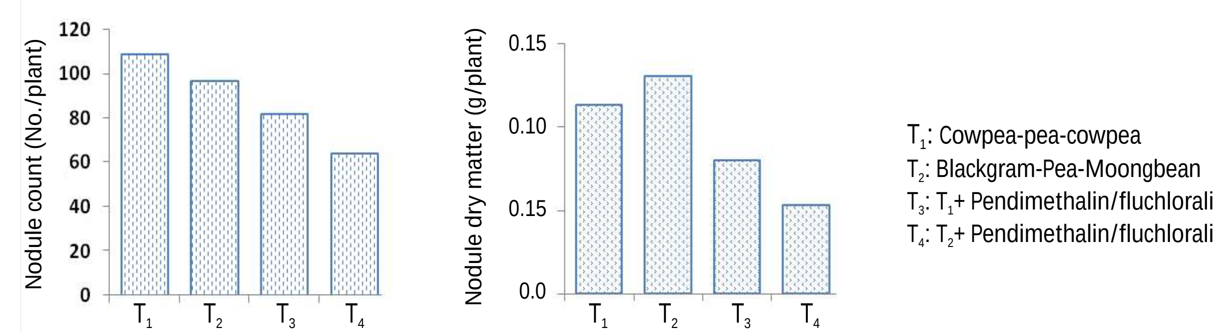


Fig. 5. Effect of weed management practices on nodulation of pea grown as in intercrop in mango orchard

Effect of integrated weed control measures on weed growth in rice grown under the system of rice intensification (SRI)

V.P. Singh and Raghwendra Singh

Alternate wetting and drying in SRI may lead to excessive weed growth which, if not managed in time, may cause immense loss in yield. Rotary weeder or cono weeder is being used to tackle weed problems in SRI, which may not be economical or feasible in some situation. Moreover, rotary weeding has to be supplemented with 1 or 2 HW to remove the weeds growing near the hills, which escapes during rotary weeding. With this background, a field trial on integrated weed management (IWM) under SRI was laid out with the treatments comprising of cono-weeder at 20 DAP, pretilachlor at 0.75 kg/ha PE (3 DAP), pyrazosulfuron at 25 g/ha at 15 DAP, bispyribac-sodium at 25 g/ha at 15 DAP, fenoxaprop at 60 g/ha at 15 DAP, fenoxaprop at 60 g/ha + almix at 4 g/ha at 15 DAP, pretilachlor at 0.75 kg/ha + cono-weeder at 20 DAP, pyrazosulfuron at 25 g/ha at 15 DAP + cono-weeder at 20 DAP and weedy check by following randomized block design with 3 replications. The experiment was initiated with transplanting of 12 days old nursery of rice variety 'JR-201' at spacing of 30 cm x 30 cm in the first week of July 2010, and repeated again in July 2011.

Echinochloa colona, Cyprus iria, Caesulia axillaris, Commelina communis and *Alternanthera sessilis* were dominant weed flora. All the weed control measures were effective in significantly reducing the population of *E. colona* and *C. iria*. Lowest population of *C. iria* was recorded with the application of pyrazosulfuron + cono-weeder, and it was at par with sole pyrazosulfuron, bispyribac-sodium and pretilachlor either alone or in combination with cono-weeder. Cono-weeder alone failed to reduce the population of *C. iria*. Fenoxaprop alone being at par with fenoxaprop + almix and bispyribac-sodium produced the lowest density of *E. colona* (Table 20).

All the weed control measures significantly reduced the total weed population and weed dry biomass over weedy check. Lowest weed density and weed dry biomass was recorded with bispyribac-sodium, followed by pretilachlor + cono-weeder and fenoxaprop + almix treatments. Bispyribac sodium being at par with pretilachlor + cono-weeder and fenoxaprop + almix produced higher tillers/hill, grains per panicle, 100 grain weight and grain yield of rice. Cono-weeder alone, pyrazosulfuron alone or in integration with cono-weeder gave lowest yield attributes and grain yield of rice compared to the other weed control measures. Presence of weeds throughout growing season caused 48% reduction in grain yield (Table 21 & 22).

Table 20. Effect of IWM practices on weed density/m^2 in rice grown under SRI method of rice cultivation

Treatment	*Echinochloa colona*	*Alternenthera sessilis*	*Cyperus iria*	*Caesullia axillaris*	*Commelina communis*
Weedy check	8.2	0.9	8.4	1.2	1.1
Cono-weeder	3.7	0.9	7.0	1.1	1.3
Pretilachlor	4.3	-	2.2	1.3	1.6
Pyrazosulfuron	4.9	1.2	2.0	1.2	1.0
Bispyribac-sodium	1.9	-	2.8	-	1.1
Fenoxaprop	1.3	0.9	6.7	0.9	2.4
Fenoxaprop + almix	1.4	-	5.1	0.9	1.4
Pretilachlor + cono-weeder	2.9	-	2.4	1.1	1.1
Pyrazosulfuron + cono-weeder	4.1	0.9	1.6	1.0	1.2
LSD (0.05)	1.2	0.4	2.2	0.7	1.3

N.B. Data subjected to $\sqrt{x+0.5}$ transformation

Table 21. Effect of IWM practices on weed and crop growth under SRI

Treatment	Weed density /m^2*	Weed dry biomass (g/m^2)*	Plant height at 60 DAP (cm)	Tillers/hill at 60 DAP
Weedy check	12.1	11.5	102.4	13.3
Cono-weeder	8.2	7.9	99.2	16.0
Pretilachlor	5.2	5.0	106.4	22.1
Pyrazosulfuron	4.7	5.9	106.4	20.0
Bispyribac - sodium	4.0	3.3	95.4	25.9
Fenoxaprop	7.8	6.4	97.0	22.3
Fenoxaprop + almix	5.2	4.2	101.7	22.2
Pretilachlor + cono-weeder	4.0	3.8	100.5	21.6
Pyrazosulfuron + cono-weeder	5.8	6.6	105.4	21.5
LSD (0.05)	3.1	3.2	12.1	6.1

*Data subjected to $\sqrt{x+0.5}$ transformation

Table 22. Effect of IWM practices on yield attributes and grain yield of rice under system of rice intensification (SRI)

Treatment	Panicle length (cm)	Grains / Panicle	100-seed weight (g)	Grain weight (g/panicle)	Grain yield (t/ha)
Weedy check	24.2	19.7	3.0	2.2	1.65
Cono-weeder	23.9	38.5	2.8	2.2	2.33
Pretilachlor	24.6	47.7	2.8	2.6	3.08
Pyrazosulfuron	23.8	47.4	2.6	2.8	2.98
Bispyribac- sodium	24.5	56.9	3.0	2.9	3.59
Fenoxaprop	25.7	47.4	2.5	2.4	3.05
Fenoxaprop + almix	21.4	53.1	2.7	3.2	3.52
Pretilachlor + cono-weeder	24.2	51.8	2.6	2.6	3.52
Pyrazosulfuron + cono-weeder	23.3	48.9	2.5	3.0	3.14
LSD (0.05)	2.5	17.5	0.5	0.8	1.14

Crop establishment and weed management practices in rice-wheat cropping system

Raghwendra Singh, V.P. Singh and K.K. Barman

The present study was conducted to evaluate the effect of crop establishment and weed management techniques on weeds and productivity of rice-wheat system. The field experiment was initiated in *kharif* 2011 by following split-plot design with three replications of four rice cultures, viz. transplanting (TP), puddled broadcast sowing with sprouted seed (PBSR), direct seeded rice (DSR) and system of rice intensification (SRI) as main plot treatments and four weed management practices, viz. weedy check, herbicide alone (bispyribac-sodium 25 g/ha), herbicide (bispyribac-sodium 25 g/ha) + 1 HW (20 DAT/DAS), and 2 HWs (20 and 45 DAS/ DAT) as sub-plot treatments.

Infestation of *Echinochloa colona* was significantly higher in DSR and PBSR as compared to transplanting and SRI methods. However, reverse trend was observed in case *of Cyperus iria*, *Caesulia axillaris* and *Eclipta alba* (Table 23).

Grain yield of rice under PBSR (4.43 t/ha) was significantly higher over all the treatments. The maximum yield was recorded with 2 HWs (4.39 t/ha) and it was at par with bispyribac-sodium *fb* HW (4.23 t/ha). Panicle length, grains/ panicle, 1000-grain weight and grain weight/panicle did not cause marked effect (Fig. 6) .

Interaction between crop establishment and weed management practices was found significant. The maximum yield (4.82 t/ha) was observed with PBSR under 2 HW. Weedy plots under SRI produced lowest yield (2.51 t/ha) and, thereby, showed highest reduction in yield due to weed. The SRI was more responsive to weed management practices as compared to other crop establishment methods (Table 24).

Soil samples were collected at maturity stage of wheat 2011-12, and were analysed for pH, EC, organic C, available N and P. No effect was noticed on these parameters after completion of the first cycle of the experiment.

Table 23. Effect of crop establishment and weed control methods on density and dry matter of weeds in rice at 60 DAS

Treatment	*Echinochloa colona*		*Cyperus iria*		*Caesulia axillaris*		*Eclipta alba*	
	Density (nos/m^2)*	Dry matter (g/m^2) *	Density (nos/m^2)*	Dry matter (g/m^2)*	Density (nos/m^2)*	Dry matter (g/m^2) *	Density (nos/m^2)*	Dry matter (g/m^2) *
Method of establishment								
Transplanting	0.28	0.20	17.00	6.12	7.33	2.93	4.67	1.15
PBSR	2.19	2.65	11.00	6.27	3.83	1.10	1.67	0.44
DSR	3.44	4.69	8.08	5.74	2.67	0.91	2.42	0.67
SRI	0.89	0.82	17.58	8.63	9.25	3.21	6.83	1.86
LSD (0.05)	1.30	0.77	3.50	2.52	1.36	1.06	1.21	0.69
Weed control practices								
Weedy check	2.16	3.36	24.50	17.60	10.42	3.83	6.08	2.51
Bispiribac-sodium	1.93	2.97	12.42	5.10	8.17	2.86	3.17	0.57
Bispiribac-sodium + HW	1.84	1.51	8.25	1.68	8.02	2.71	3.67	0.79
2 HWs	1.97	0.53	8.50	2.38	3.42	0.56	2.67	0.26
LSD (0.05)	0.93	0.23	2.10	2.18	0.87	0.93	1.23	0.77

*Data subjected to $\sqrt{x+0.5}$ transformation

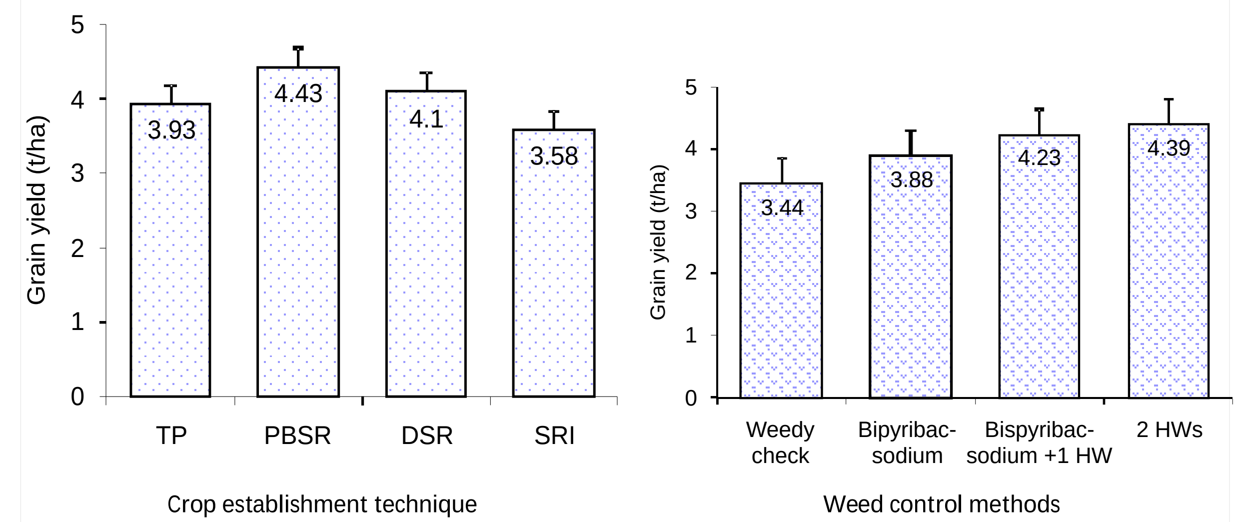


Fig. 6. Effect of crop establishment and weed control methods on growth, yield attributes and yield of rice

Table 24. Interaction between crop establishment methods with weed management practices on rice yield (t/ha)

Crop establishment methods	Weed management practices			
	Weedy check	Bispyribac-sodium	Bispyribac-sodium + 1 HW	2 HWs
Transplanting	3.19	4.05	4.27	4.23
PBSR	3.97	4.36	4.58	4.82
DSR	4.08	3.51	4.37	4.43
SRI	2.51	3.59	4.10	4.13
LSD (0.05)		0.82		

PBSR under 2 HWs (57 DAT)

SRI under weedy check (45 DAT)

Theme 3: Herbicides as a tool in weed management

Efficient weed management through herbicides in field crops and their impact on soil health

Anil Dixit

Effect of post-emergence herbicides on direct-seeded wetland rice

A field experiment was conducted in direct-seeded rice consisting of herbicides along with HW and weedy check. The major weed flora observed in the experimental field was *Echinochoa colona, Cyperus rotundus, Commelina benghalensis* and *Phyllanthus niruri.* Weeds in unweeded control reduced the grain yield of rice by 53% over 2 HWs. Herbicidal treatments recorded significantly the lower weed density and weed dry biomass as compared to weedy check. Application of fenoxaprop + ethoxysulfuron @ 60+15 g/ha, oxyfluorfen + 2,4-D @ 300+500 g/ha, bispyribac sodium @ 25 g/ha and fenoxaprop + almix @ 60+20 g/ha were on par with each other with regard to lowest weed density and weed dry biomass. Highest grain yield of 5.93 t/ha was obtained with 2 HWs (Table 25).

Table 25. Effect of different herbicides on population and dry matter of weeds at 60 DAS and rice yield

Treatment	Dose (g/ha)	Weed density /m^2*	Weed dry biomass (g/m^2)	Grain yield (t/ha)
Pyrazosulfuron (PE)	25	4.9 (13)	18	4.63
Pretilachlor (PE)	750	5.0 (14)	42	4.43
Cyhalofop (PO)	90	5.0 (32)	48	4.15
Fenoxaprop (PO)	100	3.7 (22)	23	410
Cyhalofop + almix (PO)	90+20	4.6 (18)	31	4.46
Fenoxaprop + almix (PO)	60+20	3.9 (8)	17	5.01
Azimsulfuron (PO)	35	4.3 (11)	18	5.19
Bispyribac-sodium (PO)	25	3.1 (11)	8	4.94
Fenoxaprop + ethoxysulfuron (PO)	60+15	2.5 (15)	22	5.08
Oxyfluorfen + 2,4-D (PO)	300+500	3.5 (18)	25	5.16
Metamifop (PO)	100	4.2 (27)	27	4.40
2 HWs		2.2 (4)	4	5.93
Weedy check		7.0 (89)	121	2.81
LSD (0.05)		1.3	31	0.64

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Effect of tank-mix combination of penoxsulum with insecticide and fungicide in direct-seeded rice

A field study was carried out to evaluate the efficacy of penoxsulum 25% OD formulation with chlorpyriphos and carbendazim. Penoxsulum @ 20, 22.5, 25, 50 g/ha and its tank-mix application with chlorpyriphos, carbendazim and urea 2% were compared with bispyribac sodium and pretilachlor. The major weed flora observed in the experimental field was *Echinochoa colona, Cyperus rotundus, Commelina benghalensis* and *Phyllanthus niruri.* All weed control treatments significantly reduced weed dry biomass production and increased the grain yield of rice over control. The increase in grain yield due to penoxsulum @ 50 g/ha, penoxsulum + urea 2%, bispyribac sodium @ 25 g/ha and peoxsulum + carbendazim @ 80 g/ha were respectively 159,153,150 and 150% over weedy check (Table 26). On the basis of visual observations on 0-10 point scale, none of the weed control treatments was phytotoxic on crop.

Table 26. Effect of different weed control treatments on weed population, weed dry biomass and yield of rice

Treatment	Dose (g/ha)	Weed density /m^2*	Weed dry biomass (g/m^2)	Grain yield (t/ha)
Penoxsulum 25% OD	20	7.4 (55)	44	2.82
Penoxsulum	22.5	6.4 (40)	38	3.23
Penoxsulum	25	5.7 (32)	34	3.47
Penoxsulum	50	3.1 (9)	24	4.47
Penoxsulum + chlorpyriphos	22.5	4.6 (21)	35	3.90
Penoxsulum + carbendazim	80	4.5 (20)	36	4.09
Penoxsulum + urea 2%	25	4.3 (18)	32	4.37
Bispyribac-sodium	25	5.1 (26)	21	4.32
Pretilachlor	750	5.4 (29)	51	2.93
Untreated control	-	8.4 (70)	113	1.74
LSD (0.05)	-	1.4	11	0.46

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Continuous use of herbicides on weed dynamics and crop productivity in direct-seeded rice - wheat cropping system

V. P. Singh, K.K. Barman and Shobha Sondhia

A long-term field experiment was laid out during *kharif* 2010 with treatment combinations consisting of bispyribac-sodium @ 25 g/ha PO, cyhalofop-butyl @ 90 g/ha PE and HW at 30 DAS alongwith weedy check in DSR (*kharif*) as main plot treatments, which were superimposed by post-emergence application of isoproturon @ 1500 g/ha, sulfosulfuron @ 25 g/ha and clodinafop @ 60 g/ha + 2,4-D @ 500 g/ha, HW at 30 DAS and weedy check in wheat (*rabi*) as sub-plot treatments in split-plot design with 3 replications.

Experimental field was mainly infested with *Echinochloa colona*, *Alternanthera sessilis*, *Commelina communis*, *Physalis minima*, *Caesulia axillaris*, *Corchorus* sp. and *Cyprus iria*. All the weed control treatments reduced the total weed density and weed dry biomass production significantly over weedy check. Lowest weed population and its dry biomass production were recorded with bispyribac-sodium over rest of the treatments. This was 78 % and 59.6 % lesser than cyhalofop-butyl in respect to weed density and weed dry biomass production. The application of bispyribac sodium significantly reduced the population of *E. colona* (50%), *C. iria* (87.6%), *A. sessilis* (81%), *C. communis* (74%) and *P. minima* (31%) over cyhalofop-butyl. Application of cyhalofop-butyl failed to check the growth of *C. iria*, *A. sessilis*, *C. communis* and *P. minima* but reduced the population of *E. colona* by 51% and *C. axillaris* by 13% over weedy check (Table 27). All weed control measures also influenced the yield attributes and grain yield of rice. Among herbicides, bispyribac-sodium being *at par* with 1 HW produced higher number of tillers, panicles per running meter row length and grain yield of rice over cyhalofop-butyl. However, all the treatments showed significantly higher grain counts and grain weight per panicle over weedy check. Presence of weeds throughout growing season caused 42% reduction in grain yield of rice (Table 28).

Phalaris minor and *Avena sterilis* among grassy, and *Chenopodium album*, *Medicago hispida, Physalis minima* and *Cichorium intybus* among broad leaved weeds were recorded in wheat during *rabi* 2011-12. All the treatments significantly reduced the emergence of all weed species except *C. intybus,* and also total weed population and their dry matter production. Application of clodinafop + 2,4-D caused significant reduction in *A. sterilis, P. minor* and *P. minima*, whereas lowest populations of *C. intybus, M. hispida* and *C. album* were recorded with sulfosulfuron. Isoproturon failed to check the growth of *A. sterilis* and *P. minor,* but was very effective against *C. intybus* and *C. album*. Clodinafop + 2,4-D caused 53% and 64% reduction in total weed population and weed dry biomass, respectively over weedy check. This was followed by application of sulfosulfuron. Both the herbicidal treatments, sulphosulfuron and clodinafop + 2,4-D were effective in reducing population of almost all weed species, total weed density and weed biomass production (Table 29). Presence of weeds throughout the growing season caused 31% reduction in wheat yield. The grain yield as recorded with the application of sulfosulfuron was 21% and 31% higher over isoproturon and weedy check, respectively (Table 30). Preceding treatments applied to rice did not influence the weed distribution, crop growth, yield attributes and grain yield of wheat.

Soil samples were collected at maturity stage of wheat 2011-12, and were analysed for pH, EC, organic carbon, available N and P content. No significant effect of the applied herbicides was recorded on the observed soil parameters so far, i.e. after completion of the second cycle of the experiment.

Table 27. Weed dynamics in rice as influenced by continuous use of herbicides in a long-term herbicide trial under direct seeded rice-wheat system

Treatment	Weed density/m^2*									Weed dry biomass (g/m^2)*
	C. iria	*E. colona*	*A. sessilis*	*C. communis*	*P. minima*	*C. axillaris*	*Phyllanthus* sp	*Corchorus* sp	Total	
Bispyribac-sodium @ 25 g/ha	1.3	2.5	0.8	1.0	0.9	-	-	-	2.9	2.2
Cyhalofop-butyl @ 90 g/ha	10.4	4.9	4.3	3.9	1.3	1.9	0.7	1.4	13.4	5.3
HW at 30 DAS	5.2	5.6	2.5	1.2	0.9	1.9	0.8	0. 8	8.4	4.4
Weedy check	10.6	10.1	3.7	3.6	1.7	2.2	0.9	1.0	16.0	8.0
LSD (0.05)	1.4	1.8	1.0	0.9	0.7	0.9	0.4	0.6	1.7	1.2

*Data subjected to $\sqrt{x+0.5}$ transformation

Table 28. Crop growth, yield attributes and yield of rice as influenced by continuous use of herbicides under direct seeded rice-wheat system

Treatment	Effective tillers /row length	Grains / panicle	Grain weight/ panicle (g)	100-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium @ 25 g/ha PO	62.3	95.9	3.05	2.97	5.99
Cyhalofop-butyl @ 90 g/ha PO	39.6	91.4	2.86	3.01	5.08
1 HW at 20 DAS	56.0	90.6	2.75	2.99	5.58
Weedy check	20.2	54.7	1.57	2.95	3.05
LSD (0.05)	15.0	26.6	0.71	0.12	1.89

Table 29. Weed dynamics in wheat as influenced by continuous use of herbicides in a long-term herbicide trial under direct seeded rice-wheat system

Treatment	Weed density/m^2*							Weed biomass (g/m^2)*
	A. sterilis	*P. minor*	*C. intybus*	*M. hispida*	*C. album*	*P. minima*	Total	
Sulfosulfuron @ 25 g/ha PO	5.9	0.9	1.2	2.2	1.2	2.3	7.6	3.0
Clodinafop @ 60 g/ha + 2,4-D @0.5 g/ha PO	2.3	1.8	2.4	3.4	1.6	0.8	5.3	2.2
Isoproturon	7.9	2.2	0.8	3.5	-	-	9.5	4.9
1 HW 20 DAS	5.9	2.3	1.3	2.8	2.1	1.5	8.1	3.4
Weedy check	7.2	3.7	1.4	5.7	2. 7	0. 9	11.4	6.2
LSD (0.05)	1.5	1.1	0.7	1.5	0.9	0.6	1.6	1.1

*Data subjected to $\sqrt{x+0.5}$ transformation

Table 30. Yield attributes and yield of wheat as influenced by continuous use of herbicides under direct seeded rice- wheat system

Treatment (Rabi)	Spike length (cm)	Spikes/m row length	Grains/ spike	Grain weight/ Spike (g)	100-grain weight (g)	Grain yield (t/ha)
Sulfosulfuron	13.8	98.6	51.0	2.3	4.5	5.37
Clodinafop + 2,4-D	14.8	96.9	49.4	2.2	4.4	5.87
Isoproturon	13.7	86.4	49.0	2.2	4.4	4.62
1 HW at 20 DAS	14.3	86.7	50.5	2.2	4.5	4.91
Weedy check	13.8	77.3	47.0	2.1	4.4	4.05
LSD (0.05)	1.0	8.7	2.9	0.2	0.3	0.5

Continuous use of herbicides on weed dynamics and crop productivity in direct-seeded rice-chickpea cropping system

V.P. Singh, K.K. Barman and Shobha Sondhia

A field trial consisting of bispyribac-sodium @ 25 g/ha PO, fenoxaprop @ 60 g/ha + 2,4-D @ 500 g/ha and HW at 30 DAS along with weedy check in direct-seeded rice as main plot treatments superimposed with pendimethalin @ 1250 g/ha PE, oxyfluorfen @ 200 g/ha PE, quizalofop @ 60 g/ha PO, HW at 30 DAS and weedy check in wheat, with a aim to study the long term impact of continuous use of herbicides on weed seed bank, weed dynamics and productivity of crops in DSR-chickpea cropping system was undertaken in split-plot design with 3 replications.

Echinochloa colona and *Paspaladium* sp. among grassy weeds, and *Alternanthera sessilis*, *Commelina communis*, *Physalis minima*, *Caesulia axillaris* among broadleaved weeds and *Cyperus iria* among sedges were prominent during rainy season of second cycle of experimentation. All weed control measures influenced density and distribution of weed flora, among them application of bispyribac sodium caused significant reduction in density of most of the weed species. However, application of fenoxaprop + 2,4-D failed to check the emergence of *C. iria*, *A. sessilis* and *P. minima*. Bispyribac-sodium being *at par* with fenoxaprop + 2,4-D was effective in reducing total weed density and biomass production. Bispyribac sodium caused 54 and 64% reduction in total weed population and weed dry biomass, respectively over weedy check (Table 31). Number of effective tillers per metre row (49.7 nos), grain weight per panicle (3.69 g) and grain yield (4.10 t/ha) of rice produced under the treatment of bispyribac sodium were significantly higher over HW and weedy check. This was followed by fenoxaprop + 2,4-D. However, highest grains/ panicle and 100-grain weight of rice was recorded under HW (Table 32).

Avena sterilis and *Phalaris minor* among grassy, and *Medicago hispida*, *Chenopodium album* and *Cichorium intybus* among broadleaved weeds were dominant in chickpea. Quizalofop being *at par* with HW caused reduction in density of *Avena sterilis* over rest of the treatments. However, it failed to check the emergence of *M. hispida*, *C. album* and *C. intybus* compared to pendimethalin and oxyfluorfen. Significantly lower population of *M. hispida*, *C. album* and *C. intybus* were recorded with pendimethalin and oxyfluorfen. None of the herbicides was found to be effective against *P. minor*. So far total weed population and weed dry biomass are concerned, HW produced lowest weed population and its dry biomass, which were followed by quizalofop applied as post-emergence (Table 33). Presence of weeds throughout the growing season caused 86% reduction in seed yield of chickpea. Different treatments influenced significantly yield attributing parameters and seed yield of the crop. Highest yield attributes like pods/plant, 100-seed weight and seed weight/plant and seed yield of chickpea was recorded under HW which was significantly higher over rest of the treatments. Among herbicides, quizalofop produced higher yield attributes and seed yield of chickpea. Lowest yield attributes and seed yield of chickpea were recorded under weedy check and pendimethalin, respectively (Table 34).

Observations on nodulation parameters in chickpea were recorded at 50 DAS. No significant residual effect of the weed control treatments given to the preceding *kharif* rice was noticed on the nodulation in chickpea grown during subsequent winter season. However, the significant differences among the weed control treatments given to the chickpea were noticed in terms of nodule count and nodule dry matter production. Both nodule count and nodule dry matter production in chickpea showed a depressing effect of pendimethalin application as compared to the HW treatment. Application of oxyfluorfen and quizalofop, however, did not show any toxic effect on chickpea nodulation (Table 35).

Table 31. Weed dynamics in rice as influenced by continuous use of herbicides in a long-term herbicide trial under direct seeded rice-chickpea system

Treatment (*kharif*)	Weed density/m²*								Weed biomass (g/m²)*
	E. colona	*C. Iria*	*A. sessilis*	*C. communis*	*P. minima*	*C. axillaris*	*Corchorus* sp	Total	
Bispyribac-sodium @ 25 g/ha	3.6	1.7	0.7	1.0	-	-	-	5.1	3.6
Fenoxaprop @ 60 g/ha + 2,4-D @ 500 g/ha	2.1	8.2	1.4	0.8	2.4	-	-	8.9	3.3
HW at 30 DAS	8.4	6.6	2.7	1.4	1.0	1.1	1.1	11.2	6.1
Weedy check	12.0	9.0	2.5	5.0	0.9	1.1	1. 6	16.5	10.0
LSD (0.05)	1.6	2.3	1.1	0.8	2.0	0.2	0.5	1.6	1.8

*Data subjected to $\sqrt{x+0.5}$ transformation

Table 32. Crop growth, yield attributes and yield of rice as influenced by continuous use of herbicides under direct seeded rice-chickpea system

Treatment (*Kharif*)	Effective tillers/m row length	Grains/ panicle	Grain weight/ panicle (g)	100 -grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium @ 25 g/ha PO -15 DAS	49.7	82.4	3.7	3.8	4.03
Fenoxaprop @ 60 g/ha fb 2,4 -D @ 0.5kg/ha	46.9	83.6	3.2	3.6	4.10
HW at 20 DAS	35.8	87.6	3.3	3.7	3.10
Weedy check	14.9	69.2	2.3	3.5	1.71
LSD (0.05)	14.6	11.7	0.6	0.9	0.33

Table 33. Weed dynamics in chickpea as influenced by continuous use of herbicides in a long-term herbicide trial under direct seeded rice-chickpea system

Treatment (*Rabi*)	Weed density/m²*						Weed biomass (g/m²)*
	A. sterilis	*M. hispida*	*P. minor*	*C. album*	*C. intybus*	Total	
Pendimethalin @ 1.25 kg/ha PE	29.0	4.1	1.8	1.4	2.0	29.6	11.0
Oxyfluorfen @ 0.20 kg/ha PE	27.6	3.0	1. 5	5.9	2.3	28.8	11.1
Quizalofop @ 0.06 kg/ha PO	11.4	8.4	2.6	10.7	4.9	19.3	10.5
HW at 30 DAS	11.7	2.3	2.4	4.0	1.8	13.1	8.3
Weedy check	29.8	5.2	2.0	5.0	3.0	29. 6	11.0
LSD (0.05)	2.4	1.7	0.9	1.8	1.1	3.2	1.0

*Data subjected to $\sqrt{x+0.5}$ transformation

Table 34. Crop growth, yield attributes and yield of chickpea as influenced by continuous use of herbicides under direct seeded rice-chickpea system

Treatment (*Rabi*)	No. of branches /plant	Pods/ plant	Seeds /pod	Seed weight/ plant (g)	100 -seed weight (g)	Seed yield (t/ha)
Pendimethalin @ 1.25 kg/ha PE	3.0	14.3	1.7	2.9	15 .4	0.17
Oxyfluorfen @ 0.20 kg/ha PE	3.1	15.6	1.6	3.5	16.2	0.27
Quizalofop @ 0.06 kg/ha PO	3.4	17.7	1.6	3.7	16.2	0.53
HW at 30 DAS	5.8	32.5	1.7	6.0	15.0	0.12
Weedy check	2.9	13.9	1.5	2.6	14.9	0.17
LSD (0.05)	1.00	5.1	0.2	1.5	1.6	0.12

Table 35. Nodulation in chickpea as influenced by continuous use of herbicides under direct seeded rice-chickpea system

Treatment (*Kharif*)	Treatment (*Rabi*)					
	Pendimethalin	Oxyfluorfen	Quizalofop	Hand weeding	Weedy check	Mean
	Nodule count (No. / plant)					
Hand weeding	30	33	37	41	30	34
Weedy	26	30	38	31	27	30
Bispyribac-sodium	30	40	46	47	43	41
Fenoxaprop	26	33	33	34	30	31
Mean	28	34	39	38	33	-
LSD (0.05)	*Kharif* : NS; *Rabi* : 6; *Kharif* x *Rabi*: Within row: 12, Within column: NS					
	Nodule dry matter (mg/plant)					
Hand weeding	32	58	61	68	52	54
Weedy	52	53	82	73	46	61
Bispyribac-sodium	50	62	68	70	70	64
Fenoxaprop	50	57	55	58	47	53
Mean	46	57	67	67	54	-
LSD (0.05)	*Kharif* : NS; *Rabi* : 13; *Kharif* x *Rabi*: Within row: 27, Within olumn: NS					

Long-term effect of herbicides on nodulation in soybean and black gram

K.K. Barman and Anil Dixit

Soybean

A long-term experiment was initiated during *kharif* 2010 to study the effect of post-emergence herbicides on symbiotic nitrogen fixation in soybean. Treatments comprised of 2 HW, repeated as well as rotated application of quizalofop (50 g/ha), imazethapyr (100 g/ha), fenoxaprop (100 g/ha) and weedy check. Soybean (var. JS-97-52) was sown in the first week of July, 2011. Observation on nodulation parameters were recorded twice at 40 and 60 DAS. Compared to 2 HW, none of the herbicide treatments showed any depressing effect on nodule count and nodule dry biomass production. The highest seed yield was obtained under 2 HW, which was statistically similar to the yields recorded in the herbicide treated plots. Weedy check produced significantly the lowest seed yield as well as nodulation parameters among all the treatments (Table 36).

Table 36. Nodulation and yield of soybean under long-term application of herbicides

Treatment	Nodule count (No./plant) 60 DAS	Nodule dry biomass (mg/plant) 60 DAS	Seed yield (t/ha)
Quizalofop	38	360	2.23
Fenoxaprop	36	313	2.43
Imazethapyr	37	388	2.48
Herbicide rotation*	35	332	2.24
Weed free	48	394	2.49
Weedy	23	214	1.26
LSD (0.05)	13	139	0.33

*This year fenoxaprop was applied

Blackgram

In blackgram (var. 'T-9'), compared to hand weeding treatment, all the herbicide treatments showed depressing effect on nodule count and nodule dry biomass production. Lowest count and dry biomass production of nodules were recorded under weedy check, due to heary weed intersection and poor crop growth (Table 37).

Table 37. Nodulation of blackgram under long-term application of herbicides

Teatment	Nodule count /plant	Nodule dry biomass (mg/plant)
Pendimethalin	80	64
Clodinafop	93	59
Quizalofop	74	89
Herbicide rotation*	68	77
Weed free	128	122
Weedy	51	36
LSD (0.05)	31	31

*This year clodinafop was applied

Monitoring of herbicide accumulation in soil and water under non-cropped conditions

Shobha Sondhia

Persistence of herbicide residues is a great concern as presence of herbicide residues in the soil may damage the sensitive succeeding crops and adversely affect human and animal health due to bioaccumulation of residues in crop produce. The applied herbicide may find its way into streams by runoff and may result in unfortunate consequences to non-target organisms. Thus persistence and bioaccumulation of various herbicides in soil, crop plants and fishes were studied under field conditions.

Persistence of herbicides in water and their effect on non-target organisms

Under rice-based cropping system, herbicide persistence in water and effect on non-target organisms was evaluated. In wheat, fenoxaprop-p-ethyl @ 100 g/ha, carfentrazone @ 25 g/ha and pinoxaden @ 50 g/ha were evlauted for residue at 0, 3, 6, 10, 15, 90 DAS and at harvest. After flood irrigation, samples for water were collected from the runoff collecting tanks, and rainfall received during first week of January 2012. Fishes were sampled at 60 and 90 days after rain/flood irrigation to see bioaccumulation and persistence of herbicides.

Plant samples were collected at young stage and at harvest. Collected samples were analyzed for residues using HPLC. Carfentrazone residues were in the range of 0.600-0.008 µg/g in soil during 0-60 DAS. However, 0.291-0.008 µg/g of fenoxaprop-p-ethyl and 0.139-0.020 µg/g of pinoxaden residues were detected in soil during 0-30 DAS (Table 38). Residues of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in grain and straw of wheat at harvest were below the detection limit.

Table 38. Residues of herbicides (µg/g soil) in soil

Sampling time (DAS)	Carfent-razone	Fenoxaprop-p-ethyl	Pinoxaden
0	0.600	0.291	0.139
10	0.396	0.046	0.131
20	0.093	0.008	0.020
30	0.017	0.001	0.020
60	0.008	<0.001	<0.01
90	0.001	<0.001	<0.01
120	<0.001	<0.001	<0.01

Carfentrazone residues in tank water were 0.0019 and 0.004 µg/ml after 20 and 30 days, respectively. Fenoxaprop residue at 10 days was 0.0014 µg/ml. However, pinoxaden residue was not found in the tank water (Table 39).

Slight increase in pH and EC was noticed in tank receiving runoff from carfentrazone treated plots followed by pinoxaden and fenoxaprop, but the effect was not significant. DO and TDS in water also did not vary significantly among the treatments.

Table 39. Dissipation of herbicides (µg/ml) in pond water adjacent to wheat field

Days after application	Carfent-razone	Fenoxaprop-p-ethyl	Pinoxaden
2	<0.001	<0.001	<0.01
10	<0.001	0.0014	<0.01
20	0.0019	<0.001	<0.01
30	0.004	<0.001	<0.01
60	<0.001	<0.001	<0.01
90	<0.001	<0.001	<0.01
120	<0.001	<0.001	<0.01

No bioaccumulation of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in fish and its mortality was noticed during *rabi* 2011-12.

Wheat plants showed respectively 0.027 and 0.02 µg/g of carfentrazone and fenoxaprop residues at its early growth stage. Carfentrazone residues in straw and grain samples at harvest were 0.015 and 0.079 µg/g, respectively. Pinoxaden residues in plant samples were <0.01 µg/g through out the growing period (Table 40).

Table 40. Persistence of herbicides in plant samples at harvest

Matrixes	Carfent-razone	Fenoxaprop-p-ethyl	Pinoxaden
Wheat plant green	0.0270	0.020	<0.01
Wheat straw	0.0150	0.007	<0.01
Wheat grain	0.0798	<0.001	<0.01

Evaluation of risk of ground water contamination by continuous use of herbicides

As most of the herbicides are soluble in water and thus they may pose risk for ground water and its contamination under saturated moisture regime. Hence, an experiment was conducted to study the leaching potential of herbicides under natural rainfall conditions using lysemeter of 1, 2 and 3 meters depth.

Cyhalofop-p-butyl was sprayed at 90 and 180 g/ha doses to the lysemeter and allowed to receive natural rain. Soil samples were collected from different depth and analyzed for cyhalofop-p-butyl residues by HPLC. Leachates were also collected from the lysemeter columns and analyzed to see the movement of this herbicide. The results are given in table 41. Cyhalofop-p-butyl residues of 1.1-2.2 ng/L were detected in the leachates of 1 and 2 m height lysemeters during June-July 2011. Its highest concentration was detected in the leachates of 1 m column as compared to other lysemeter columns.

Highest concentration of cyhalofop-p-butyl residue was observed in the surface soil of all the columns. It was detected upto 50 cm depth in 1 m lysemeter. However, its residues and major metabolites were found upto 100 cm depth in 3 m lysemeter. After 3-days of application, the residue content of soil at 0-50 cm depths of 1 m soil column varied from 0.028-0.0014 and 0.072-0.0020 µg/g at 90 and 180 g/ha rates, respectively. Whereas, in 3 m column the residues for corresponding level of application varied from 0.048-0.0011 and 0.0480-0.001 µg/g at 0-125 cm depths.

After 10 days of application, residue contents of the soil were found 0.0025-0.0015 µg/g at 0-25 cm depth in 1 m lysemeter, 0.0083-0.0010 µg/g at 0-75 cm depth in 2m-lysemeter, 0.0043-0.0011 at 0-125 cm depth in 3m-column.

Leachates collected after each rain showed a significant increase in pH upto one month after herbicide application. There was variation in EC of leachates depending upon the amount of rainfall received as well as due to movement of cyhalofop-p-butyl through soil profile (Table 42).

After 10 days, major metabolites of cyhalofop-p-butyl were detected in significant amount in soil and leachates. Major metabolites detected by LC/MS/MS were (R)-2-4-(4-cyanao 2-fluroophenoxy) phenoxypropanoic acid (cyhalofop acid), (R)-2-4(4-caboxyl-2-flurophenoxy) phenoxypropanoic acid (cyhalofop-diacid) and cyhalofop-phenol (Fig. 7).

Table 41. Cyhalofop-p-butyl residue content of soil at various depths of 1, 2 and 3 m height lysemeter columns at 3 and 10 days after application (DAA)

Soil depth (cm)	Application rate 90 g/ha			Application rate 180 g/ha		
	1 m column	2 m column	3 m column	1 m column	2 m column	3 m column
At 3 DAA						
0-5	0.0284	0.036	0.0488	0.072	0.0630	0.0480
5-25	0.0019	0.0022	-	0.0055	0.0064	-
25-50	0.0014	0.0021	-	0.0020	0.0018	-
50-75	<0.001	0.0015	0.0042	<0.001	0.0014	0.0041
75-100		0.0011	0.0032		0.0015	0.0031
100-125		0.0010	0.0026		<0.001	0.001
125-150		<0.001	0.0033		<0.001	0.001
150-175			0.0011			<0.001
175-200		<0.001	<0.001			<0.001
200-225			<0.001			<0.001
At 10 DAA						
0-5	0.0025	0.0083	0.0025	0.0029	0.0059	0.0043
5-25	0.0015	0.0010	-	0.0018	0.0024	-
25-50	<0.001	<0.001	-	<0.001	0.0014	-
50-75	<0.001	<0.001	0.0017	<0.001	<0.001	0.0045
75-100		<0.001	<0.001		<0.001	0.0011
100-125		<0.001	<0.001		<0.001	<0.001
125-150		<0.001	<0.001		<0.001	<0.001
150-175			<0.001			<0.001
175-200			<0.001			<0.001
200-225			<0.001			<0.001

Table 42. pH and EC of leachates collected on different dates during rainy season of 2011 after cyhalofop-p-butyl application

Treatments		Date of sampling										
		June	July					August				September
		27	01	16	22	23	25	04	06	10	16	02
							pH					
1 m !	T_1	7.80	7.36	8.59	8.72	6.32	9.20	8.50	8.50	8.00	7.50	7.30
	T_2	7.81	7.34	8.69	8.74	6.40	9.52	8.25	8.60	8.00	7.35	8.15
2 m	T_1	7.20	7.36	9.03	8.50	7.01	9.19	8.15	NL	8.00	8.30	8.08
	T_2	7.43	7.31	8.81	8.43	8.17	8.37	8.10	7.80	7.75	7.25	6.61
3 m	T_1	NL *	7.34	8.59	7.72	7.28	8.90	NL	NL	7.50	NL	NL
	T_2	NL	7.36	8.69	8.74	7.35	9.00	NL	8.00	7.50	7.20	8.14
							EC (dS/m)					
1 m	T_1	1.76	1.15	1.08	0.94	0.70	0.61	0.66	0.56	0.79	0.79	0.84
	T_2	1.98	1.48	1.35	1.04	0.87	0.51	0.81	0.59	0.87	0.89	1.15
2 m	T_1	0.96	0.94	1.14	1.43	1.46	0.94	0.72	NL	0.74	0.80	0.98
	T_2	1.61	1.53	1.51	1.25	1.28	0.96	0.77	0.95	0.68	0.80	0.95
3 m	T_1	NL	1.30	1.66	1.28	1.75	1.06	NL	NL	1.14	NL	NL
	T_2	NL	1.74	2.00	1.91	1.80	1.75	NL	1.48	1.03	1.06	0.52

! Column height, T1: 90 g/ha, T2: 180 g/ha, * Leachate not found

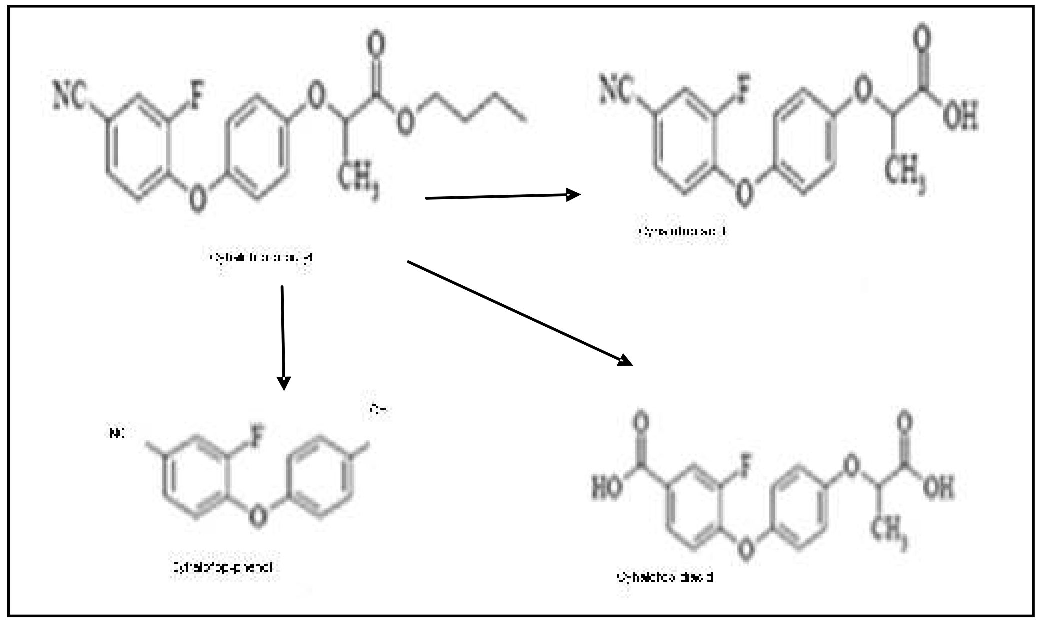


Fig. 7. Metabolites of cyhalofop-p-butyl identified from soil and leachates

Phototransformation of herbicides on leaf cuticle surface and in environment

P.P. Choudhury

To investigate the phototransformation of isoproturon and 2,4-D on leaf cutin surface, experiment was conducted on the thin-film of cutin material extracted from different weeds under artificial UV-light and sunlight as well. Similarly, for the investigation of photolytic behavior of sulfosulfuron, the compound was irradiated in aqueous as well as son oil phase. After irradiation, degradates were extracted in suitable solvents, processed and analysed by LC-MS/MS. For the rate of degradation study, samples were drawn at regular interval, processed and analysed hplc.

Cutin of *Phalaris* and *Avena* slowed down the degradation process of isoproturon under UV light and, consequently, it substantially increased the half-life as compared to standard glass surface. The photoproducts of isoproturon are 2-amino-5-isopropyl-N,N-dimethyl benzamide, 2. 4-isopropyl phenyl isocyanate, and 1,1-dimethyl-3-methyl-3-isopropyl urea. During the phototransformation 2,4-D ethyl ester has been transformed to 2,4-D, 2,4-dichlorophenoxy acetyl chloride, chlorophenoxy acetic acid ethyl ester, and 2,4-dichlorophenol.

The major photometabolites of sulfosulfuron were: 4,6-dimethoxy-2-amino pyrimidine, N-(4,6-dimethoxy-2-amino pyrimidinyl)urea, N,N'-bis (4,6-dimethoxy-2-amino pyrimidinyl)urea, 2-ethyl sulfonyl imidazo [1,2-a]-pyridin-3-yl sulfonamide, and 1-(2-ethylsulfonylimidazo[1,2-a] pyridin)-3-sulfonamide isolate. These photoproducts were structurally elucidated by LC-MS/MS.

Microbial degradation of chlorimuron-ethyl

Fungi like *Fusarium* and *Alternaria* could not survive in the artificial media containing chlorimuron-ethyl at the level of 25 mg/l, whereas, *Aspergillus niger* survived at the level of 200 mg/l of media. *Aspergillus niger* degrades the herbicide to harvest energy through two major routes. One route involves the cleavage of sulfonylurea bridge resulting in the formation of two major metabolites, viz. ethyl-2-aminosulfonyl benzoate (I) and 4-methoxy-6-chloro-2-amino-pyrimidine (II). The other route is the cleavage of sulfonylamide linkage, which forms the metabolite *N*-(4-methoxy-6-chloropyrimidin-2-yl) urea (III). Two other metabolites, saccharin and *N*-methyl saccharin, formed from the major metabolite-II, were also identified. Thus, a metabolic pathway for the degradation of chlorimuron by *Aspergillus niger* has been proposed (Fig. 8).

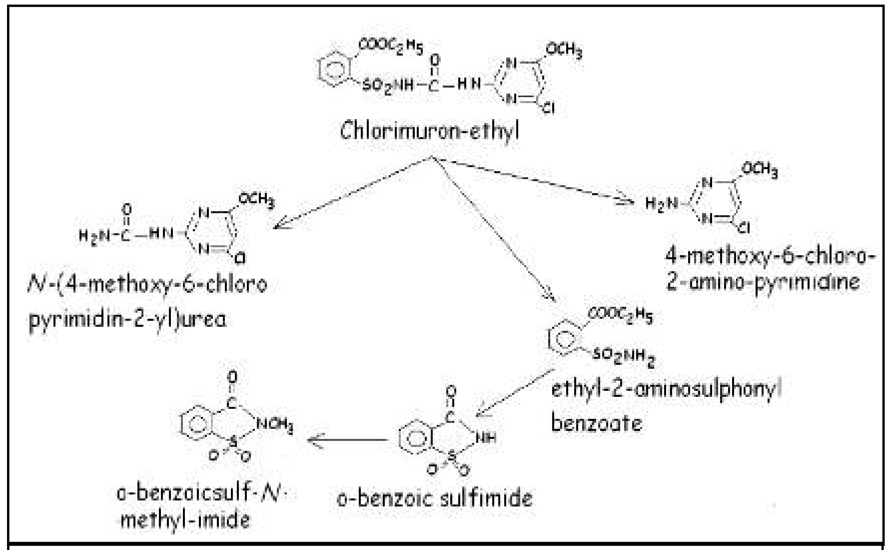


Fig. 8. Degradation pathway of chlorimuron-ethyl by *Aspergillus niger*

Theme 4: Biopesticides and biocontrol of weeds

Bio-herbicidal potential of plant constituents against targeted weeds

D.K. Pandey

Phytotoxicity of ethyl acetate fraction of neem seed allelochemical crude

Seeds of neem (*Azadirachta indica*) were shade dried, ground (80 mesh), steeped in water at 1% (w/v) for 24 hours at 25-30°C, and decanted suspension was then dried at the ambient temperature and designated as allelochemical crude. This crude was extracted with ethyl acetate and filtered. The extract was evaporated and ethyl acetate soluble constituents left subsequently were monitored and evaluated for bio-herbicidal activity on representative aquatic weeds. The constituents were lethal to green musk *Chara* at 20 ppm, *Ceratophyllum demersum* and *Najas* at 50 ppm, water lettuce at 75 ppm and to *Hydrilla* at 100 ppm (Table 43).

Table 43. Phytotoxicity of ethyl acetate fraction of neem seed allelochemical crude on floating and submerged aquatic weeds

Weed species	Lethal concentration (ppm)
Floating weeds	
Eichhornia crassipes	Nil
Pistia stratiotes	75
Lemna pausicostata	Nil
Spirodella polyrrhiza	Nil
Submerged weeds	
Hydrilla verticillata	100
Potamogeton cispus	50
Ceratophyllum demersum	50
Najas graminea	50
Chara zeylanica	20

Isolation of bioherbicidal allelochemical constituents from *Solanum viarum*

Allelochemical crude of the tropical soda apple (*Solanum viarum)* seeds was prepared using the method as described above for neem seed. The constituents of the allelochemical crude were solubilized in 13 different solvents over a range of polarity, and further fractionated to chemical classes of phenolics, alkaloids and terpenoids using thin layer chromatography. At each step the fractions showing herbicidal activity on the target aquatic weeds were taken up for further investigations. Using the fraction isolation, herbicidal activity verification and further fractionation approach, none of the six phenolic fractions was found toxic to water lettuce (*Pistia stratiotes* L.) and coontail (*Ceratophylum demersum* L.) individually or in combinations up to 100 ppm.

Out of five terpenoids isolated, two were lethal to coontail at 100 ppm. All the fractions combined at 15 ppm were lethal to coontail. The alkaloid fraction comprised of four components, of which one was lethal to coontail at and above 100 ppm. This fraction comprised of two components. The components are being isolated in larger quantities for further work.

Isolation of bioherbicidal allelochemical constituents from *Parthenium* leaf

Two promising bio-herbicidal molecules were isolated in sizable quantities from *Parthenium* leaf and subjected to mass, IR and NMR spectroscopy. The data were analyzed with the expertise from the scientists of IICT, Hyderabad.

One compound with molecular mass 262, about 88% purity, appeared to be close to parthenin. Phytotoxicity of this molecule was greatly influenced by temperature. Concentration as low as 12.5 ppm was lethal to many submerged aquatic weeds at 35°C.

Herbicidal activity of *Croton bonplandianum* on aquatic weeds

Ban tulsi (Croton bonplandianum) is largely known for its medicinal properties and for anti-tumor, insecticidal, insect repellent, antimicrobial and allelopathic activity on terrestrial plant species. In the present study, the potential herbicidal molecules of *ban tulsi* leaf and stem residue on water hyacinth (*Eichhornia crassipes*) was explored.

Ban tulsi leaves and stems were washed, shade dried, powdered and suspended at different levels in a standard nutrient medium. Pre-weighed water hyacinth plants were placed in the medium and kept outdoors. Biomass of the plants was monitored up to 15 days and toxicity symptoms were recorded. Phenolics in the medium were estimated in the beginning of the experiment (after 24 hours) and by the end of the experiment (after 15 days).

Ban tulsi leaf residue promoted growth of water hyacinth up to 0.1% (dry w/v) but killed the weed at 0.50% in about 10 days. At the inhibitory concentration (0.25%) of leaf residue, the water hyacinth plants became flaccid followed by death and decay. At 1.0% leaf residue, the phenolic constituents in the medium were 198 ± 7.6 ppm after 24 hrs of the treatment, which declined to 59±1.7 ppm by the end of 15 days. At 0.5% leaf residue, there was 12 ± 0.3 ppm phenolic constituent after 15 days (Table 44). The stem residue promoted growth of water hyacinth up to 0.5% but was lethal at and above 0.75% (Table 45). The phenolic constituents in the medium by 24 hours after initiation of the treatment at 1.0% stem residue were 79 ± 3 ppm which declined to 10±2.3 ppm by the end of 15 days. At 0.75%, there was 5±1.3 ppm phenolic constituent after 15 days (Table 46). The phenolics appear to dissipate rapidly in aquatic environment outdoors. The stem residue had lower phytotoxicity to the water hyacinth.

Table. 44. Phytotoxicity of *ban tulsi* leaf residue on *Eichhornia crassipes*

Leaf residue (% w/v)	Change in biomass of *Eichhornia crassipes* (%)		
	5 DAT	10 DAT	15 DAT
0	11 ± 10.0	20±13.3	32±19.2
0.10	12 ± 10.5	23 ± 3.2	35 ± 2.9
0.25	-8 ±1.2	-64 ± 1.1	-89 ± 0.9
0.50	-100	-100	-100
0.75	-100	-100	-100
1.00	-100	-100	-100

Hundred % reduction of biomass signifies death and decay of the treated plants. DAT : Days after treatment.

Table 45. Phytotoxicity of *ban tulsi* stem residue on *Eichhornia crassipes*

Leaf residue (% w/v)	Change in water hyacinth biomass (%)		
	5 DAT	10 DAT	15 DAT
0.0	6 ± 1.0	9 ± 0.7	17 ± 2.2
0.10	8 ± 2.1	20 ± 7.8	31 ± 15.4
0.25	14 ± 6.0	26 ± 16.0	36 ± 19.8
0.50	17 ± 1.8	28 ± 3.0	42 ± 9.3
0.75	-68 ± 1.0	-100	-100
1.00	-62 ± 1.6	-100	-100

Hundred % reduction of biomass signifies death and decay of the treated plants. DAT : Days after treatment.

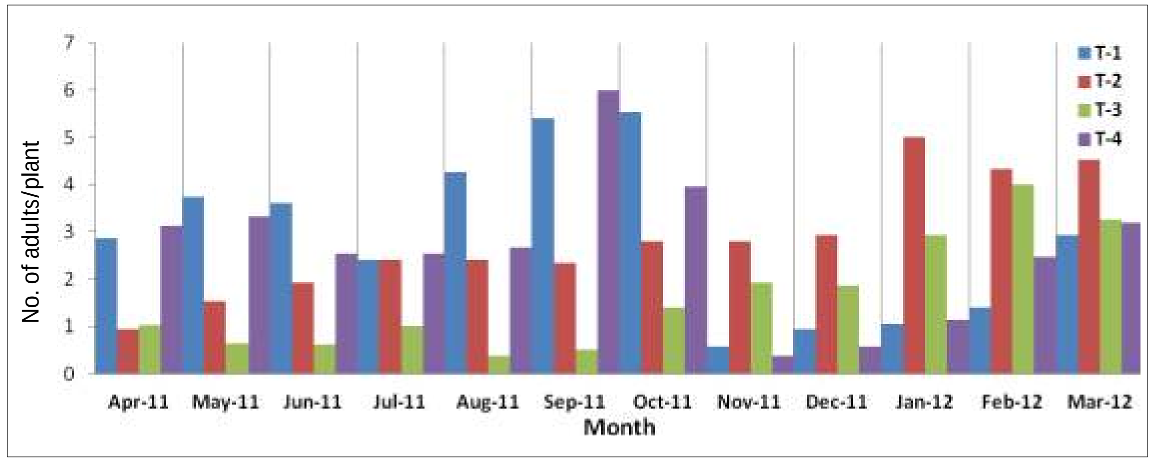
Table 46. Phenolics in *ban tulsi* leaf and stem residue suspensions days after 1 and 15 initiation of the treatment

Treatment	Phenolics in the medium (ppm)		LSD (0.05)
	1 DAT	15 DAT	
Leaf residue suspension (1%, w/v)	198.0±6.2	62.0±1.2	12.4
Stem residue suspension (1%, w/v)	79.0±1.2	10.0±2.0	10.0±2.0

DAT: Days after treatment; values are means ±SD of three replications

Activity enhancement of *Neochetina* species for biological control of *Eichhornia crassipes*

After three years of inoculative release, *Neochetina* population was significantly higher in the tanks receiving augmented release than in the tanks where only inoculative release was made (Fig. 9). Consequently, water hyacinth was completely controlled in the augmented tanks within 8-10 months, compared to 14-15 months needed in un-augmented tanks.



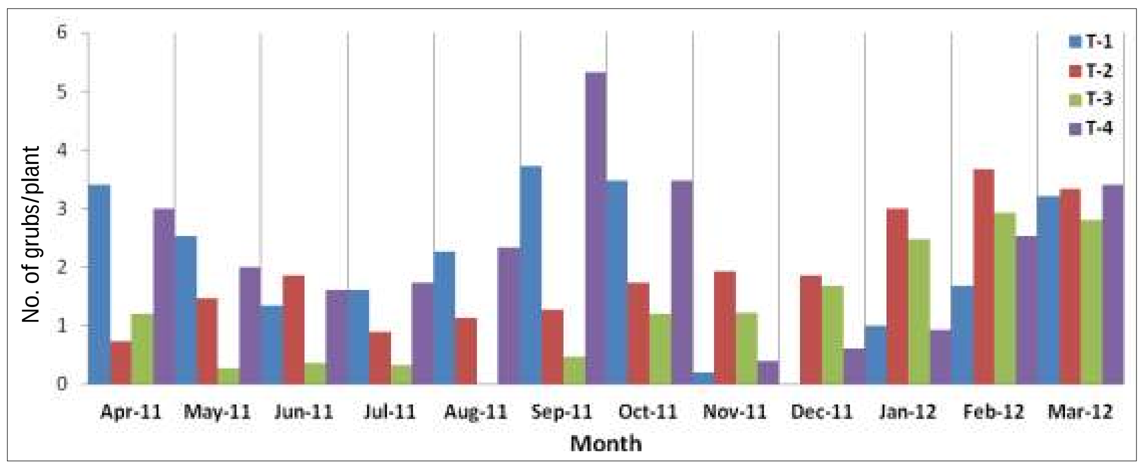


Fig. 9. Monthly population of grubs and adults of *Neochetina* in different treatments (T-1 : Initial release 10 pairs/m^2 T-2 : Augmentation 5 pairs/m^2 at 3, 6, 12 months interval , T-3: Augmentation 5 pairs/m^2 at 6 months interval, T-4: Spray of leaf extract af 3, 6, 12 month interval)

Biological control of *Chromolaena odorata* using gallfly

About 3000 *Chromolaena* galls infested with gall fly (*Cecidocharus connexa)* were collected from the Bengaluru and adult gall fly which emerged from the galls were collected in laboratory. The fifty adult gall flies were released in *Chromolaena* infested area of Jagdalpur. The branches of *C. odorata* were tagged with healthy galls, containing adult bio-agents inside, so that newly emerged flies could start their life cycle there itself.

Survey, characterization and evaluation of plant pathogens for management of water hyacinth and *Cuscuta*

Water hyacinth

Integrated application of fungal bio-agents, *Alternaria alternata* (IMI No. 501353) and *A. eichhorniae* along with insect (*Neochetina bruchii*) were more effective and killed water hyacinth more rapidly than when beetles were released alone. *Alternaria* did not infect other aquatic plants like *Pistia stratiotes* and *Eleocharis dulcis* (water chestnut), indicating host specificity of the pathogen.

Alternaria alternata with integration of beetle for a rapid submerging of water hyacinth plants

Cuscuta

An experiment was conducted in the containment chamber to study the directional movements of Cuscuta towards the host plant chickpea. Host seed treated with different bio-agents was sown in pots and observation was recorded on the germination, attachment and penetration behavior of *Cuscuta* in chickpea. *Cuscuta* was able to germinate in the absence of host; however, the germinated seedlings could not survive more than 8-12 days. It has also been observed that the germinated seedlings moved even from 12-15 cm distance towards the host for attachment. Treatment with SA and Pf delayed the attachment of *Cuscuta* seedlings and there was 40% reduction in host recognition. The initiation of the haustoria, attachment and penetration of *Cuscuta* were studied under microscope using thin hand sections and appropriate dyes. The anatomical structures observed in the infected host tissues suggested that the searching hyphae elongated through the host tissue and entered the host phloem or xylem with minimum damage to the host cells. After attachment to the host stem, the inner or lower haustorium invaded the host cortex tissues by creating a fissure within a period of 24 - 48 hrs.

Cross-section of chickpea stem showing penetration and establishment of *Cuscuta campestris* haustoria (H)

Theme 5: Weed utilization

Evaluation of weedy plants for phytoremediation of heavy metal contaminated drain water

P.J. Khankhane

Heavy metal contamination in food chain through crops irrigated with untreated waste water is posing serious environmental hazards. The removal of contaminants from polluted water using macrophyte at source is easier than from the sites where these get accumulated by adsorption. Investigation was, therefore, carried out to test the performance of *Arundo donax* using constructed phytoremediation system.

Arundo was planted hydroponically in first pair of tanks containing in porous media. The polluted water from drain was pumped in pre-treatment overhead tanks, and after settling of solid particles the water was directed through sequential treatment tanks. The water samples collected from the system were analyzed for nitrates, phosphates and different heavy metals at an outlet point of the sedimentation, floating, surface and subsurface tanks.

Extensive root system (110-134 cm in length) and average density (172.3/m^2) were observed in hydroponically grown plants. As far as water flow through porous media is concerned, no clogging was seen, resulting free discharge of water to irrigation plots. The concentration of total soluble salts (TSS), nitrate, copper, nickel, zinc and manganese were reduced to the extent of 64.0, 88.4, 69.3, 62.4, 78.0 and 61.7%, respectively in treated water as compared to untreated drain water (Table 47). It may be concluded that *Arundo*-based metal (Ni, Cu, Zn, Mn) remediation wetland system reduced the pollutant concentration in treated water.

Table 47. Changes in contaminants of drain water treated using *Arundo donax*

Treatment	pH	TSS (mg/l)	NO_3 (ppm)	PO_4 (ppm)	Cu (ppm)	Ni (ppm)	Zn (ppm)	Mn (ppm)	Bacteria (cfu/ml)
Sedimentation	7.4	238	19.5	2.72	0.39	0.27	0.43	1.8	6.5×10^4
Tank I (Hydroponics)	7.3	152	9.40	1.90	0.34	0.19	0.41	1.2	24.0×10^3
Tank II (Surface)	7.2	134	8.79	1.71	0.19	0.16	0.35	0.93	14.7×10^2
Tank III (Sub -surface)	7.2	89	2.29	1.56	0.14	0.11	0.12	0.69	8.1×10^2
Untreated water	7.5	249	20.3	2.91	0.47	0.31	0.54	1.83	18.7×10^4
Remediation efficiency (%)	-	64	88.4	46.3	69.36	62.40	78.0	61.7	

Waste water carrying drain from industrial source

Extensive root growth of *Arundo*

Treated water and drain water in hydroponic tanks

Theme 6: Transfer of technology and impact assessment

Demonstrations on weed management technology and their impact assessment

P.K. Singh

Several demonstrations on proven weed management technologies for different crops were laid out on farmers' fields. The number of demonstrations conducted during *kharif* 2011 and *rabi* 2011-12 was as follows:

Season/Crops	Number of demonstrations
Kharif 2011	
Direct-seeded rice	22
Soybean	5
Maize	7
Blackgram	3
Rabi 2011-12	
Wheat	35
Mustard	5
Chickpea	5

Rice

Echinochloa colona, *Commelina*, *Cyperus* spp., *Corchorus* spp., *Eclipta*, *Alternanthra* and *Ceasulia axillaries* were major weed species at the demonstrated sites. Most of the farmers are small and marginal, uneducated and they follow manual weeding using their traditional implements like *khurpi*.

Performance of bispyribac-sodium, different combinations of fenoxaprop, chlorimuron + metsulfuron and 2,4-D, and premix of bensulfuron + pretilachlor was evaluated in large scale at farmers' field. Bispyribac-sodium @ 30 g/ha or fenoxaprop @70 g/ha at 20-25 DAS effectively controlled *Echinochloa colona* in comparison to other demonstrated herbicides. Application of chlorimuron + metsulfuron @ 4 g/ha or 2,4-D @ 500 g/ha one week after fenoxaprop @ 70 g/ha resulted in broad-spectrum weed control. Maximum economic benefit was recorded in case of bispyribac-sodium (Table 48). It may be concluded that in the *Echinochloa colona* dominated areas, bispyribac-sodium may be used. If there is problem of broadleaved weeds along with *Echinochloa colona*, application of chlorimuron + metsulfuron or fenoxaprop + 2,4-D should be made. The farmers expressed their satisfaction on the performance of demonstrated technologies.

Table 48. Field demonstration on weed management technology in rice

No. of demons-trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice* (%)	WCE** (%)	Cost of technology (`/ha)	Economic benefit due to technology** (`/ha)
10	Bispyribac-sodium	4.43	32	70	1590	12260
5	Fenxoprop *fb* 2,4-D	3.89	30	48	1075	9740
4	Chlorimuron ethyl + metsulfuron methyl *fb* fenoxaprop-p-butyl	4.21	31	46	1050	10780
7	Premix of bensulfuron + pretilachlor	4.32	31	48	1775	10621

* Farmer's practice was one hand weeding at 30 DAS
** Over farmer's practice

Soybean

The fields were infested with mixed weed flora, viz. *Echinochloa colona, Commelina communis, Dinebra retroflexa, Digera arvenisis, Cyperus* spp. and *Parthenium hysterophorus.* The technologies demonstrated were the application of chlorimuron-ethyl @ 10 g/ha (PO) + fenoxaprop-p-butyl @ 100 g/ha (PO) and imazethapyr @ 100 g/ha (PO) at 20 DAS. Application of chlorimuron-ethyl + fenoxaprop-p-butyl gave broad-spectrum weed control and higher benefit (` 7238/ha) (Table 49).

Table 49. Field demonstrations on weed management technology in soybean

No. of demons-trations	Demonstrated technology	Grain yield (t/ha) Demonstrated technology	Increase in yield over farmer's practice* (%)	WCE (%)	Cost of technol-ogy (`/ha)	Economic benefit due to technology (`/ha)
3	Chlorimuron-ethyl + fenoxaprop-p-butyl	1.46	38	67	1650	7238
2	Imazethapyr	1.39	23	62	1600	4296

* Farmer's practice was one hand weeding at 30 DAS

Weedy soybean crop

Treated soybean crop

Field demonstration in soybean crop

Maize

The fields were infested with mixed weed flora, viz. *Echinochloa colona, Commelina communis, Alternenthara sessilis, Dinebra retrotlexa, Cyperus* spp. and *Euphorbia geneculata.* The demonstrated technologies consisted of atrazine @ 1 kg/ha, atrazine + 1 HW at 45 DAS, and one hoeing at 30 DAS. The farmers were satisfied with the performance of atrazine + HW, which gave the maximum benefit (Table 50).

Table 50. Field demonstrations on weed management technology in maize

No. of demons trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice (%)	WCE (%)	Cost of technol ogy (`/ha)	Economic benefit due to technology (`/ha)
3	Atrazine	3.60	17	33	772	6000
3	Atrazine + HW at 45 DAS	4.20	40	76	2300	8500
1	Hoeing at 30 DAS	3.20	08	32	800	4200

* Farmer's practice was one hand weeding at 30 DAS

Weedy

Treated

Field demonstration in maize crop

Blackgram

The performance of imazethapyr @ 50 g/ha and one hoeing at 30 DAS were demonstrated in the blackgram fields infested with mixed weed flora under prevailing farming situation. Application of imazethapyr @ 50 g/ha was found more effective than hoeing and gave the benefit of `` 4300/ha over farmers' practice (Table 51).

Table 51. Field demonstrations on weed management technology in blackgram

No. of demons-trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice* (%)	WCE (%)	Cost of technology (`/ha)	Economic benefit (`/ha)
2	Imazethapyr	0.68	33	68	800	4300
1	Hoeing at 30 DAS	0.52	16	40	600	3500

* Farmer's practice was one hand weeding at 30 DAS

Wheat

Technologies consisted of clodinafop (60 g/ha) + metsulfuron (4 g/ha, PO), mesosulfuron methyl + iodosulfuron methyl (18 g/ha PO), sulfosulfuron + metsulfuron-methyl (32 g/ha) and clodinafop (60 g/ha PO) were demonstrated at five locations. *Lathyrus sativa, Vicia sativa, Melilotus alba, Chenopodium album, Avena sterlis, Medicago hispida, Phalaris minor* were the main problem the demonstration sites. Technologies for demonstrations were chosen depending upon the nature of weed flora of the location. All the technologies were more effective in controlling the weeds as compared to farmers' practice (Table 52). Farmers were more satisfied with the performance of the combination of metsulfuron-methyl (4 g/ha, PO) with either clodinafop (60 g/ha) or iodosulfuron-methyl.

The above herbicidal technologies were demonstrated in combination with zero tillage (ZT) technology and compared with farmers' practice i.e. conventional tillage. Benefit due to demonstrated herbicides under ZT situation were slightly higher than that under CT. In addition to this, ZT saved around Rs. 2500/ha, incurred for land preparation.

Table 52. Field demonstration on weed management technology in wheat

No. of demons-trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice* (%)	WCE (%)	Cost of technology (`/ha)	Economic benefit (`/ha)
2	Clodinafop + metsulfuron	4.01	39	56	1905	13524
18	Mesosulfuron-methyl + iodosulfuron	3·98	37	55	1375	13528
12	Clodinafop	3.62	33	53	1305	11215
3	Sulfosulfuron + metsulfuron-methyl	3.92	27	47	1375	10273

* Farmer's practice was one hand weeding at 30 DAS

Chickpea

Performance of chemical technology i.e. pendimethalin 1.0 kg/ha (PE) and mechanical technology i.e. hoeing at 30 DAS were demonstrated in chickpea fields, infested mainly with *Avena sterilis (wild oat), Phalaris minor, Chenopodium album, Medicago hispida, Lathyrus sativa. Farmers were more satisfied with the chemical technology, i.e.* pendimethalin, as it was more effective in controlling weeds with higher benefit (Rs. 10530/ha) (Table 53).

Table 53. Field demonstrations on weed management technology in chickpea

No. of demons-trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice* (%)	WCE (%)	Cost of technology (`/ha)	Economic benefit (`/ha)
3	Pendimethalin	1.73	40	59	1325	10530
2	Hoeing	1.56	26	25	1000	6850

* Farmer's practice was one hand weeding at 30 DAS

Mustard

Technologies consisting of pendimethalin at 1.0 kg/ha (PE) and hoeing (one) at 30 DAS were demonstrated at farmers' fields. *Chenopodium album, Medicago hispida, Vicia sativa, Parthenium hysterophorus, Cyperus iria* were the major weeds of mustard in the demonstration sites. Farmers were more satisfied with the chemical technology, i.e. pendimethalin, as it was more effective in controlling weeds (WCE 69%) and gave higher economic benefit (` 11415 /ha) (Table 54).

Table 54. Field demonstrations on weed management technology in mustard

No. of demons-trations	Demonstrated technology	Grain yield (t/ha)	Increase in yield over farmer's practice* (%)	WCE (%)	Cost of technology (`/ha)	Economic benefit (`/ha)
3	Pendemethalin	1.74	57	69	1325	11415
2	Hoeing	1.48	34	45	1000	6460

* Farmer's practice was one hand weeding at 30 DAS

Service Projects

Contract research: Testing of new molecules

Anil Dixit

Bioefficacy of fluazifop 12.5% + fomasafen 12.5% in soybean

Bioefficacy of fluazifop 12.5% + fomasafen 12.5% in soybean was studied in a field trial during *kharif* season of 2011. The treatments consisting of 4 doses of a ready-mix combination of fluazifop + fomasafen @ 200, 250, 313, 500 g/ha), fluazifop-p-butyl @ 125 g/ha alone, fomasafen @ 250 g/ha alone, imazethapyr @ 100 g/ha, 2 HWs and weedy check were laid out in a randomized block design with three replications. The experimental field was uniformly infested with *Echinochloa colona, Commelina benghalensis, Dinebra retroflexa, Phyllanthus niruri, Physalis minima* and *Cyperus iria*. Post-emergence ready-mix application of fluazifop + fomasafen at all the rates reduced the population of grassy as well as broad weeds in soybean. Superior yield attributing characters and effective weed control contributed to higher yields under higher doses of fluazifop + fomasafen readymix. The yields obtained in all the treatments were significantly superior to weedy check. Two HWs resulted in the highest seed yield of 2.79 t/ha, which was at par with the seed yield of 2.36 t/ha as recorded in fluazifop + fomasafen @ 500 g/ha (Table 55).

Evaluation of premix saflufencil 17.8% + imazethapyr 50.2% in soybean

Several herbicides are available in the market for weed control in soybean, but alone does not provide complete control. Tank mixture often results in antagonism or crop injury, thus reducing crop yield. A field experiment was conducted to evaluate the efficacy of premix saflufencil 17.8% + imazethapyr 50.2% (85 to 272 g/ha) and compared with alone application of saflufencil (35 g/ha) and imazethapyr @ 100 g/ha along with standard premix pendimethalin + imazethapyr (Valor) @ 960 g/ha and weedy check. Premix of saflufencil 17.8% + imazethapyr 50.2% @ 136 and 272 g/ha provided effective control of *Echnochloa colona, Physalis minima, Phyllanthus niruri* and *Cyperus iria*, which were not effectively controlled by sole application of these herbicides.

Effect of premix combination of penoxsulum + cyhalofop-butyl in transplanted rice

A field study was conducted using premix combination of penoxsulum + cyhalofop premix @ 105, 120, 135 and 150 g/ha which were compared with penoxsulum @ 22.5 g/ha, cyhalofop-butyl @ 80 g/ha, bispyribac sodium @ 20 g/ha, pretilachlor @ 750 g/ha, 2 HWs and weedy check. *Echinochloa colona, Commelina benghalensis, Alternanthera sesillis, Physalis minima, Caesulia auxillaris* and *Cyperus iria*

Table 55. Effect of fluazifop-p-butyl + fomasafen ready-mix combination on population and dry matter of weeds at 45 DAS, and seed yield of soybean

Treatment	Dose (g/ha)	Weed count /m^2*	Weed dry biomass (g/m^2)	Seed yield (t/ha)
Fluazifip-p-butyl 12.5%+ fomasafen 12.5%	200 g	4.0 (16)	47	1.67
Fluazifop + fomasafen	250 g	3.7 (14)	33	1.95
Fluazifop + fomasafen	313 g	3.0 (9)	31	2.23
Fluazifop + fomasafen	500 g	3.1 (10)	27	2.36
Fluazifop-p-butyl	125 g	4.5 (20)	66	1.61
Fomasafen 25% SL	250 g	4.5 (20)	57	1.69
Imazethapyr (Pursuit)	100 g	3.6 (13)	36	1.99
2 HWs	-	2.1 (4)	8	2.79
Weedy check	-	7.4 (55)	115	0.87
LSD (0.05)	-	1.1	23	0.47

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

were the dominant weeds. The lowest density and dry weight of weeds were recorded with post-emergence application of cyhalofop + penoxsulum @ 150 g/ha and it was closely followed by its lower dose @ 135 g/ha and bispyribac sodium @ 25 g/ha. The grain yield obtained under penoxsulum + cyhalofop @ 150 g/ha was superior over its 105 g/ha dose and significantly increased the yield of rice by 43% over weedy check due to lower weed competition (Table 56).

Table 56. Effect of premix combination of penoxsulum + cyhalofop-butyl in transplanted rice

Treatment	Dose (g/ha)	Weed density* (Nos/m^2)	Weed dry biomass (g/m^2)	Grain yield (t/ha)
Penoxsulum + cyhalofop-butyl	105	6.3 (24)	24	3.37
Penoxsulum + cyhalofop-butyl	120	5.5 (28)	17	3.80
Penoxsulum + cyhalofop-butyl	135	5.4 (19)	14	3.88
Penoxsulum + cyhalofop-butyl	150	4.7 (17)	12	3.95
Penoxsulum	22.5	7.0 (50)	31	3.40
Cyhalofop-butyl	80	7.7 (59)	42	3.07
Bispyribac-sodium	25	4.7 (22)	13	4.07
Pretilachlor	750	5.4 (29)	19	3.28
2 HWs		2.4 (5)	5	5.05
Untreated control	-	9.5 (91)	76	2.28
LSD (0.05)		0.8	12	0.43

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Effect of premix combination of penoxsulum + cyhalofop-butyl in direct-seeded rice

A field experiment was conducted to study the efficacy of different doses of premix combination of penoxsulum + cyhalofop–butyl on weed growth in direct seeded rice. Treatments comprised of a penoxsulum + cyhalofop-butyl premix @ 105, 120, 135 and 150 g/ha, penoxsulum alone @ 22.5 g/ha, cyhalofop @ 80 g/ha, bispyribac-sodium @ 25 g/ha and pretilachlor @ 750 g/ha along with 2 HW and weedy check were laid out in randomized block design with three replications. The experimental field was mainly infested with *Echinochloa colona, Cyperus* sp. *Commelina benghalensis, Alternanthera sessilis* and *Phyllanthus niruri*. Weeds in un-weeded plots reduced the grain yield of rice by 52% over 2 HWs. The ready-mix combination of penoxsulum + cyhalofop @ 150 g/ha was at par with the same combination @ 135 g/ha in terms of bioefficacy and yield (Table 57).

Table 57. Effect of premix combination of penoxsulum + cyhalofop-butyl in direct-seeded rice

Treatment	Dose (g/ha)	Weed density /m^2*	Weed dry biomass (g/m^2)	Grain yield (t/ha)
Penoxsulum + cyhalofop-butyl	105	4.8 (23.6)	47	4.27
Penoxsulum + cyhalofop-butyl	120	4.8 (23.0)	36	4.49
Penoxsulum + cyhalofop-butyl	135	4.3 (18.6)	33	4.48
Penoxsulum + cyhalofop-butyl	150	4.0 (16.3)	20	4.61
Penoxsulum	22.5	5.6 (32.6)	42	4.21
Cyhalofop-butyl	80	4.3 (18.6)	38	4.23
Bispyribac-sodium	25	3.2 (10.3)	17	4.81
Oxyfluorfen	200	4.6 (21)	38	4.45
2 HWs	-	2.2 (4.3)	4	5.93
Weedy check	-	4.9 (23.5)	104	2.89
LSD (0.05)		1.1	13	0.83

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

Evaluation of alachlor 50% for control of weeds in soybean

A field study was conducted to find out the effect of EC formulation of alachlor 50% on the weed control in soybean. Weed flora was dominated by *Echinochloa colona, Commelina benghalensis, Phyllanthus niruri, Dinebra retroflexa* and *Cyperus iria*. Pre-emergence application of alachlor @ 1.25 kg/ha provided good weed control, but the sponsored sample was slightly better than the market sample. Application of sponsored alachlor sample @ 1.25 kg/ha reduced the weed biomass to a greater extent and was superior to pre-emergence application of pendimethalin. However, post-emergence application of fenoxaprop was superior to all other treatments. Application of chlorimuron @ 9 g/ha as post-emergence could not control the grassy weeds and thus resulted in poor seed yield. Two HWs recorded highest seed yield (2.94 t/ha), followed by fenoxaprop (2.28 t/ha) and sponsored sample of alachlor (2.04 t/ha) (Table 58).

Supply and monitoring of Mexican beetle (*Zygogramma bicolorata*) establishment, spread and impact

About 50 thousand beetles were reared and supplied to AICRP-WC centres, KVKs, farmers, municipalities, NGOs and colony residents during 2011-12. The beetles were also sent to West Bengal in the month of April, 2011 coinciding with the early rains in this area. On the basis of feedback from the different locations, beetles have established well in U.P., lower Uttrakhand, many parts of H.P., M.P., A.P., Punjab, Delhi, Haryana, Maharashtra, Orissa, Bihar and Jharkhand and in some pockets of Rajasthan. In contradiction to the earlier reports from Gwalior,

Table 58. Effect of alachlor on population and dry biomass of weed growth at 45 DAS and seed yield of soybean

Treatment	Dose (g/ha)	Weed density /m^2*	Weed dry biomass (g/m^2)	Seed yield (t/ha)
Alachlor 50% + PE (Sponsor)	1250	4.9 (23)	55	2.04
Alachlor 50% + PE	1250	5.5 (30)	84	1.68
Pendimathalin	1000	4.6 (21)	96	1.95
Chlorimuron-ethyl 25% WP	9 g	5.5 (30)	69	1.56
Fenoxaprop-p-ethyl	100g	4.1 (17)	31	2.28
Two HWs	-	3.0 (9)	18	2.94
Weedy check	-	6.4 (40)	123	1.11
LSD (0.05)	-	1.0	31	0.35

*Data subjected to $\sqrt{x+0.5}$ transformation, values in parentheses are original

survey revealed the establishment of beetle in large area. In addition to this, about 22.5 lakh beetles were released in Nagpur region under consultancy project during 2011. Besides, the nucleus culture of *Neochetina* spp. was also sent for biological control of water hyacinth to Hyderabad, Hisar and Jagdalpur.

Vermicompost from weed biomass and agricultural wastes

Above 4.2 t of vermicompost was prepared from *Echinochloa* spp, *Parthenium*, and also from crop residues, viz. soybean, blackgram and greengram. Germination of *Parthenium* from vermicompost revealed that *Parthenium* seeds remained viable even after passing through earthworm guts.

View of vermicompost unit and Initial inoculation of earthworms in pits

4 EDUCATION AND TRAINING

Dr. Bhumesh Kumar

- National Consultation on Climate Change Resilient Agriculture held during September 19-20, 2011 at CRIDA, Hyderabad.
- Brain storming session on Prioritization of Plant Physiology and Biochemistry Research for XII Plan Period held during August 5-6, 2011 at IARI, New Delhi.
- Training on Current Techniques and Protocols in Plant Biochemistry and Molecular Biology held during December 8-28, 2011 at CAFT, Division of Biochemistry, IARI, New Delhi.

Dr. D.K. Pandey

- Training on Current Techniques and Protocols in Plant Biochemistry and Molecular Biology held during December 8-28, 2011 at CAFT, Division of Biochemistry, IARI, New Delhi.

Dr. K.K. Krishnani

- Operational training for 3200 QTRAP LC-MS/MS system with Shimadzu UFLC held during June 6-8, 2011 at Labindia Life Sciences, Gurgaon.

Dr. P.P. Choudhury

- Operational training for 3200 QTRAP LC-MS/MS system with Shimadzu UFLC held during June 6-8, 2011 at Labindia Life Sciences, Gurgaon.

Dr. Shobha Sondhia

- Operational training for 3200 QTRAP LC-MS/MS system with Shimadzu UFLC held during June 6-8, 2011 at Labindia Life Sciences, Gurgaon.

Dr. Sushilkumar

- Workshop on Biological Control held during May 27-28, 2011 at NBAII, Bengaluru.
- Workshop on ZTM-BPD held during January 14-15, 2012 at CIRCOT, Mumbai .

Dr. V.S.G.R. Naidu

- Training programme on Carbon Sequestration, Carbon Trading and Climate Change at Natural Resource Ecology Laboratory, Dept. of Soil and Crop science, Colorado State University, Fort Collins, Colorado, USA, during February 1 - April 30, 2011 .

Students completed dissertation during 2011-12

1	Ms Poonam Phabiyani	Govt MH College of Home Science & Science for Women, Jabalpur	Dr. C. Kannan	Isolation and identification of Rhizospheric micro-organism of major invasive weeds and effect of herbicides on antagonistic fungi
2	Ms Shalini Dubey	Govt MH College of Home Science & Science for Women, Jabalpur	Dr. C. Kannan	Isolation and identification of Rhizospheric population of major crop weeds and their biological control
3	Ms Nishita Dwivedi	Govt MH College of Home Science & Science for Women, Jabalpur	Dr. K.K. Krishnani	Isolation and characterization of agriculturally important bacteria
4	Mr S. Sachin	NGM College, Pollachi	Dr. Bhumesh Kumar	Effect of elevated CO_2 on physiological, biochemical and molecular aspects of chickpea and associated weeds
5	Ms Seema Sharma	RDVV, Jabalpur	Dr. P.P. Choudhury	Identification of chlorimuron-ethyl degrading fungus and its mode of degradation
6	Ms Anubhuti	RDVV, Jabalpur	Dr. P.J. Khankhane	Effect of weedy plants on physico-chemical and bacterial properties of waste water
7	Ms Anamika Astik	RDVV, Jabalpur	Dr. Bhumesh Kumar	Screening of different weeds for salt stress and water deficit

3 TECHNOLOGY DISSEMINATION

Advisory services

Farmer-scientist interactions on improved weed management technologies on different *kharif* and *rabi* crops were organized at farmers' fields during both *kharif* and *rabi* seasons. Besides more than 500 farmers and farm women, from different localities/ states were imparted knowledge through lectures/ exhibits/ trainings on weed problems in crops and their management as part of the advisory services.

Farmers-scientists interactions

Kisan Mela

A *Kisan Mela* was organized on January 23, 2012. Around 5000 farmers from Jabalpur and adjoining districts participated in this programme. Thirty progressive farmers of the area were honoured. A technical session and field visit were also arranged. About 50 stalls of various organizations demonstrated their latest technology and products. Extension folders and related materials were distributed to the farmers, stakeholders and other visitors.

Kisan Mela organized at the Directorate

Awareness Campaign

Awareness week was organized from August 16, 2011, involving farmers, NGOs, KVKs, school children and media with an objective to create public awareness about ill effects of *Parthenium* and its management. A scientist-farmer interface meeting/ *Kisan Goshthi* were also organized at Magarmuha village on the occasion of *Parthenium* Awareness Week.

Various programmes during *Parthenium* Awareness Week

Exhibition

DWSR participated in the exhibition organized on the occasion of 6th National KVK Conference by ZPD Zone VII at JNKVV, Jabalpur during December 3-5, 2011.

DWSR exhibition stall at KVK conference

Radio talks

Four radio talks related to the following aspects of weed management were delivered by the DWSR scientists from All India Radio, Jabalpur.

- कॉस एवं दुब का वैज्ञानिक विधि द्वारा प्रबंधन : अप्रैल 22, 2011
- खरीफ फसलों में खरपतवार प्रबंधन : जुलाई 13, 2011
- दलहनी फसलों में प्रमुख खरपतवार एवं नियंत्रण : सितम्बर 4, 2011
- रबी फसलों में खरपतवार नियंत्रण : दिसम्बर 9, 2011

Stakeholders' Consultation and Innovative Farmers Meet

A one-day stakeholder meet involving innovative farmers, representatives from industries, scientists of DWSR and nearby institutes/organizations was organized by the Directorate on 23.01.2012 under the chairmanship of DDG (NRM), ICAR. Director and scientists of DWSR, Zonal Project Directorate, KVKs and IFFCO participated in the meet. About 40 progressive farmers, NGOs, representatives from the industries participated in the meet.

Stakeholders' meet at DWSR

Training Programmes

The DWSR imparted knowledge on weed management to agriculture officials / IFFCO officials / SMS / farmers through lectures and video films. The Directorate also participated in different training programmes on weed management organized by FTC/State Agricultural Department and other organizations. Agriculture officials / farmers were briefed about the importance of weed management practices. Scientists of the Directorate explained the chemical and biological weed management in crop and non-cropped situations, use of mechanical tools and implements for weed control in field crop.

The Directorate in collaboration with IFFCO jointly organized a one-day training programme on weed management on May 26, 2011 for the technical officers of IFFCO. The Director, DWSR, the Chairman of the meeting narrated the importance of weed management in agriculture. The State Manager, Marketing Division, West Zone, IFFCO, highlighted their future programme and stated the importance of DWSR to execute those activities. Dr. V.P. Singh delivered a lecture on non-chemical approaches of weed management in crop production. Dr. Anil Dixit elaborated the herbicide application techniques. Er. H.S. Bisen threw light on mechanical weed control. Dr. P.K. Singh discussed about the positive attitude of the local farmers towards technologies disseminated from this Directorate.

Training programmes at DWSR

Village adoption

Tagar village under Panagar block of Jabalpur was adopted by the DWSR in the year 2008. Prior to adoption, the farmers of this agriculturally backward village was not well aware about the modern weed management technologies and in general practiced manual weeding during *Kharif* and no weeding operation during *Rabi* seasons. Rice-wheat system was the major cropping pattern of the village, and none of the farmers practiced commercial cultivation of vegetables and other cash crops due to severe weed menace.

On the basis of survey data collected prior to adoption, the strategies to transfer the improved weed management technologies were formulated as per the local needs in terms of practicability and commercial viability. The action plan was initiated in 2008 by conducting few preliminary demonstrations for showing performance, practicability and profitability of improved weed management technologies for *Kharif* rice to the villagers. Observing the positive response of the villagers, especially of the youth, towards the performance of the preliminary technological interventions, it was subsequently decided to demonstrate improved weed management technologies for *Rabi* crops also. Consequently, massive awareness programme, group discussion, farm and home visits, field demonstrations and need based trainings were conducted on regular basis with an objective to bring the whole village under weed free village concept.

DWSR adopted village

broad-leaved weeds in wheat at Pantnagar, Faizabad and Palampur. Combined application of sulfosulfuron + pinoxaden (25+40 g/ha) was effective to control grassy as well as broad leaf weeds in wheat at Gwalior.

- Applications of clodinafop + metribuzin @ 60+122.5 g/ha) and sulfosulfuron + metribuzin @ 25 + 105 were significantly superior herbicides in wheat at Pusa, Raipur, Meerut and Agra. Tank mixing of sulfosulfuron + pinoxaden showed antagonism at Ludhiana.
- In maize, oxyfluorfen @ 0.2 kg/ha alone and oxyfluorfen / atrazine both *fb* one hoeing, and 2 hoeing recorded the highest grain yield at Ludhiana and Parbhani. Applications of pendimethalin, oxyfluorfen or atrazine as pre-emergence at 3 DAS *fb* mechanical weeding at 30 DAS and oxyfluorfen *fb* 2,4-D Na-salt at 30 DAS were effective at Bengaluru, Palampur, Dharwad, Hyderabad and Akola.
- In sugarcane ratoon crop, pre-emergence application of metribuzin @ 0.88 kg/ha with one HW at 45 days after planting and application of 2,4-D Na-salt @ 0.5 kg/ha at 90 days after planting recorded significantly the lowest weed density both at 120 DAS and at harvest. Best combinations against complex weed flora in sugarcane ratoon at Hisar were found to be atrazine @ 1500 g/ha fb 2,4-D amine @ 750 g/ha, or metribuzin @ 880 g/ha *fb* hoeing *fb* 2,4-D amine @ 750 g/ha.
- Normal transplanting and SRI were superior to drum seeding and broadcasting of rice at Bengaluru, Pantnagar, Sriniketan, Coimbatore, Hyderabad, Thrissur and Pusa. Transplanting method performed better in terms of significant reduction in weed intensity and higher grain yield at Jorhat, Bhubaneswar, Kanpur. Pre-emergence application of pyrazosulfuron-ethyl @ 25 g/ha *fb* mechanical weeding (45 DAS/P) was very effective in lowering weeds of all types and gave higher yield at Bengaluru, Bhubaneswar, Kanpur, Sriniketan, Coimbatore, Hyderabad, Ranchi and Pusa.

Long term trial on tillage in different cropping systems

- Wheat sown with zero till methods gave significantly higher grain and straw yield over conventional methods of sowing. Highest grain yield of wheat was obtained with hand weeding twice and at par with application of isoproturon @ 1.0 kg + metsulfuron-methyl @ 4 g/ha. In transplanted rice application of butachlor @ 1.5 kg/ha *fb* 2,4–D @ 0.5 kg/ha recorded at par grain yield over hand weeding twice at Pantnagar and Faizabad.
- Conventional-conventional method and conventional-zero method of tillage and butachlor @ 1.5 kg/ha pre-emergence + 2,4-D @ 0.5 kg/ha post-emergence in rice and isoproturon @ 0.75 kg/ha + 2,4-D @ 0.5 kg/ha post-emergence in wheat produced significantly higher grain yields at Ranchi.
- At Kanpur, conventional tillage and application of pendimethalin (1.0 kg/ha) followed by chlorimuron + metsulfuron (4 g/ha) was recommended in rice. While, in rice-rice cropping system, integration of ZT-ZT method and use of butachlor @ 1.5 kg/ha gave the maximum B: C ratio of 1.85 at Bhubaneswar.

Long term trial on herbicides in different cropping systems

- In transplanted lowland rice-rice cropping system, at Coimbatore, shift in weed species from *Echinochloa colona* to *Panicum distachyon* and absence of *Eclipta alba* was observed. Integration of weed control by butachlor + 2,4-DEE with 100% inorganic nitrogen recorded maximum yield.
- At Hisar, the continuous use of clodinafop in wheat, and butachlor in rice provided effective control of weeds.
- Application of chlorimuron + metsulfuron @ 4 g/ha PO alone or in combination with butachlor @ 1.5 kg/ha PE in rice and isoproturon @ 1.5 kg/ha + 2,4-D @ 0.5 kg/ha in wheat can be practiced for higher productivity and profitability of rice – wheat cropping system at Ranchi.

5 AWARDS AND RECOGNITIONS

Dr. Anil Dixit

- Received the 'Best Poster Presentation Award' on the occasion of the International Conference on 'Climate Change, Sustainable Agriculture and Public Leadership' held during February 7-9, 2012 at the National Agricultural Science Centre, New Delhi.

Dr. P.K. Singh

- Received the 'Best Poster Presentation Award' on the occasion of the International Conference on 'Climate Change, Sustainable Agriculture and Public Leadership' held during February 7-9, 2012 at the National Agricultural Science Centre, New Delhi.

Dr. Shobha Sondhia

- Recognized as National Speaker in the INDO-US workshop on Green Chemistry held at Dehradun during March 11-14, 2012
- Recognized as external examiner by the University of Madras for Ph.D. thesis evaluation in the field of Organic Chemistry and Nano-Chemistry during 2011

Dr. V.P. Singh

- Recognized as External Examiner for Ph.D. thesis evaluation by Banaras Hindu University, Varanasi and Bundelkhand University, Jhansi during 2011

Dr. V.S.G.R. Naidu

- Received National Agricultural Innovation Project (NAIP) fellowship for three months to get advance training on "Carbon trading, carbon sequestration and climate change" at Natural Resource Ecology Lab and Department of Soil and Crop Sciences, Colorado State University, USA, 2011
- Conferred "Recognition Award" in appreciation of the contribution towards NIWS scheme implementation at TNAU, Coimbatore
- Received the 'Best Poster Presentation Award' on the occasion of the International Conference on 'Climate Change, Sustainable Agriculture and Public Leadership' held during February 7-9, 2012 at the National Agricultural Science Centre, New Delhi.

6 ALL INDIA COORDINATED RESEARCH PROJECT ON WEED CONTROL

Weed survey and surveillance

- In Punjab, the development of cross resistance in *Phalaris minor* to clodinafop and sulfosulfuron in near future has been indicated.
- In *Jhum* or shifting cultivation areas with rice-based cropping systems, in Dima Hasao district of Assam, prevalence of Asteraceae weeds were observed.
- In rice field, infestation of weedy rice (*Oryza* spp.) and the Chinese sprangletop (*Leptochloa chinensis*) were seen fast-spreading in all the major rice growing tracts of Kerala, namely, Kuttanad, Thrissur, Kole, and Palakad regions.

Leptochloa chinensis infested rice field

- In Raipur, *Alternanthra triandra* in cropped fields, especially in direct seeded rice and non-cropped areas has emerged as a serious weed. Another fast spreading weed invading the non-cropped area is *Malwa pusila*. However, it is replacing *Parthenium hysterophorus*.

Infestation of *Alternanthera triandra* on road side

- In eastern parts of Uttar Pradesh in the low lying areas of rice, weedy rice (*Oryza nivara, O. sativa f. spontanea* and *O. rufipogon*) were recorded and farmers noticed the increasing severity year after year. Four species of weedy rice, namely, *Oryza rufipogon, O. barthii, O. minuta* and *O. nivara* were identified at Sriniketan. Infestation of weedy rice varied from 10-50% in direct-seeded rice in Palampur.

Weedy rice [*Oryza sativa f. spontanea*]

Weedy rice [*Oryza nivara*] a troublesome weed for rice

Weedy rice (*Oryza rufipogon*) a troublesome weed for rice

- *Parthenium hysterophorus* is becoming new major weed in Southern dry and Southern transition zones. A new weed similar to *Solanum carolinense* L. is spreading in more areas in Mysore city. A new weed similar to *Parthenium* with underground root propagation were noticed on cropped fields and road sides in Southern Karnataka.

Solanum sp.

Biology and management of herbicide resistant biotypes of *Phalaris minor*

- In Ludhiana, for management of isoproturon resistant populations of *P. minor*, pinoxaden and clodinafop were the most effective herbicides. However, there are indications that at farmers fields the *P. minor* is developing resistance against recently recommended herbicides, viz. pinoxaden and mesosulfuron + iodosulfuron along with clodinafop and sulfosulfuron.
- Increased doses of clodinafop (75 g/ha), sulfosulfuron (30 g/ha), pinoxaden @ 50-60 g/ha and recommended doses of mesosulfuron + iodosulfuron (14.4 g/ha) and pinoxaden (50 g/ha) provided effective control of *P. minor* in wheat in Uttarakhand. Resistance in *P. minor* was observed in the seed lots collected from farmers' fields in Nainital and U.S. Nagar districts.
- *Echinochloa colona* showed no resistance against butachlor under red and lateritic zones.

Effect of CO_2 enrichment on growth and development of weed species

- Bengaluru centre reported that *Parthenium hysterophorus* and *Ageratum conyzoides* had higher ED_{50} in elevated CO_2 condition, whereas *Cyperus rotundus* had lower ED_{50}.
- At Thrissur, in C_3-plants like *Ludwigia*, positive effect of CO_2 enrichment on all the growth parameters were observed. However, in the case of a C_4-plant like *Echinochloa*, the effect was not so evident.

Weed management in crops and cropping systems

- Post-monsoon sowing lowered the dry weight of weeds and increased yield of rice at Kanpur, Bhubaneswar, Faizabad, Pantnagar, Coimbatore, Ranchi, Dapoli . Time of sowing did not influence the grain yield significantly at Raipur, Palampur and Bengaluru.
- Significantly higher grain yield and net return under direct-seeded rice were recorded from butachlor @ 1.5 kg/ha fb one hand weeding followed by pretilachlor @ 0.5 kg/ha + safener + hand weeding 30 DAS at Raipur, Kanpur, Bhubaneswar, Jorhat, Sriniketan, Bengaluru, Coimbatore, Dapoli, Parbhani, Pantnagar, Hyderabad and Faizabad centres reported similar results when followed by cyhalofop-butyl @ 90 g/ha and 2,4-D @ 0.5 kg/ha. Application of azimsulfuron, chlorimuron and cyhalofop-butyl also proved as effective as weed free at Palampur.
- Combined application of fenoxaprop along with chlorimuron + metsulfuron @ 4 g/ha gave the highest grain yield in direct dry-seeded rice at Pantnagar, Bhubaneswar, Bengaluru, Parbhani, Hyderabad, Dapoli and Meerut. Post-emergence mixture of fenoxaprop + ethoxysulfuron at 30 DAS was found effective in aerobic rice at Coimbatore.
- In wheat, clodinafop and pinoxaden alone provided effective control of *Phalaris minor*. Tank mixing of these herbicides with metribuzin helped in controlling *Rumex dentatus* and *Chenopodium album*. Sulfosulfuron alone provided effective control of *P. minor, Medicago denticulata* and *C. album* at Ludhiana and Hisar.
- Tank mix application of pinoxaden @ 50 + metribuzin @ 122.5 g/ha or clodinofop – propargyl @ 60 + metribuzin @ 122.5 g/ha were found most effective against grassy as well as

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Sondhia, S. 2012. Phytoremediation of herbicide contaminated soil, a step towards green sustainable agricultural chemistry, pp. 53. In: *Abstracts/Proceedings of INDO-US Workshop on Green Chemistry*, held at Dehradun during March 11–14, 2012.

- In rice-groundnut system, application of butachlor + 2,4-DEE rotated with pretilachlor without organic matter in rice along with use of alachlor in groundnut recorded significantly the lowest weed density in groundnut during initial stages of crop growth (25 DAS) at Bhubaneswar.
- In maize, interculture + HW twice and pre emergence application of tank mix of pendimethalin (0.25 kg/ha) with atrazine (0.50 kg/ha) at 30 DAS produced lowest weed density. In wheat, higher grain yield was recorded in hand weeding and pre-emergence application of pendimethalin @ 0.50 kg/ha and post-emergence application of metsulfuron-methyl @ 4.0 g/ha at Anand.
- In rice-chickpea cropping system, free-living bacteria phosphate solubilizers were more under hand weeding as compared to herbicidal application at Pantnagar, Faizabad and Pusa. Pendimethalin @ 0.75 kg/ha *fb* hoeing significantly reduced the dry matter of *P. minor*, *Rumex* and *Coronopus*, and recorded the highest field pea and chickpea seed yield and was significantly better at Ludhiana. In chickpea rhizosphere, at 3 DAT bacterial population in pendimethalin treated plot was very low as compared to mechanical weeding at Hisar.
- In rice-wheat cropping system, the microbial population of *Azotobacter, Azospirillum* and PSB remained smaller than the untreated weedy or mechanical weeding plots at Jorhat.
- In maize, application of atrazine @ 0.75 kg/ha as PE *fb* 2,4-D as PO (30 DAS) and in chickpea, application of pendimethalin @ 0.75 kg/ha *fb* hand weeding (30 DAS) significantly reduced weed population, weed dry matter, gave highest weed control efficiency and resulted in maximum grain yield of crop at Akola.

Management of parasitic weeds

- In lucerne, deep summer ploughing; application of imazethapyr @ 75 g/ha and pre-emergence pendimethalin @ 1.0 kg/ha applied as sand mix controlled dodder (*Cuscuta*) and produced significantly higher pooled green fodder yield at Bikaner. In niger, similar treatments gave significant control of dodder at Bhubaneswar. For effective control of *Cuscuta* in *Rabi* lablab bean crop, the field should be ploughed before sowing and pendimethalin @ 1.0 kg/ha be applied as pre- emergence with sand mix for obtaining higher yield and net returns at Dapoli.

Cuscuta problem in lucerne

- In tomato, use of metribuzin @ 0.5 kg/ha, pendimethalin @ 1.0 kg/ha and oxyfluorfen @ 0.1 kg /ha, all at 3 days after planting lowered and delayed emergence of *Orobanche* by 10–15 days than usual emergence of 50–60 days after planting at Bengaluru.

Infestation of *Orobanche aegyptiaca* in tomato crop

- In early planted sugarcane, pre-emergence application of atrazine @ 1.0 kg/ha +2,4-D Na-salt @ 1.0 kg/ha + urea 1% + soap solution 1% as PO on 75 days after planting followed by mulching with cane trash after final inter cultivation on 120 days after planting was found effective at Coimbatore.

Herbicide residues, persistence, leaching behaviour and toxicity

- Residues of pretilachlor in direct-seeded rice soils when applied @ 1.0 kg/ha were recorded up to 45 days and @ 2. 0 kg/ha were observed up to 60 days. In post-harvest soil, grain and straw samples, the residues were below detectable limit of 0.001 ppm at Bhubaneswar.
- Residues of butachlor and pretilachlor in rice grain and straw and in groundwater after harvest of the crop were below detectable level (10 ppb) at Jorhat. No residues of isoproturon and butachlor were detected in ground water at Pantnagar.
- No residue of atrazine and pendimethalin was detected in maize-chickpea and field pea cropping systems at Ludhiana. While at Coimbatore, in maize soil and crop produce, atrazine @ 1 kg/ha persisted in soil up to harvest while up to 90 days @ 0.5 kg/ha at application rate. However, fifty per cent of applied herbicide was degraded from the soil before 30 days after application and residue of atrazine was below detectable limit in maize grain and straw.
- In tea plants, more than 75% of glyphosate was lost in 15 days after application. Half-life in tea leaves varied from 5.8 to 7.9 days at Palampur.
- Paraquat residues were detected up to fifteen days from the application of herbicide in water when applied for management of water hyacinth at Anand. Persistence of paraquat residues in the aquatic system covered with *Alternanthera philoxeroids* was less than 2 weeks at Thrissur.
- Dissipation of 2,4-D was relatively rapid and more than 90% of applied amount was degraded from the aquatic system and only 2% of the applied 2,4-D was recovered in the water at 10 days after its application at double dose in water hyacinth at Coimbatore.
- Total amount of atrazine adsorbed increased with increasing initial concentration from 2.5 to 25 µg/ml of equilibrium solution (25 µg to 250 µg/g soil). The amount of atrazine adsorbed varied from 18.0 to 141.2 µg/g at Anand. Increase in the concentration of oxyfluorfen increased its adsorption. Amount of adsorbed oxyfluorfen desorbed from soil was in the range of 0.38 to 35.2% at Coimbatore.
- Butachlor and pretilachlor were strongly adsorbed on laterite soil and their adsorption onto soils was enhanced by the presence of organic matter, i.e. FYM retained more quantity of herbicides than vermicompost at Thrissur.

Transfer of Technology

- Use of bioagent, *Zygogramma bicolorata* against *Parthenium* resulted in significant control at Raipur, Pantnagar, Coimbatore, Bengaluru, Hyderabad and Palampur. Larval population, eggs and adults of *Zygogramma* beetles were highest during August to September at Pantnagar and Hisar. Large scale establishment of the beetles under natural condition and considerable damage on *Parthenium* have been successfully observed in 2011 at Sriniketan.
- On-farm trials on groundnut in Mangalpur, Pipili, and Puri district during 2010-11 revealed that highest yield was obtained with oxyfluorfen @ 0.05 kg /ha (2.57 t/ha) followed by pendimethalin @ 0.5 kg/ha (2.40 t/ha). The saving in weeding cost over farmer's practice was in the tune of ₹ 1950 to 2100/ha at Bhubaneswar.
- On farmer's field, application of atrazine (500 g/ha) in barnyard millet and finger millets in hills, application of clodinafop 15% + metsulfuron methyl 1 % (60 g/ha) in wheat, and bispyribac-sodium (20 g/ha) in transplanted rice recorded higher yield in plains as compared to farmer's practice at Pantnagar.
- Weed management in upland direct-seeded rice conducted in 8 locations in two districts, viz. Golaghat and Jorhat of Assam revealed the highest mean grain yield of 3.23 t/ha with pretilachlor @ 0.75 kg/ha + grubber at 35 DAS.
- Weed management in potato at farmer's field at Anand, metribuzin @ 0.35 kg/ha applied at 10 days after planting or post emergence application of paraquat @ 0.5 kg/ha before emergence of crops gave higher potato yield.
- At Sriniketan, 10 on-farm trials in rice, 2 in yellow sarson and 2 in potato were conducted.

Pyrazosufuron-ethyl + HW, pretilachlor + HW in rice; isoproturon, fenoxaprop-p-ethyl in yellow sarson and metribuzin, pendimethalin + earthing up effectively controlled weeds, gave more yield and economic return.

- In Coimbatore, at three locations, pre-emergence application of pendimethalin @ 0.75 kg + imazethapyr @ 60 g/ha 15 DAS for broad spectrum weed control and higher seed yield and economic returns in greengram and blackgram were observed.
- At Bengaluru, under on-farm trials in transplanted rice in southern dry zone, use of bensulfuron methyl 0.6% G @ 60 g/ha + pretilachlor 6% G @ 600 g/ha 3 days after planting and pyrazosulfuron ethyl @ 25 g/ha – 3 DAS gave 12 - 17% higher yield than hand weeding and gave additional returns of ₹ 8590 to 12,930/ha over farmers' practice.
- At Hyderabad, in groundnut, application of imazethapyr (PO) coupled with pendimethalin (PE) resulted in a net profit of around ₹ 3014 to 11590/ha when compared with farmers' practice.

Impact analysis of weed management

- At Palampur, extent of yield gain due to adoption of weed management technology was 0.80-1.00 t/ha in wheat, where as in rice crop it was 1.20-1.50 t/ha. Sixty eight percent farmers were satisfied with weed management technology adopted by them in wheat crop where as in rice, all the farmers were satisfied by adopting weed management technology.
- Adopters of integrated weed management obtained an increased onion yield to the level of 3.88 t/ha. The difference in the farm income was ₹ 59957/ha between the adopters and the non adopters at Coimbatore.

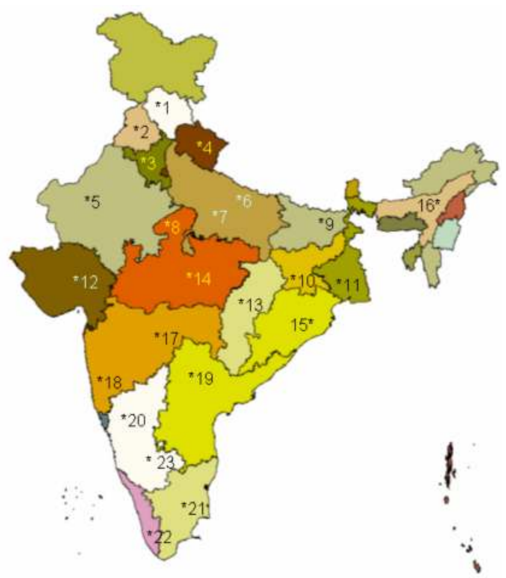
9 LINKAGES AND COLLABORATION

The Directorate plays a role of nodal agency for research and training in the field of weed science and also as a repository of information in weed science in the country, offers research and training to the research scholars, and provides expertise and consultancy to the staff and students of SAUs, ICAR Institutes, NGOs, herbicide industries, etc.

Besides coordinating with its 22 numbers of regular and a large number of volunteer centres, being operated at different agro-climatic zones of the country, DWSR also collaborates with several other educational and research institutions. MoU was signed with Jawaharlal Nehru Krishi Vishva Vidyalaya, Jabalpur, enabling better collaboration in the area of research, teaching and extension. This Directorate has also been recognized by Rani Durgavati Vishva Vidyalaya, Jabalpur, as a post-graduate research centre for their students. In addition, the Directorate is open to several educational institutions all over the country for their research and training activities. This Directorate made linkages with other ICAR institutes, SAUs, PDBC, DBT, DST and several herbicide industries for generation and sharing of data, HRD, technology dissemination and impact analysis.

Representatives from Directorate of Maize Research, New Delhi, Central Arid Zone Research Institute, Jodhpur, and Directorate of Oilseeds Research, Hyderabad, participated in the annual group meeting of AICRP-Weed Control at Anand Agricultural University, Anand on February 28 - March 1, 2011, where the technical programmes of AICRP-WC and also of these ICAR institutes were discussed. The Director, Directorate of Rapeseed-Mustard Research, Bharatpur, participated in the RAC meeting of the Directorate and focused on the issues related to weed management in oilseed crops specially about the severity and difficulties in managing *Orobanche* in mustard and explored the possibilities of formulating a joint project. Similarly, this Directorate also participated in the annual group meetings/ workshops of AICRPs on Rapeseed-Mustard, Chickpea, Rice, Soybean, etc. and suggested improvements in their technical programmes vis-à-vis weed management.

They have briefed about the problems and characteristics of weeds, and the weed management programmes being pursued at their respective institutes/areas. They were advised to make some necessary improvements in the technical programme taken up at their institutes.



AICRP-WC coordinating centres in different states

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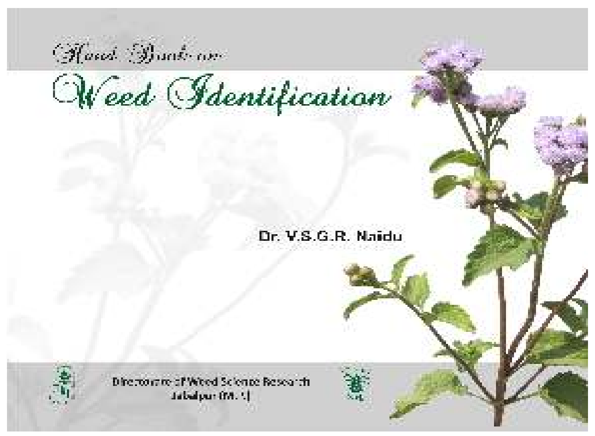

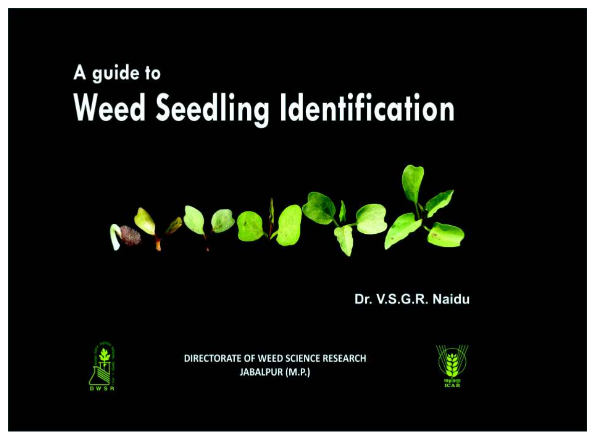

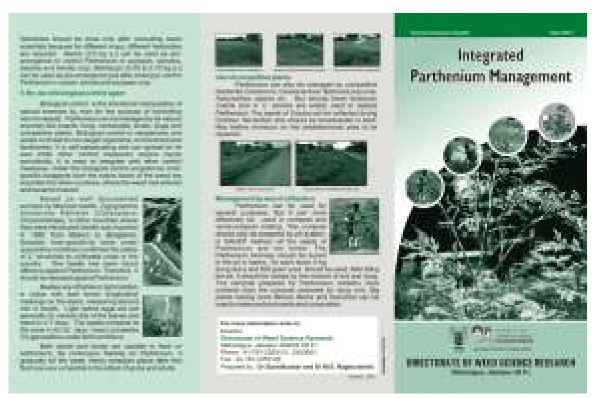

8 RESEARCH PROJECTS

In-house Research Projects

1. Weed Biology and Ecophysiology

1.1. Characterization of important weed seeds of central and southern India

1.2. Effect of elevated CO_2 on physiological, biochemical and molecular aspects in mungbean, chickpea and their associated weeds

1.3. Characterization of weedy rice biosimilars

2. Weed Management Techniques

2.1. Development of organic weed management in rice-wheat, soybean-wheat cropping systems, vegetable and medicinal crops

2.2. Development of weed management techniques in mango and citrus orchards

2.3. Design, development and evaluation of wick applicator and also spray techniques for weed management in crops

2.4. Effect of crop establishment techniques and weed management practices on growth and yield of rice under rice-wheat cropping system

3. Herbicides as a Tool in Weed Management

3.1. Long-term effect of herbicides on weed dynamics, soil microflora, non-tageted organisms, and herbicide residues in direct seeded rice-wheat and direct-weeded rice-chickpea cropping systems

3.2. Efficient weed management through herbicides in field crops and their impact on soil health

3.3. Monitoring of herbicide accumulation in soil and water under non-cropped conditions

3.4. Photo-transformation of isoproturon, 2,4 D on leaf surface and sulfosulfuron and propaquizafop in environment

3.5. Impact of soil physical environment on the efficacy of pre-emergence rice herbicides

4. Biopesticides and Biocontrol of Weeds

4.1. Evaluation of *Neochetina* species for biological control of water hyacinth

4.2. Survey, characterization and evaluation of plant pathogens for management of water hyacinth and *Cuscuta* species

4.3. Bio-herbicidal potential of plant constituents from Lantana, neem, tropical soda apple and *Parthenium* against targeted weeds

4.4. Development and evaluation of diverse methods for herbicide slow delivery and weed control

4.5. Biological control of *Chromolaena odorata* using gall fly by inoculative release in Chhattisgarh region

5. Weed Utilization

5.1. Identification and evaluation of weedy plants for phyto-remediation of heavy metal contaminated drain water

6. Transfer of Technology and Impact Assessment

6.1. Demonstrations on weed management technology ion crop and non-crop situations and their impact assessment

Service Projects

1. Testing of new herbicides
2. Vermicomposting of *Echinochloa, Parthenium* and water hyacinth
3. Mass multiplication, release and impact evaluation of *Z. bicolorata*
4. Evaluation of commercial formulations of herbicides available in the market for their active ingredient
5. Training and awareness activities

Consultancy Project

1. Survey, release and monitoring of *Zygogramma bicolorata* for the control of *Parthenium* in Nagpur region

Externally-Funded Projects

1. Precision farming technologies based on microprocessor and decision support systems for enhancing input application efficiency in production agriculture
2. Development and formulation of microbial metabolites for the management of root parasite weed *Orobanche* in mustard