खरपतवार विज्ञान अनुसंधान निदेशालय
DIRECTORATE OF WEED SCIENCE RESEARCH
महाराजपुर, अधारताल, जबलपुर - 482 004 (म.प्र.)
Maharajpur, Adhartal, Jabalpur - 482 004 (M.P.)
Telephones : 0761-2353101, 2353934
Fax : 0761-2353129
E-mail : dirdwsr@icar.org.in
URL : www.nrcws.org

वार्षिक प्रतिवेदन 2013–2014 Annual Report

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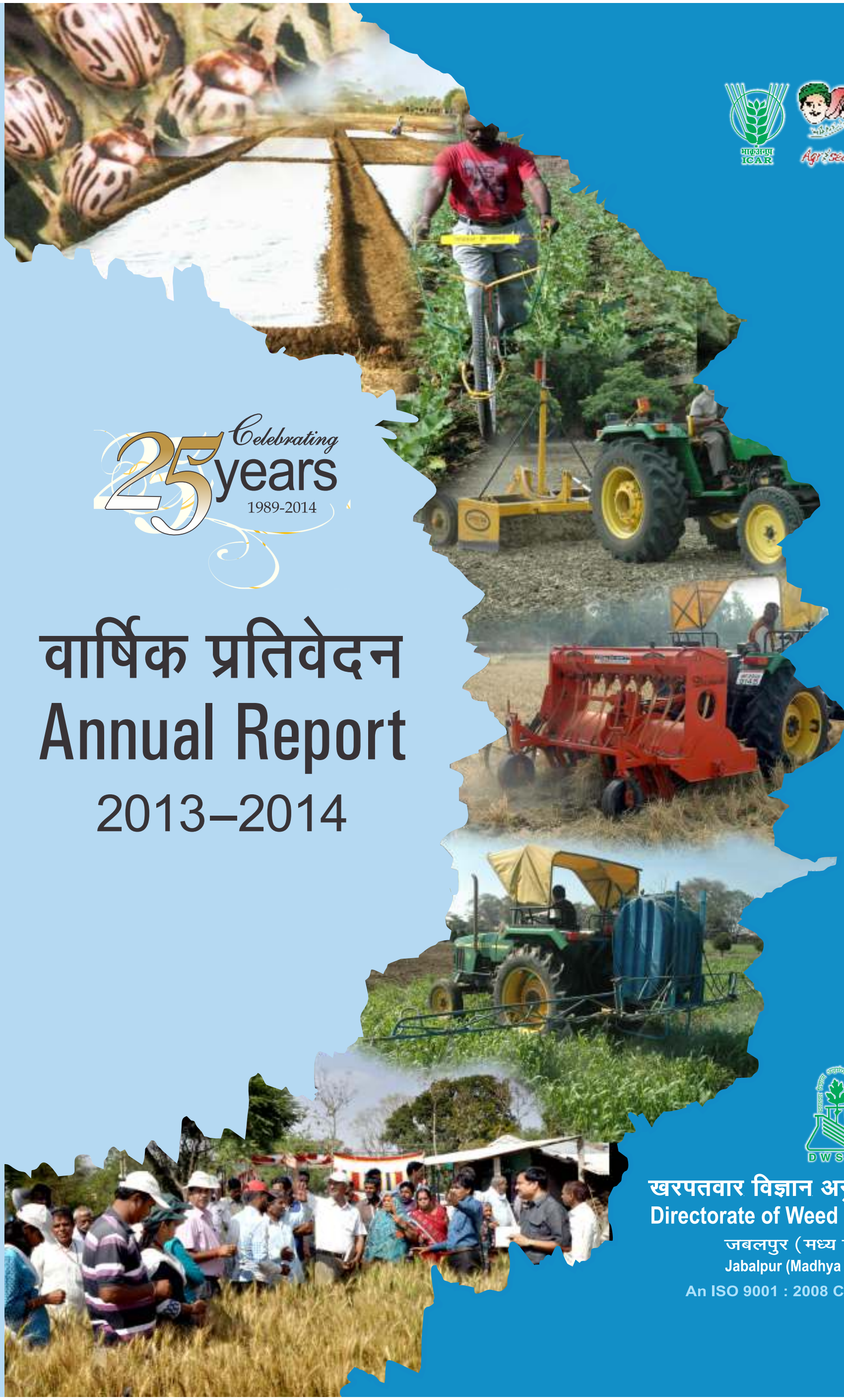
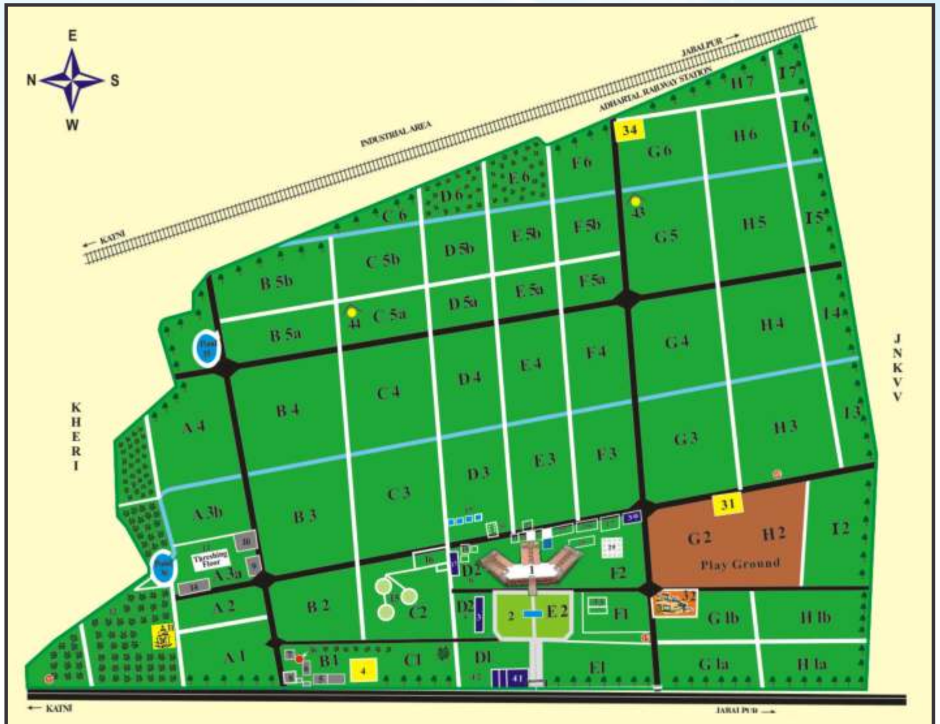
Agrisearch with a Human touch



Celebrating 25 years 1989-2014

वार्षिक प्रतिवेदन
Annual Report
2013–2014

खरपतवार विज्ञान अनुसंधान निदेशालय
Directorate of Weed Science Research
जबलपुर (मध्य प्रदेश) भारत
Jabalpur (Madhya Pradesh) India
An ISO 9001 : 2008 Certified Institution



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निदेशालय परिसर मानचित्र
DWSR CAMPUS MAP

DWSR in the NEWS

वार्षिक प्रतिवेदन
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Dr. A.R. Sharma
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Editorial Committee
Er. H.S. Bisen
Dr. D.K. Pandey
Dr. P.P. Choudhury
Mr. Sandeep Dhagat

Photographs
Mr. M.K. Bhatt
Mr. Basant Mishra

Cover page design
Mr. Sandeep Dhagat
Mr. M.K. Bhatt

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Cover theme

Front : Directorate has completed 25 years of its glorious existence. Over the years, weed management technologies in diversified areas have been developed which have led to increased productivity and profitability. The photos in sequence from top show Mexican beetles for *Parthenium* control, soil solarization technique, cycle-hoe for mechanical weeding, laser land leveling, happy seeder technology, multi-boom power spraying, and on-farm research trials.

Back : Directorate has developed impressive infrastructure over the last 25 years of its establishment to conduct high-quality research on different aspects of weed science. The photos in sequence from top show lysimeters for herbicide leaching studies, containment facility for controlled environment, bioremmediation model, open top chambers, FACE facility, weed cafeteria and runoff tanks for herbicidal effects on fish.

Preface

Research work on weed management is going on in our country for the past 60 years since the initiation of a coordinated scheme in principal crops like rice, wheat and sugarcane in 1952. This work was strengthened with the launching of All India Coordinated Research Project on Weed Control in 1978, now being implemented through 22 centres all over the country. National Research Centre for Weed Science (NRCWS) was established on 22 April 1989, which was further upgraded as the Directorate of Weed Science Research (DWSR) on 23 January 2009 to develop innovative, economic and ecofriendly weed management technologies for sustainable agriculture and societal benefits.

This Directorate has contributed significantly in identification of major weeds in different crops and non-crop situations, weed dynamics in crops and cropping systems, weed competitive crop cultivars, weed smothering intercrops, management of parasitic and perennial weeds, and developing effective, economic and eco-friendly weed management practices. The information generated has been very well documented in the form of weed identification kit, and national database on weeds covering 435 districts of the country. Besides this, several technical bulletins, manuals, books, extension pamphlets, posters and video films have also been released for the farmers and stakeholders. In addition to print media, this Directorate has also disseminated weed management packages through electronic means, *Kisan Mela* and *Sangoshthi*, exhibitions, trainings, and several FLDs across the length and breadth of the country. The impact of all these efforts can be gauged from the fact that there has been significant increase in acceptance of herbicides as a cheaper and effective tool in weed management. This Directorate has done commendable work in evaluating and disseminating the bio-control technologies for major non-crop weeds, viz. *Parthenium hysterophorus* through use of Mexican beetle (*Zygogramma bicolorata*) and water hyacinth (*Eichhornia crassipes*) using a weevil (*Neochetina* spp.). Several competitive plants such as *Cassia tora, Cassia serecia, Tagetus* spp. etc. have also been recommended to suppress *Parthenium* effectively.

Research and development programmes in weed management were reorganized in 2012 in view of the emerging concerns and challenges in agricultural production particularly with respect to weed infestation. Target-oriented research programmes were launched to address the emerging challenges and develop improved weed management strategies in order to increase crop productivity and resource-use efficiency. Sustainable weed management practices in diversified cropping systems address issues of weed management in conservation agriculture systems; adoption of systems approach with emphasis on horticultural, rainfed and organic farming systems; improving use-efficiency of water, nutrients and other resources through weed management; and efficient spraying techniques for low-volume high-potency herbicide molecules and mechanical tools for weed management. In the context of climate change and herbicide resistance, the research focus is on the effect of CO_2 and temperature on crop-weed associations, biochemical and physiological aspects of herbicide resistance development in weeds, weed risk analysis and development of weed seed standards. Some weed species are gaining serious proportions in different parts of the country, and are causing havoc to agricultural production, biodiversity and environment. Herbicides are becoming increasingly popular because of their high efficacy and increasing shortages of labour in almost all parts of the country, but there may be some concerns with respect to their residues and effects on environment. A strong programme for transfer of technology has been launched with emphasis on on-farm evaluation of weed management technologies, their adoption and impact assessment.

It is my privilege to present the 25th Annual Report of the Directorate during the Silver Jubilee Year. This report contains information on the achievements in research, education, training, extension and other activities organized during the period from April, 2013 to March, 2014. We have made significant progress over the previous year, and took new initiatives to further improve the quality of research and visibility of our output. Several programmes were organized at the Directorate for the first time to commemorate the Silver Jubilee Year.

I am highly thankful to Dr. S. Ayyappan, Director General (ICAR) and Secretary DARE for his special interest, and providing constructive criticism and visionary thoughts for strengthening the activities of this Directorate. I am equally grateful to Dr. A.K. Sikka, Deputy Director General (NRM); Dr. B. Mohan Kumar, Assistant Director General (Agronomy and Agroforestry), and Dr. S.K. Chaudhary, Assistant Director General (Soil and Water Management), ICAR for their kind consideration, generous support and critical inputs. I express my sincere gratitude to Er. H.S. Bisen, Dr. D.K. Pandey, Dr. Partha P. Choudhury and Mr. Sandeep Dhagat for compiling this report, and all the other scientists and staff members of the Directorate for their help and cooperation.

31 May, 2014

(A.R. Sharma)

CONTENTS

विशिष्ट सारांश

निदेशालय ने अनुसंधान और प्रौद्योगिकी के हस्तांतरण में अपने लक्ष्यों को प्राप्त करने के लिये 2012–13 में पांच बहु–आयामी अनुसंधान कार्यक्रम आरंभ किये। अनुसंधान कार्यक्रमों में विविध फसल प्रणाली के अंतर्गत दीर्घकालिक खरपतवार प्रबंधन के तरीकों का विकास, संरक्षित कृषि के अंतर्गत खरपतवार प्रबंधन, फसलचक्र से खरपतवारों में बदलाव, खरपतवारों की वृद्धि तथा विकास एवं पारिस्थितिक–कार्यिकी से संबंधित अनुसंधान, जलवायु परिवर्तन का फसल–खरपतवार प्रतिस्पर्धा पर प्रभाव, शाकनाशी प्रतिरोध, शाकनाशियों के प्रभाव बढ़ाने एवं उनके भूमि में अवशेष संबंधित अनुसंधान और फसली और गैर फसली क्षेत्रों में जटिल खरपतवारों का जैवकीय नियंत्रण, आदि शामिल है। निदेशालय द्वारा इस साल भी गाजरघास के नियंत्रण हेतु एकीकृत प्रबंधन का पूरे भारत में प्रभावी तौर पर प्रचार एवं प्रसार किया। निदेशालय द्वारा संरक्षित कृषि के अंतर्गत फसल अवशेषों का उपयोग करके उन्नत खरपतवार प्रबंधन तकनीक का किसानों के प्रक्षेत्रों पर परीक्षण एवं प्रदर्शन किया गया। इसके अतिरिक्त, समय–समय पर लघु प्रशिक्षण कार्यक्रम और किसान दिवस के आयोजन के माध्यम से भी किसानों को खरपतवार प्रबंधन के बारे में जागरूक किया गया।

वर्ष 2013–14 के दौरान विभिन्न अनुसंधान कार्यक्रमों के अंतर्गत मुख्य परिणाम संक्षेप में इस प्रकार हैं ।

विविध फसल प्रणाली में दीर्घकालिक खरपतवार प्रबंधन तकनीकों का विकास

- संरक्षण कृषि प्रणाली के तहत चावल–गेहूं–मूंग अनुक्रम के अंतर्गत, फसल (धान) स्थापना विधि ने विभिन्न खरपतवारों (*ईकाईनोक्लोवा कोलोना* और *डाईनेब्रा रेटेरोफ्लेक्सा* को छोड़कर) के उद्‌भव को अर्थपूर्ण रूप से प्रभावित किया। सबसे कम खरपतवारों का घनत्व बिना जुताई के (जैड. टी.) धान की सीधी बुवाई (डी. एस. आर.) + सेसबनिया के अवशेष के साथ पाया गया जो कि पारंपरिक जुताई (सी.टी.) के बाद ट्रांसप्लांटेड विधि से लगाये गये धान (टी. पी. आर.) में खरपतवारों के घनत्व के बराबर था। बिस्पायरीबेक सोडियम + जैड. टी में बुवाई पूर्व गैर चयनात्मक शाकनाशी का लगातार प्रयोग करने से खरपतवारों की संख्या और शुष्क पदार्थ की मात्रा सबसे कम और धान के अनाज और भूसें की उपज सबसे अधिक दर्ज की गई। बिस्पायरीबेक सोडियम, फिनाक्साप्रोप और 2,4–डी का कोई भी अवशेष नहीं पाया गया। डी. एस. आर. के बाद फसल अवशेष पुर्नचक्रण के पश्चात् उगाई गई गेहूं की फसल (सी. टी. और जैड. टी. दोनों ही स्थितियों में) बिना फसल अवशेष पुर्नचक्रण के पश्चात् उगाई गई फसल की तुलना में अधिक अनाज की उपज दर्ज की गई। खरपतवार नियंत्रण के उपायों के कारण गेहूं की उपज बिना खरपतवार नियंत्रण की तुलना में अधिक दर्ज की गई। फसल के अवशेष पुनर्चक्रण के कारण सभी जुताई प्रणालियों और खरपतवार नियंत्रण के उपायों के अंतर्गत मिट्‌टी में श्वसन की अधिक दर में वृद्धि हुई।
- संरक्षण कृषि प्रणाली के अंतर्गत मक्का–गेहूं–मूंग अनुक्रम में सी. टी. विधि की तुलना में जैड. टी. विधि द्वारा बुवाई करने से अधिक उपज दर्ज की गई। अंकुरण से पहले एट्राजीन+पेंडीमेथेलीन (0.5+0.5 कि.ग्रा. / हे.) तथा उसके उपरांत 25 दिन बाद एक बार हाथ से निदाई करने से एट्राजीन+पेंडीमेथेलीन (0.5+0.5 कि.ग्रा. / हे.) तथा उसके उपरांत 2,4–डी (0.5 कि.ग्रा. / हे.) के प्रयोग की तुलना में अधिक उपज प्राप्त हुई।
- शाकनाशियों के लगातार प्रयोग के चौथे चक्र के उपरांत, बिसपायरीबैक–सोडियम (25 ग्रा. / हे.) के प्रयोग से घास कुल के खरपतवारों (*ईकाइनोक्लोवा कोलोना, साइप्रस इरिया* व *कौमेलिना कम्यूनिस*) के घनत्व में 95 प्रतिशत तक कमी दर्ज की गई। बिसपायरीबैक–सोडियम का प्रयोग करने पर साइहेलोफॉप–ब्यूटाइल की तुलना में खरपतवारों के घनत्व में 89 प्रतिशत तक एवं शुष्क पदार्थ की मात्रा में 82 प्रतिशत तक कमी दर्ज की गई।
- गेहूं में क्लोडिनाफाप (60 ग्रा. / हे.) तथा उसके बाद 2, 4–डी (500 ग्रा. / हे.) का प्रयोग करने से *ऐविना, फेलेरिस माइनर चिकोरियम* (बथुआ) एवं *चिकोरियम एन्टाइवस* की संख्या में अर्थपूर्ण कमी दर्ज की गयी, जबकि सल्फोसल्फ्यूरान के प्रयोग से *मेडिकागो डेन्टीकुलेटा* की संख्या में अर्थपूर्ण कमीं पायी गयी। *आइसोप्रोट्‌यूरान* का प्रयोग *एविना* एवं *फेलेरिस माइनर* की वृद्धि को रोकने में असफल पाया गया। जबकि *चिकोरियम एन्टाइवस* एवं *चीनोपोडियम एलबम* के विरूद्ध इसका प्रयोग बहुत प्रभावी रहा।
- डी.एस.आर.–चना फसल चक्रण प्रणाली में खरपतवारनाशियों के लगातार उपयोग ने खरपतवार बीज भंडार, खरपतवार गतिशीलता तथा फसल उत्पादकता को प्रभावित किया। पेंडीमिथेलिन और आक्सीफ्लोरफेन ने समान रूप से खरपतवार प्रजातियों के घनत्व एवं शुष्कभार उत्पादन को कम किया। आक्सीफ्लोरफेन एवं पेंडीमिथेलीन के उपयोग से चनें में अधिक फली / पौधा (46 प्रतिशत) तथा बीज उपज (80 प्रतिशत) प्राप्त हुई।
- धान–गेहूं प्रणाली में प्रक्षेत्र खाद (FYM) का 10 टन / हेक्टेयर + दो बार हाथों की निंदाई (25 एवं 45 दिनों पर) से सबसे कम खरपतवार घनत्व एवं खरपतवार जैव शुष्कभार दर्ज किया गया। जबकि NPK+खरपतवारनाशी के उपयोग से गेहूं की अधिक उपज दर्ज की गई।

सोयाबीन और गेहूं प्रणाली में 50 प्रतिशत NPK + 50 प्रतिशत प्रक्षेत्र खाद एवं खरपतवारनाशी + 1 बार हाथों की निदाई के प्रयोग से खरपतवारों की संख्या सबसे कम दर्ज की गई। गेहूं की उपज NPK + खरपतवारनाशी के उपयोग में उच्चतम थी।

- भिण्डी–टमाटर फसल प्रणाली में काली पॉलीथीन मल्च तथा प्रक्षेत्र खाद (FYM) के उपयोग करने से टमाटर की अधिक उपज दर्ज की गई। आम बागानों में आम के वृक्षों के बीच की खाली जगहों में सनई एवं ढैंचा लगाने पर देखा गया कि बुआई के 60 दिनों पश्चात् खरपतवार घनत्व में क्रमशः 95 एवं 93 प्रतिशत की कमी हुई।
- धान में श्री (SRI) प्रणाली की अन्य प्रणालियों से तुलना करने पर बाली की लम्बाई, 1000 दानों का वजन और उपज सभी अधिक दर्ज की गई। खरपतवार प्रबंधन तरीकों में दो बार हाथों की निदाई से अधिकतम उपज दर्ज की गई जो कि बिसपायरीबैक–सोडियम + 1 बार हाथ निदाई के बराबर थी।
- सोयाबीन में खरपतवार प्रबंधन तरीकों में 50 दिन पश्चात् पेंडीमेथिलीन के बाद इमेजेथापायर के प्रयोग से खरपतवारों का घनत्व और शुष्कभार सबसे कम पाया गया।
- मूंग में अंकुरण के पूर्व पेंडीमेथिलीन का 1000 ग्रा./हे. उपयोग या खड़ी फसल में क्विजालोफाप–पी–इथाइल 60 ग्रा./हे. या इमेजेथापयर 100 ग्रा./हे. का उपयोग बुवाई के 25 दिनों बाद करने से अधिक उपज प्राप्त हुई।
- सरसों में बुवाई के 25 तथा 35 दिनों पश्चात् ग्लाइफोसेट की कम मात्रा (40, 50 तथा 60 ग्रा./हे.) का उपयोग करने पर पौधों की वृद्धि एवं उपज पर कोई हानिकारक प्रभाव नहीं देखा गया।

जलवायु परिवर्तन के दौर में खरपतवार गतिकी व प्रबंधन तथा शाकनाशी प्रतिरोधकता

- सामानतः उच्च कार्बन–डाई–आक्साईड की उपस्थिति में चनें (*लेथाइरस सटाइवस* एवं *मेडिकागो डेन्टीकुलाटा*) की प्रजनन चरण प्रारंभ में 10 दिनों की उन्नति देखी गई। वायुमण्डलीय कार्बन–डाई–आक्साईड में बढ़ोत्तरी का वृद्धि एवं प्रकाश संश्लेषण पर सकारात्मक प्रभाव तथा साथ ही रंध्रीय चालकता व वाष्पोत्सर्जन दर में तीनों प्रजातियों में गिरावट दर्ज की गई। उच्च कार्बन–डाई–आक्साईड ने तीनों प्रजातियों में कार्बोनिक एनहाइड्रेज की सक्रियता बढ़ाई एवं शायद यह उच्च कार्बन–डाई–आक्साईड की स्थिति में बढ़ी हुई प्रकाश संश्लेषण दर का एक कारक हो सकता है। इसी प्रकार उच्च कार्बन–डाई–आक्साईड की स्थिति में तीनों प्रजातियों में नाइट्रेट रिडक्टेज की सक्रियता में वृद्धि होना पाया गया।
- उच्च कार्बन–डाई–आक्साईड की उपस्थिति में एण्टीआक्सीडेंट एन्जाइम्स की आइसोएन्जाइम [सुपरआक्साइड डिस्म्युटेज (SOD), गुआइयेकॉल परॉक्सीडेज (POX) और ग्लूटाथिआन रिडक्टेज (GR)] का भिन्नात्मक विनियमन एवं साथ ही नये समरूपियों का उद्दीपन पाया गया। खरपतवार प्रजातियां विशेषकर *लेथाइरस* में चनें की तुलना में मजबूत एन्टीआक्सीडेंट रक्षा तंत्र उपस्थित पाया गया। जो कि इस बात की ओर इशारा करता है कि जलवायु परिवर्तन परिस्थिति में एंटीआक्सीडेंट रक्षा तंत्र का योगदान है।
- *फेलेरिस माइनर* के समयुग्मी जो पंतनगर, फैजाबाद, आई.ए.आर.आई., नई दिल्ली एवं जबलपुर के थे उनमें आइसोप्रोट्यूरान के विरूद्ध बहुत कम प्रतिरोध पाया गया। पंजाब से लिये गये समयुग्मियों में तलवंडी के समयुग्मी ने मध्यम तथा राजपुरा एवं बरनाला के समयुग्मी ने उच्च प्रतिरोध प्रदर्शित किया। जबकि हरियाणा से लिये गये समयुग्मी जो पानीपत, पीपली एवं नरवाना से थे, आइसोप्रोट्युरान के विरूद्ध उच्च प्रतिरोध प्रदर्शित किया। हरियाणा एवं पंजाब से लिये गये समयुग्मियों ने पिनोक्साडेन के खिलाफ, अटलान्टिस (मिजोसल्फ्युरान + आयडोसल्फ्यूरान) तथा टोटल (सल्फोसल्फ्यूरान + मेटसल्फ्यूरान) के विरूद्ध (कम से मध्यम) प्रतिरोध प्रदर्शित किया।
- *कान्वोन्वुलस आरवेन्सिस, मेलीलोटस अल्बा, चिकोरियम इन्टाइबस, सोलेनम सरेटेन्स, लेथाइरस सटाइवा, मेडीकागो डेन्टीकुलाटा, सोलेनम वायरम, चिनोपोडियम एल्बम, लेथाइरस अफाका* एवं *यूफोरबिया जेनीकुलाटा* के कुछ पौधों ने 2,4–डी (750 ग्रा./हे.), 2 गुना तथा 3 गुनी मात्रा के विरूद्ध सहिष्णुता प्रदर्शित की। *इकाइनोक्लोआ* प्रजाति के कुछ पौधों ने बिस्पायरीबैक–सोडियम के 1 गुना (25 ग्रा./हे.) 2 गुना, 3 गुनी एवं 4 गुनी मात्रा के विरूद्ध भी सहिष्णुता प्रदर्शित की।
- विभिन्न खरपतवार प्रजातियों की विभिन्न विकास अवस्थाओं (जैसे कि बीज, जल आत्मसात किये हुये बीज तथा उनके प्रजनन अंगों) के चित्र लिये गये जिनको खरपतवार पहचान साफ्टवेयर के विकास एवं खरपतवार एटलस के विकास में उपयोग होना है। खरपतवार एटलस के लिये 16 खरपतवारों की विभिन्न सूचनाओं को समाहित किया जा चुका है।
- धान के एस. एस. आर. मार्कर का उपयोग *इकाइनोक्लोआ* की चार प्रजातियों/उपप्रजातियों में विविधता का पता लगाने हेतु किया गया। जो कि आण्विक स्तर पर प्रजाति की पहचान में उपयोगी हो सकते हैं।
- खरपतवार बीजों की जीवन क्षमता जिसे खरपतवार फैलाव जोखिम क्षमता भी कहते हैं, 13 प्रजातियों में 6–10 वर्ष एवं चार प्रजातियों में 11–13 वर्ष पाई गई।

- गाजरघास की पत्तियों से पार्थेनीन जैसा एक एलीलोकैमिकल निष्कर्षित किया गया जिसने जलीय खरपतवार (*पोटामोगेटॉन क्रिस्पस*) को नियंत्रित परिस्थितियों में 10 पी.पी.एम. पर मारा तथा 15 पी.पी.एम. पर बाहय परिस्थितियों में मारा। इस एलिलोकैमिकल की शाकनाशी क्रियाशीलता 35°C तापमान पर सर्वाधिक थी जबकि यह 20–27°C पर जहरीला था परंतु घातक नहीं था। यह प्रयोग प्रयोगशाला परीक्षण था।

फसलीय एवं गैर फसलीय क्षेत्रों में समस्यात्मक खरपतवारों का जीवविज्ञान एवं प्रबंधन

- खरपतवारीय धान के विभिन्न जर्मप्लाज्म, जो देश के विभिन्न हिस्सों से इकट्ठे किये गये हैं के बाहय आकारिकी मापदंडों, प्रकाश संश्लेषण एवं आइसो एंजाइम स्वरूप (गुआइयेकाल पराक्सीडेज) में अत्यंत भिन्नता पाई गई।
- खरपतवारीय धान के विभिन्न एक्सेशन को बाहय–कार्यिकी तथा बाहय आकार्यिकी आंकड़ों के आधार पर समूहित करने पर पाया गया कि कुछ एक्सेशन कल्टीवेटेड तथा जंगली धान के साथ समूहित हुये जबकि कुछ ऐक्सेशन स्वतंत्र पाये गये। मध्यप्रदेश के खरपतवारीय धान एक्सेशन्स की आण्विक अंगुली छापन (finger print) के आधार पर बनाये गये शाखित चित्र (डेन्ड्रोग्राम) में भी खरपतवारीय धान ने कल्टीवेटेड एवं जंगली धान के साथ समानता प्रदर्शित की।
- जो खरपतवारीय धान के एक्सेशन्स एक ही राज्य से इकट्ठे किये गये हैं उनके भी अंकुरण प्रतिशत में परिवर्तन पाया गया। झारखण्ड, बिहार, केरल, मध्यप्रदेश एवं छत्तीसगढ़ के एक्सेशन्स ने कम मात्रा में सुषुप्तावस्था प्रदर्शित की। खरपतवारीय धान के वे एक्सेशन्स जो छत्तीसगढ़, बिहार, मध्य प्रदेश एवं उत्तर प्रदेश से इकट्ठे किये गये हैं, जमीन में 10 सेमी. गहराई तक से अंकुरण की अच्छी क्षमता पाई गई।
- खरपतवारीय धान में अनाक्सीय परिस्थितियों में भी अंकुरित होने की क्षमता है। झारखण्ड, बिहार उत्तर प्रदेश एवं मध्य प्रदेश के एक्सेशन्स में 10 से.मी. खड़े पानी में भी अन्य की तुलना में अंकुरण की क्षमता है।
- रबी 2013 में खिन्नी गांव में सर्वेक्षण करने पर पाया गया कि फंगस (*स्क्लेरोटियम रोल्फाई* के रूप में उसके बाहय आकार पर आधारित पहचान की गई थी) को टमाटर की तुलना में भुईफोड़ अधिक पसंद था।
- नियंत्रित परिस्थितियों में प्रयोग में जब *ओरोबैंकी क्रीनाटा* (*O. crenata*) या औरोबेंकी पर विभिन्न जैव प्रतिनिधियों जैसे कि ट्राइकोडर्मा विरडी, ग्लाइओक्लेडियम विरेन्स, फ्यूजेरियम स्पीशीज डी. डब्ल्यू. एस. आर. 2 तथा एस. रोल्फाई का स्प्रे किया गया तो यह पाया गया कि केवल *स्क्लेरोटियम रोल्फाई* (भुईफोड़) ने संक्रमण उत्पन्न किया जिससे निरंतर नम गलन जैसा लक्षण दिखा। जबकि टमाटर के पौधों में कोई लक्षण नहीं दिखे। यह दिखाता है कि इस विशेष एस. रोल्फाई के आइसोलेट की पसंद केवल भुईफोड़ (*ओ. क्रिनाटा*) है।
- मध्यप्रदेश के ग्वालियर जिले में बिलौआ ग्राम (26°02'59, 32"N, 78°17'00.03"E) से भुईफोड़ से एक कीट *फाइटोमाइजा ओरोबेंकीया* काल (*Phytomyza orobanchia* Kal.) बेगन के खेत से जिसमें अंतरवर्ती फसल के रूप में मिर्च लगाई गई थी से इकट्ठा किया गया। भुईफोड़ के डंठलों का समीपी निरीक्षण करने पर छेद एवं सुरंग नन्हें प्यूपा एवं सफेद मेगट के साथ, जो कैप्स्यूल्स रसीलें डंठल एवं बीज दाना से अपना भोजन प्राप्त कर रहे थे पाये गये।
- फ्यूजेरियम स्पी. डी.डब्ल्यू.एस.आर. 1 के सूक्ष्मजीवीय मेटाबोलाइट्स भुईफोड़ के अंकुरण को कम करने में प्रभावशाली पाये गये। मेटालैक्जिल एम जेड एवं ग्लाइफोसेट ने भुईफोड़ के अंकुरण एवं विकास को विलंबित किया।
- मेटसल्फ्यूरॉन–मिथाइल 6 ग्रा./हे. पिस्टिया स्ट्रेटियोटस को नियंत्रित करने में प्रभावी रहा। जल की सतह पर शाकनाशी का उपयोग पानी की गुणवत्ता को प्रभावित नहीं करता है। परंतु जब इसे पिस्टिया पर उपयोग किया गया तो घुलित आक्सीजन कम हुई तथा संयोग से खरपतवार अपघटन भी दर्ज किया गया। पिस्टिया ने जल की सम्पूर्ण सतह को ढंका हुआ था और जल की घुलित आक्सीजन को कम किया।

पर्यावरण में शाकनाशी अवशेषों एवं प्रदूषकों की निगरानी, अधमता एवं उनका घटाव

- प्रारंभ में पायराजोसल्फ्यूरॉन–एथाइल, पिनोक्सुलम तथा प्रेटिलाक्लोर के 95, 297 तथा 576 नैनोग्राम/ग्रा. अवशेष धान की मिट्टी में पाये गये जो कि 30 दिनों में 8.8, 17.6 तथा 37.5 नैनोग्राम/ग्रा. रह गये। धान की मिट्टी में पायराजोसल्फयूरान–एथाइल, पिनोक्सुलम तथा प्रेटिलाक्लोर की अर्ध आयु 9.84, 7.8 तथा 10.4 दिन पायी गई।
- दस दिनों में तालाब के जल में पायराजोसल्फयूरॉन–एथाइल, पिनोक्सुलम एवं प्रेटिलाक्लोर के 31.4, 37.0 एवं 11.3 नैनोग्राम/मि.ली. अवशेष पाये गये। 60 दिनों में पायराजोसल्फयूरॉन एथाइल के अवशेष 1.0 से नीचे पाये गये, जबकि 60 दिनों पर प्रेटिलाक्लोर के 5.4 नैनोग्राम/मि.ली. अवशेष पाये गये, जो कि तालाब के जल में 1.0 नैनोग्राम/मि.ली. से कम थे।
- धान के हरे पौधों में 10 से 30 दिनों पर पायराजोसल्फयूरॉन के अवशेष 238.4 से 11.7 नैनोग्रा./ग्रा. पाये गये। जबकि हरे पौधों में 10 से 30 दिनों पर

प्रेटिलाक्लोर के अवशेष क्रमशः 1.1247 से 0.825 माइक्रोग्राम/ग्रा. पाये गये।

- 60 दिनों पर मछलियों में पायराजोसल्फयूरॉन–एथाइल, पिनोक्सुलम एवं प्रेटिलाक्लोर अवशेष क्रमशः 1.0, 1.7 तथा 1.0 नैनोग्राम/ग्रा. पाये गये जो कि 100 दिनों पर खोज सीमा से नीचे 1.0 नैनोग्राम/ग्रा. थे ।
- गेहूं की फसल में प्रारंभिक रूप में मृदा में फिनोक्साप्रोप–पी–एथाइल, कारफेन्ट्राजोन एवं पिनोक्साडेन के 43.4, 88.8 एवं 166.1 नैनोग्राम/ग्रा. अवशेष पाये गये जो 90 दिनों में घटकर ढ 1.0 नैनोग्राम/ग्रा. रह गये।
- मृदा एवं तालाब के जल से पायराजोसल्फयूरॉन–एथाइल का अपघटन होने पर प्राप्त उत्पादों को एल.सी./एम.एस./एम.एस. द्वारा एथाइल–5–[(4,6–डाईमेथॉक्सी पाइरीमिडीन–2–इलकार्बामाइल)] सल्फेमाइल,–1–मेथाइलपाइराजोल–4–कार्बोक्सिलिक एसिडय एथाइल 1–मेथाइल–5–सल्फेमाइल–1 एच–पाइजोल–4 कार्बोक्सिलेट और 4,6–डाई मेथाक्सीपाइरीमिडीन–2–एमाइन, 1–मेथल–5–सल्फामाइल–1 एच–पाइजोल–4–कार्बोक्सीलिक एसिड के रूप में पहचाना गया।
- मृदा एवं तालाब के जल से प्रेटिलाक्लोर के अपघटन उत्पादों को 2′,6′. डाईएथाइल–N– (प्रोपाक्सी एथाइल) एसिटेनिलाइडय 2′,6′. डाईएथाइल–N–(प्रोपाक्सी एथाइल) एनीलीनय 2′,6′. डाईएथाइल–N–(2–हाइड्राक्सीएथाइल) एनीलीनय 2′,6′.(डाईएथाइल) –N–(एथाइल) एनीलीनय 2–क्लोरो–2′–) 1–हाइड्राक्सीएथाइल, 6′ एथाइल) –N – (2– प्रोपाक्सी एथाइल एसिटेनिलाइडय एसिटेनिलाइड एवं 2–क्लोरो–1 (9–एथाइल–3–हाइड्राक्सी– 2,3,4,5–टेट्राहाइड्रो–1 एच–1 बेंजाजापिन–1–इल) एथेनोन के रूप में पहचाना गया।
- मृदा में पिनोक्सुलम के तीन अपघटन उत्पादों 1,2,4 ट्रायाजोलो– [1,5– c] पाइरीमिडीन–2 एमाइन, 5,8 डाईकार्बोक्सिलिक एसिडय 2–(2,2–डाईफलोरो एथाक्सी) – 6 (ट्राई फ्लोरोमेथिल) बेंजीन सल्फोनामाइड और 3–[[[2–(2,2–डाईफलोरोएथॅक्सी)–N–[1,2,4, ट्रायाजोल [1,5 सी] 6– ट्राईक्लोरोमेथिल) बेंजीन सल्फोनामाइड कार्बोक्सिलेट को पहचाना गया।
- खेत की मृदा में प्रेटिलाक्लोर के सात अपघटन उत्पादों 2′6′–डाईएथाइल–एन– (प्रोपॉक्सीएथाइल) एसिटेनिलाइडय 2′6′–डाईएथाइल–एन–(प्रोपॉक्सी एथाइल) एनीलीनय 2′6′–डाईएथाइल–एन–(एथाइल) एनीलीलय एसिटेनिलाइडय 2–क्लोरो–2′,) 1–हाइड्राक्सीएथाइल, 6′ एथाइल)–छ– (2–प्रोपाक्सी एथाइल एसिटनिलाइडय और 2– क्लोरो–1 (–9–एथाइल–3–हाइड्राक्सी– 2,3,4,5– टेट्राहाइड्रो–1 एच–1 बेंजाजापिन –1–इल) इथेनोन की पहचान की गई।
- पर्यावरण में बिस्पायरीबैक–सोडियम के प्रकाश अपघटन से उत्पन्न होने वाले सात अपघटित उत्पादों को अलग किया गया।
- धान की मिट्टी से सात आर्थोसल्फाम्युरॉन–अपघटनकारी फंगस को निकाला गया तथा आर्थोसल्फाम्युरॉन का अपघटन मार्ग प्रस्तावित किया गया।
- संरक्षित खेती पर खरपतवारनाशी का लंबे समय तक प्रभाव वाले प्रयोग से लिये गये धान के दाने एवं भूसे में बिस्पायरीबैक–सोडियम, 2,4–डी एवं फिनोक्साप्राप का कोई अवशेष नहीं पाया गया। मक्के की फसल वाली मृदा से एट्राजीन के चार मेटाबोलाइट्स की पहचान की गई।
- औद्योगिक नालियों में बहने वाले प्रदूषित जल से भारी धातुओं को दूर करने हेतु स्थलीय खरपतवार प्रजातियों का फाइटोरेमेडियेशन तंत्र के अंतर्गत उपयोग किया गया। नालों के पानी में लोहा, तांबा एवं कैडमियम 0.3282, 0.0363 एवं 0.0126 मि.ग्रा/ली. सांद्रता में क्रमशः उपस्थित थे। उपचार के पश्चात् जलीय टेंक में लोहा, कापर एवं कैडमियम की सांद्रता घटकर 0.1548, 0.0286 तथा 0.0093 मि.ग्रा/ली. रह गई। सतही टैक में यह सांद्रता 0.0356, 0.0276 एवं 0.0106 मि.ग्रा/ली. तथा टाइफा आधारित उपसतही टैक में यह सांद्रता क्रमशः 0.0650, 0.016, 0.0106 मिग्रा/लीटर रह गई। टाइफा आधारित तंत्र में उच्च पोषक अलगाव 70.45, 58.80 तथा 80.39 प्रतिशत नाइट्रेट एवं 42.59, 12.18 एवं 29.56 प्रतिशत फास्फेट सतही एवं उपसतही तंत्र में दर्ज किया गया।
- टमाटर की फसल में प्रदूषित नाले के पानी से सिंचाई कर मृदा के दूषितकरण प्रभाव को देखा गया। परिणामों से पता चला कि ट्यूबवेल के पानी से सिंचाई की तुलना में अनउपचारित पानी से सिंचाई वाले प्लाटस में उच्च सांद्रता डी. टी. पी. ए. उद्धरणीय भारी धातुओं (केडमियम, कापर, मैंगनीज, निकेल तथा सीसा) की थी। मृदा में भारी धातुओं के जमा होने का क्रम $Cu<Pb<Zn<Ni<Cd$ था। टमाटर के फलों में उसके तने तथा जड़ की तुलना में भारी धातुओं की मात्रा कम थी।
- तीन पौध प्रजातियों–वेटिवेरिया जिजिनोइड्स, टाईफा लेटीफोलिया तथा एकोरस केलमस पर प्रेटिलाक्लोर (0,750 एवं 1500 ग्रा./हे.) के विरूद्ध सहिष्णुता देखने हेतु गमला प्रयोग लगाया गया। इस प्रयोग में पाया गया सभी पौध प्रजातियाँ प्रेटिलाक्लोर 750 ग्रा./हे. के लिये सहिष्णु थी। प्रेटिलाक्लोर की उच्च मात्रा वृद्धि (पौधे की लंबाई, टिलर की संख्या, शुष्कभार पत्ती क्षेत्रफल) एकोरस एवं टाइफा की तुलना में वेटीवेरिया में ज्यादा प्रभावित हुई।

खरपतवार प्रबंधन तकनीकों का प्रक्षेत्र शोध एवं प्रदर्शन तथा उनके प्रभाव का मूल्यांकन

- गेहूं में क्लोडिनोफाप + मेटसल्फ्यूरॉन, सल्फोसल्फ्यूरान + मेटसल्फ्यूरान एवं मीजोसल्फ्यूरान + आयोडोसल्फ्यूरान की अनुशंसित मात्राओं के प्रयोग ने व्यापक स्तर पर खरपतवार नियंत्रण तथा 13000 रू./हेक्टेयर का उच्च लाभ साथ 28.3 प्रतिशत उपज वृद्धि हुई।
- जबलपुर क्षेत्र में पहली बार हैप्पी सीडर का उपयोग गेहूं की बुआई के लिये किया गया। फसलों की खूंटी बिना निकाले ही खेतों मे बुआई की गई। जीरो टिलेज सीड ड्रिल से भिन्न हैप्पीसीडर से धान की फसल अवशेष को उपयोग कर खेत को मल्च किया। इससे खरतपवार प्रबंधन में मदद मिली तथा मृदा की स्थिति में सुधार हुआ। परिणामस्वरूप गेहूं की उपज परंपरागत कृषि की तुलना में अधिक पायी गई।
- चनें में प्रक्षेत्र अनुसंधान एवं प्रदर्शन मझौली एवं शहपुरा स्थानों पर किये गये। यहां पेन्डीमेथीलीन के अंकुरण पूर्ण प्रयोग ने उच्च स्तरीय खरपतवार नियंत्रण के साथ 20,000 रू./हे. का लाभ दिया।
- मटर में अनुसंधान एवं प्रदर्शन खुक्कम स्थान पर किया गया। जिसमें देखा गया कि पेन्डीमेथीलीन होइंग की तुलना में ज्यादा प्रभावी था तथा इसने 12000 रू./हे. का लाभ दिया।
- धान में बोआई के 20–25 दिनों बाद बिस्पायरीबैक–सोडियम का 25 ग्रा./हे. की दर से उपयोग किया गया जिसने इकानोक्लोआ कोलोना को प्रभावकारी रूप में नियंत्रित किया। बिस्पायरीबैक–सोडियम के उपयोग के एक सप्ताह पश्चात् 2,4–डी (एमाइन साल्ट) का 500 ग्रा./हे. उपयोग व्यापक खरपतवार नियंत्रण तथा 9320 रूपये/हेक्टेयर का लाभ देने में सक्षम था ।
- कृषि प्रक्षेत्र अनुसंधान में अनुसंधान सह प्रदर्शन में खरपतवार प्रबंधन की तकनीकों और हैप्पीसीडर का परीक्षण ग्रीष्म कालीन मूंग में किया, जिसमें इमेजेथापायर का 100 ग्रा./हे. की दर से प्रयोग किया गया जो काफी प्रभावी था और दानों की उपज 1.4 टी./हे. संरक्षित खेती में देखा गया और इनकी तुलना कृषक प्रथा से की गई (परंपरागत खेती + बिना नींदे) और इससे किसान को अतिरिक्त लाभ 13000 रू./हे. हुआ।
- जागरघास जागरूकता सप्ताह 16–22 अगस्त 2013 में मनाया गया जिसका उद्देश्य लोगों में इससे होने वाली बीमारी और इसके प्रबंधन की जानकारी देना था। यह कार्यक्रम अलग–अलग स्थानों में जबलपुर के बनखेड़ी, पनागर, गोसलपुर, कुण्डम एवं शहपुरा आदि स्थानों पर किया गया, जो किसानों, शिक्षकों, स्कूली बच्चों, एन.जी.ओ., कृषि विज्ञान केन्द्र एवं जबलपुर मीडिया के सहयोग से संपन्न हुआ।
- खरपतवार विज्ञान अनुसंधान निदेशालय द्वारा ग्रहित स्थानों पर सन् 2012–13 में सामाजिक आर्थिक अध्ययन किया गया जिससे ज्ञात हुआ कि किसानों ने धान–गेहूं फसल चक्रण को ग्रहण किया धान में खरपतवार नियंत्रण के लिए अधिक श्रमिक लगते हैं जो कि समय पर उपलब्ध नहीं होते तथा यह एक महंगी प्रक्रिया है। रासायनिक खरपतवार नियंत्रण की लागत मात्र 1500–2000 रू./हे. है जबकि परंपरागत तरीकों (हाथ की निदाई) की लागत 4000–5000 रू./हे. होती है।
- सन् 2011–13 के दौरान निदेशालय ने मध्यप्रदेश, छत्तीसगढ़ एवं उड़ीसा के 87 कृषि विज्ञान केन्द्रों द्वारा खरपतवार प्रबंधन की उन्नत तकनीकों का समावेश करने हेतु जोनल प्रोजेक्ट डायरेक्टोरेट (जोन VII) तथा कृषि विज्ञान केन्द्रों के साथ सहभागिता की। गेहूं, टमाटर, सोयाबीन, धान और मूंगफली में 1500 आ. एफ. टी./एफ. एल. डी. द्वारा 20 उन्नत खरपतवार प्रबंधन तकनीकों का प्रदर्शन किया गया, पाया गया कि खरपतवार तीव्रता घटने के साथ ही उत्पादकता (18.2 प्रतिशत) बढ़ी एवं उत्पादन की लागत में कमी आई।
- पनागर में 26 मार्च 2014 को प्रक्षेत्र दिवस–सह–संगोष्ठी का आयोजन किया गया।
- निदेशालय ने ज्ञान प्रबंधन सेवा (के. एम. एस.) एस. एम. एस. द्वारा प्रारंभ की गई, जिसके द्वारा देश के किसानों को खरपतवार प्रबंधन तकनीकों के बारे में जानकारी दी जाती है।
- खरपतवार नियंत्रण परीक्षण पर डाटा एंट्री, सूचना संग्रहण एवं डाटा विश्लेषण के लिए एक वेब आधारित सूचना तंत्र ए. आई. सी. आर. पी. के लिए विकसित किया गया है। यह वेब आधारित साफ्टवेयर उपयोगकर्ता के प्रमाणीकरण पर आधारित है। चार स्तरीय प्रमाणीकरण जैसे कि इन्ड यूजर, उप प्रशासक, प्रशासक और श्रेष्ठ प्रशासक विकसित किया गया। ए. आई. सी. आर. पी.– डब्ल्यू. सी. परीक्षणों के डाटा के विश्लेषण हेतु सांख्यिकीय मापक तैयार किया जा रहा है।
- आई. एम. डी. पूने से अलग–अलग क्षेत्रों के लिये मौसम संबंधित डाटा (वर्षा, अपेक्षित आर्द्रता, न्यूनतम व अधिकतम तापमान) एकत्रित किये गये। इन डाटा के प्रयोग मैक्सिकन बीटल्स (गाजरघास के जैवनियंत्रकों) के स्थापन्न की भविष्यवाणी के लिये माडल तैयार करने के लिये किया जा रहा है।

EXECUTIVE SUMMARY

Directorate launched five major programmes in 2012-13 to achieve its targets in research and transfer of technology. Research programmes include development of sustainable weed management practices in diversified cropping systems, weed dynamics and management under the regime of climate change and herbicide resistance, biology and management of problematic weeds in cropped and non-cropped areas, monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment, and on-farm research and demonstration of weed management technologies and impact assessment. Besides, Directorate also carried location-specific research trials on weed management in different cropping systems through its network programme. Continuous efforts are being made by the Directorate to create awareness about *Parthenium* and to popularize its bio-control by Mexican beetle (*Zygogramma bicolorata*) throughout the country involving AICRP centres in different SAUs and consultancy services. Effective linkages and collaboration were developed with ICAR institutes and SAUs, KVKs and NGOs to solve area-specific weed problems. Various awareness campaigns i.e. training, farmers' day/kisan sangoshthi, agriculture education day and industry day were organized to educate farmers and other stakeholders. Directorate has accomplished its targets in research and transfer of technology during 2013-14.

Salient research achievements under different research programmes are summarized below:

Development of sustainable weed management practices in diversified cropping systems

- In rice-wheat-green gram sequence under conservation agriculture system, crop (rice) establishment techniques significantly influenced the emergence of different weed flora (except *Echinochloa colona* and *Dinebra retroflexa*). Lowest total weed density was recorded with ZT (DSR) + *Sesbania* without residue retention which was at par with CT (TPR). Continuous use of bispyribac-sodium + pre-sowing non-selective herbicides in ZT recorded lowest weed population and weed dry matter and higher grain and straw yield of rice compared to weedy check. No residue of bispyribac-sodium, fenoxaprop and 2,4-D was detected. The wheat grown after DSR with crop residue produced higher grain yield in both CT and ZT as compared to crop grown without crop residue recycling. Amongst weed control treatments, application of recommended herbicides with and without manual weeding produced significantly higher grain yield over weedy check. Crop residue recycling increased soil respiration rate irrespective of tillage systems and weed control measures.
- In maize-wheat-green gram sequence under conservation agriculture system, higher grain yield was recorded under ZT than that recorded in CT. Application of atrazine + pendimethalin (0.5 + 0.5 kg/ha) PE *fb* 1 HW at 25 DAS recorded significantly higher yield than atrazine + pendimethalin (0.5 + 0.5 kg/ha) PE *fb* 2,4-D (0.5 kg/ha) and unweeded control.
- After fourth cycle of continuous use of herbicides, application of bispyribac-sodium @ 25 g/ha in rice significantly reduced the population of *Echinochloa colona*, *Cyperus iria* and *Commelina communis* in rice by more than 95% over weedy check. Amongst herbicides, applications of bispyribac-sodium significantly reduced the weed density (89%) and weed biomass (82%) over cyhalofop-butyl.
- Application of clodinafop @ 60 g/ha *fb* 2, 4-D @500 g/ha in wheat caused significant reduction in *Avena sterilis, Phalaris minor, Chenopodium album* and *Cichorium intybus*, whereas the lowest populations of *Medicago denticulata* was recorded with sulfosulfuron. Application of isoproturon failed to check growth of *Avena sterilis* and *Phalaris minor* over rest of the herbicides, but was very effective against *Cichorium intybus* and *Chenopodium album*.
- Continuous use of herbicides influenced weed seed bank, weed dynamics and crop productivity in DSR-chickpea cropping system. Pendimethalin being at par with oxyfluorfen caused significant reduction in density and dry matter production of all weed species. Application of oxyfluorfen and pendimethalin resulted in higher pods/plant (46%) and seed yield (80%) of chickpea over weedy check.

- In rice-wheat system, application of FYM @ 10 t/ha + 2 HW at 25 and 45 DAS recorded the lowest weed density and weed dry biomass. However, wheat grain yield was significantly higher under NPK + herbicide. In soybean–wheat system, the lowest weed population was recorded under 50% NPK + 50% FYM and herbicide + 1 HW. Wheat grain yield was significantly higher under NPK + herbicide.
- In okra-tomato system, the highest tomato yield was recorded under FYM with black polythene mulch. In mango orchard, growing sesbania and sunhemp in the inter spaces of mango trees could reduce the weed density at 60 DAS by 94.6 and 94.3 %, respectively.
- In rice, higher panicle length, 1000-seed weight and yield was recorded under SRI as compared to other crop establishment practices. Among weed management practices, highest grain yield was recorded with 2 HW which was at par with bispyribac-sodium + 1 HW.
- Pre-emergence application of pendimethalin @ 1000 g/ha *fb* post-emergence application of either quizalofop-p-ethyl @ 60 g/ha or imazethapyr @ 100 g/ha at 25 DAS produced higher yield of greengram.
- Glyphosate applied at lower doses (40, 50 and 60 g/ha) at 25 and 35 DAS was selective against mustard plant, and did not have any detrimental effect on growth and yield of this crop.

Weed dynamics and management under the regime of climate change and herbicide resistance

- In general, exposure to elevated CO_2 brought about 10 days advancement of reproductive stage in chickpea as well as weed species (*Lathyrus sativus* and *Medicago denticulata*). Enrichment of atmospheric CO_2 had a positive effect on overall growth and photosynthesis concomitant with decrease both in stomatal conductance and transpiration rates in all the three species studied.
- Elevated CO_2 also resulted in higher activity of carbonic anhydrase in all the three species and may be a contributing factor to the observed higher rates of photosynthesis. Similarly, activity of nitrate reductase increased in all the three species under elevated CO_2.
- Isoenzyme activity profile of antioxidant enzymes (superoxide dismutaseguaiacol peroxidase and glutathione reductase) depicted differential regulation as well as induction of new iso-forms in response to elevated CO_2; especially *Lathyrus* exhibited stronger antioxidant defence as compared to chickpea pointing towards an involvement of antioxidant defence system in adaptation to changing climate.
- Biotypes of *Phalaris minor* from Pantnagar, Faizabad, IARI, New Delhi and Jabalpur showed no or very low degree of resistance against isoproturon. Biotypes from Punjab showed medium (Talwandi) to high (Rajpura and Barnala) resistance while biotypes from Haryana (Pipli, Panipat and Narwana) showed very high resistance against isoproturon. Biotypes from Haryana and Punjab also showed resistance (low to medium degree) against pinoxaden, mesosulfuron + iodosulfuron and sulfosulfuron + metsulfuron in addition to isoproturon.
- Some of the plants of *Convolvus arvensis*, *Melilotus alba*, *Cichorium intybus*, *Solanum surattense*, *Lathyrus sativa*, *Medicago denticulata*, *Solanum viarum*, *Chenopodium album*, *Lathyrus aphaca* and *Euphorbia geniculata* showed tolerance to 2, 4-D at 750 g/ha (x), 2x and 3x levels. Some plants of *Echinochloa* sp. also showed tolerance to bispyribac-sodium at 25 g/ha (x), 2x and 4x levels.
- Images of different weeds at different stages (i.e. seeds, imbibed seeds, and reproductive parts) have been taken for developing weed identification software and weed atlas. Information on 16 weeds has been compiled for the weed atlas.
- Rice SSR markers were screened for polymorphism amongst four *Echinochloa* species/subspecies may be useful for identifying the species at molecular level.
- Viability of weed seeds, referred to as weed spread risk potential, was 6-10 years in 13 species and 11-13 years in 4 species.
- Parthenin-like constituent isolated from *Parthenium* leaf allelochemical crude inhibited pondweed *(Potamogeton crispus)* at 10 ppm and killed at and above 15 ppm under outdoor conditions. Herbicidal activity of the parthenin-

like constituent on the pondweed was more prominent at 35°C proving lethal as compared to showing toxicity but not proving lethal at 20 and 27°C under laboratory conditions (at about 200 $\mu E\, cm^{2} s^{-1}$ PPFD).

Biology and management of problematic weeds in cropped and non-cropped areas

- Weedy rice accessions collected from different parts of country have immense diversity in their phenological parameters, photosynthesis and other gas exchange parameters, and iso-enzyme pattern of guaiacol peroxidase.
- Clustering of all weedy rice accessions based on morpho-physiological and phenological data revealed that weedy rice accessions can group with cultivated as well as wild rice, however, few accessions also behaved independently. Dendrogram generated by molecular fingerprinting of weedy rice from M.P. also revealed similarity to both cultivated as well as wild rice.
- Significant variation in germination amongst weedy rice accessions was noticed, even amongst those from the same state. Accessions from Jharkhand, Bihar, Kerala, M.P. and Chhattisgarh showed low degree of dormancy. Weedy rice accessions from Chhattisgarh, Bihar, M.P. and U.P. had relatively higher potential of emergence from depth (10 cm).
- Weedy rice had ability to germinate under anaerobic conditions. Accessions from Jharkhand, U.P., Bihar and M.P. had higher potential to emerge from 10 cm standing water than other accessions.
- Survey conducted during *Rabi* 2013 at Khinni village revealed that fungus (identified as *Sclerotium rolsfii* based on morphological characters) had prefered *Orobanche* over tomato.
- In the experiment under controlled conditions, stalks of *Orobanche crenata* were sprayed with spore suspension of different bioagents viz., *Trichoderma viride, Gliocladium virens, Fusarium* sp. DWSR1, *Fusarium* sp. DWSR 2 and *Sclerotium rolsfii*. Results indicated that only *S. rolsfii* caused infection on *O. crenata* with symptoms like upwards progressive wet rotting, but no symptom was observed in the associated tomato plants. This showed that the particular isolate of *S. rolsfii* had preference to *O. crenata*.
- An insect *Phytomyza orobanchia* Kal. was collected from *Orobanche crenata* stalks from a brinjal field with chili (*Capsicum annuum*) as inter crop in the Billua village (26^{0}02'59,32" N; 78^{0}17'00.03"E) of Gwalior district in Madhya Pradesh. Closer observation of the stalks of *Orobanche crenata* revealed bore holes and extensive tunnels with tiny brown pupae and small white maggots, feeding on the capsules, succulent stalk and tubercles.
- Microbial metabolites of *Fusarium* sp. DWSR1 were found to suppress germination of *Orobanche*. Metalaxyl and glyphosate delayed development and emergence of *Orobanche*.
- Metsulfuron-methyl @ 6 g/ha was found effective to control *Pistia stratiotes*. Application of the herbicide on water surface did not affect water quality, but when applied on *Pistia*, dissolved oxygen (DO) was reduced, coinciding with decomposition of the weed. *Pistia* covering entire water body was found to reduce DO significantly.

Monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment

- Initially 95, 297 and 576 ng/g residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor were found in paddy soil which dissipated to 8.8, 17.6 and 37.5 ng/g at 30 days. Half-lives of pyrazosulfuron-ethyl, penoxsulam and pretilachlor in soil of rice field ware found 9.84, 7.8 and 10.4 days.
- At 10 days, 31.4, 37.0 and 11.3 ng/ml residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor were found in pond water. Residues of pyrazosulfuron-ethyl were below 1.0 ng/ml after 60 days. However, 5.4 ng/ml pretilachlor residues were detected at 60 days which were found below 1.0 ng/ml after 60 days in pond water.
- Pyrazosulfuron residues in rice green plants at 10 to 30 days were 238.4 to 11.7 ng/g, respectively. Whereas, pretilachlor residues were 1125 to 825 ng/g in green plants at 10 to 30 days, respectively.
- At 60 days, pyrazosulfuron-ethyl, penoxsulam and pretilachlor residues in fishes were <1.0, 1.7 and 1.0 ng/g, respectively, which had reduced to below the detection limit (<1.0 ng/g) at 100 days, respectively.

- Degradation products of pyrazosulfuron-ethyl were detected from soil and pond water and identified by LC/MS/MS as ethyl-5-[(4, 6-dimethoxypyrimidin-2-ylcarbamoyl) sulfamoyl]-1-methylpyrazole-4-carboxylic acid; ethyl 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylate and 4, 6-dimethoxypyrimidin-2-amine, 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylic acid.
- Degradation products of pretilachlor were detect from soil and pond water and identified as 2',6'-diethyl-N-(propoxyethyl)acetanilide; 2',6'-diethyl-N-(propoxyethyl)aniline; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'(diethyl)-N-(ethyl)aniline; 2-chloro-2'-)1–hydroxyethyl, 6'ethyl)-N-(2-propoxyethyl acetanilide; acetanilide and 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone.
- Three degradation products of penoxsulam in field soil were identified as 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine, 5,8 dicarboxylic acid; 2-(2,2-difluoroethoxy) -6 (trifluromethyl) benzenesulfonamide and 3-[[[2-(2,2-difluoroethoxy)-N-[1,2,4] triazole [1,5c]-6-triflurομethyl) benzene sulfonamide carboxylate.
- Seven major degradation products of pretilachlor in field soil were identified as 2',6'-diethyl-N-(propoxyethyl)acetanilide; 2',6'-diethyl-N-(propoxyethyl)aniline; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'-diethyl-N-(ethyl)aniline; acetanilide; 2-chloro-2',)1 –hydroxyethyl, 6'ethyl)-*N*-(2-propoxyethyl acetanilide; and 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone.
- Seven degraded products were isolated and identified from the photodegradation of bispyribac-sodium in the environment.
- Seven orthosulfamuron-degrading fungus were isolated and identified from the rice soil and the degradation pathways for orthosulfamuron were proposed.
- No residue of bispyribac-sodium, 2,4-D and fenoxaprop was detected in the rice grain and straw samples obtained from the experiments on the long-term impact of herbicides under conservation agriculture. Four metabolites of atrazine were identified from the soil of maize crop.
- Polluted water from industrial drain was subjected to treatment in phytoremediation system using terrestrial weed species for removal of heavy metals. The concentration of iron, copper and cadmium in drain water was 0.3282, 0.0363 and 0.0126 mg/L, respectively. After treatment, concentration of iron, copper and cadmium was reduced to 0.1548, 0.0286, 0.0093 mg/L in hydroponic tanks, 0.0356, 0.0276, 0.0106 mg/L in surface tank and 0.0650, 0.016, 0.0106 mg/L in sub-surface tanks of *Typha*-based system, respectively. Higher nutrient removal to the extent of 70.5, 58.8 and 80.4% of nitrate and 42.6, 12.2 and 29.6% of phosphate under hydroponic, surface and subsurface system was recorded in *Typha*-based system**.**
- Effect of polluted drain water on soil contamination was assessed after irrigation of tomato crop with it. Results indicated higher concentration of DTPA extractable heavy metals (cadmium, copper, manganese, nickel and lead) in plots irrigated with untreated drain water as compared to tube well water. The sequence of heavy metal accumulation in soil was Cu > Pb >Zn >Ni >Cd. Lower concentration of heavy metals were retained in fruits of tomato than its shoot and root part.
- Pot experiment conducted to evaluate the tolerance of the three plant species viz *Vetiveria zizinoides, Typha latifolia,* and *Acorus calamus* towards pretilachlor (0, 750 and 1500 g/ha) revealed that all the plant species tolerated pretilachlor at 750 g/ha. At higher dose, pretilachlor affected growth (plant height, number of tillers, dry weight and leaf area) more in *Acorus* and *Typha* than *Vetiveria*.

On-farm research and demonstration of weed management technologies, and impact assessment

- In wheat, application of clodinafop + metsulfuron, sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron at recommended doses gave broad-spectrum weed control and higher benefit of Rs. 13000 per ha with an increase in the yield by 28-33% over farmers' practice.

- Happy seeder was used for sowing of wheat for the first time at farmers' field in Jabalpur region. Sowing was done without removing or burning the standing crop stubbles. Unlike ZT seed drill, happy seeder utilized the rice crop residue to mulch the field, hence, also helped in managing weed menace and improved soil condition and higher grain yield of wheat as compared to conventional agriculture.
- In chickpea, on-farm research and demonstrations conducted in Majhouli and Shahpura localities revealed that pre-emergence application of pendemethalin gave higher weed control efficiency with additional benefit of Rs. 20000 per ha.
- In field pea, demonstrations carried out in Khukham locality revealed that pendimethalin was more effective than hoeing and gave the maximum benefit of Rs. 12000 per ha.
- In rice, application of bispyribac-sodium @ 25 g/ha at 20-25 DAS effectively controlled *Echinochloa colona*. Application of 2,4-D (amine salt) @ 500 g/ha one week after bisbyribac-sodium application resulted in broad-spectrum weed control and higher economic benefit of Rs.9520/ha over farmers' practice.
- On-farm research-cum-demonstration trials on weed management technology with happy seeder in summer green gram revealed that imazethapyr @ 100 g/ha was effective and gave a seed yield of 1.4 t/ha under conservation agriculture as compared to 1.0 t/ha under farmers' practice (conventional tillage + no weeding), and provided an additional net return of Rs. 13000 per ha.
- *Parthenium* Awareness Week was organized from 16-22 August, 2013 with an objective to create public awareness about its ill effects and management. The programme was arranged in different localities of Jabalpur like Bankhedi, Panagar, Gosalpur, Kundam, Shahpura and Gosalpur etc. involving farmers, residents, school children, teachers, NGOs, KVKs and media of Jabalpur.
- Socio-economic studies conducted in DWSR adopted localities during 2012-13 revealed that most of the farmers adopted the rice-wheat cropping pattern. For weed control in rice involves more labourers, which is mostly not available at the time of need and is also capital intensive. The cost of chemical weed management is only Rs. 1500-2000/ha, while the conventional practice (manual weeding) requires around Rs. 4000-5000/ ha.
- DWSR collaborated with KVKs of Zonal Project Directorate (Zone VII) to introduce and demonstrate the improved weed management technologies for different cropping systems through 87 KVKs across Madhya Pradesh, Chhattisgarh and Orissa during 2011-13. Demonstrations on 20 improved weed management technologies through 1500 OFTs/ FLDs in wheat, soybean, tomato, paddy and groundnut crops were conducted. It has been recorded that weed intensity decreased with increase in productivity (18-27%) and decrease in cost of production.
- The Directorate organized field day-cum-sanghosthi on 26/3/2014 at Panager locality. An interface meeting of progressive farmers, officers of state departments and scientists was organized at DWSR on 29/4/2014.
- DWSR has initiated Knowledge Management Service through SMS for disseminating weed management technologies to farmers of the country.
- A web based information system is developed for AICRP on Weed Control trials for data entry, information retrieval and analysis of the data. This web-based software needs user authentication. Four levels of authentications, viz end-user, sub administrator, administrator and super administrator have been developed. Statistical module is being prepared for the analysis of data of AICRP-WC trials.
- Data have been collected from Indian Meteorological Department, Pune on weather parameters like rainfall, relative humidity (RH), and minimum and maximum temperature of different regions. Different indices of weather parameters are being prepared to make their use in model development for prediction of successful establishment of Mexican beetle.

1 INTRODUCTION

Considering the growing infestation of weeds and their management in cropped and non-cropped lands, the Indian Council of Agricultural Research decided to establish the National Research Centre for Weed Science, which came into existence on 22nd April, 1989 with the joining of its first Director, Dr V.M. Bhan. This centre was upgraded as Directorate of Weed Science Research on 23rd January, 2009. This is a unique institute in the National Agricultural Research System, which is probably the only one of its kind in the whole world dealing exclusively with weed science research. Besides, training, coordination, consultancy and collaborative programmes on weed management are also undertaken with various stakeholders.

Jabalpur is an ancient city of Madhya Pradesh, situated at the center of India in the Mahakoshal region and surrounded by a spectacular variety of nature including holy river Narmada, marble rocks of Bhedaghat and waterfall called "Dhuandhar". Jabalpur falls under the agroclimatic region of Kymore plateau and Satpura hills zone. The climate of the region is sub-tropical, with average rainfall of ~ 1400 mm. The soil are mostly black and crops grown are rice, soybean, sugarcane, pigeonpea and balckgram during rainy season, and wheat, chickpea, lentil, pea and mustard in winter season. The Directorate is located on the national highway (NH-7) at 23.13°N latitude, 79.58°E longitude and altitude of 412 m above mean sea level. It is well connected by railways (11 km from Jabalpur railway station) and airways (28 km from Dumna airport).

DWSR Campus, Jabalpur

Over the last 25 years, the institute has played an apppreciable role in conducting weed survey and surveillance, development of weed management technologies for diversified cropping systems, herbicide resistance in weeds, biology and management of problem weeds in cropped and non-cropped areas, and environmental impact of herbicides. Adoption of these technologies has been promoted on large areas through on-farm research and demonstrations, which have raised agricultural productivity and livelihood security of the farmers. Continuous efforts are being made to address core issues relating to management of weeds in rainfed and dryland ecosystems, threats posed by alien invasive weeds, parasitic weeds, aquatic weeds, weed dynamics due to climate change and herbicide resistance and monitoring of impact of herbicides on environment. Keeping in view the challenges ahead, the Directorate has adopted diversified conservation agriculture system for improved and sustainable weed management for facilitating better crop production.

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, strategic and applied research for developing efficient weed management strategies in different agro-ecological zones
- To provide leadership at country level in weed science and coordinate the network research with state agricultural universities for generating location-specific technologies for weed management in different crops, and 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 is under the administrative control of the Director, and receives guidance from Quinquennial Review Team (QRT), Research Advisory Committee (RAC), Institute Management Committee (IMC), and Institute Research Council (IRC) for research, teaching / training and extension activities. There are 5 major research sections, 22 centres of AICRP on Weed Control, 4 administrative sections, and about one dozen other units and cells to support the administration and smooth coordination.

Laboratories

The Directorate has well-equipped laboratories with modern and sophisticated scientific instruments like LC-MS/MS system, GC, HPLC, IRGA, lyophilizer, thermal cycler, gel documentation unit, AAS, 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, and spectroradiometer etc. It has containment facility and two controlled environment chambers to facilitate research under controlled environment conditions. Free Air CO_2 Enrichment (FACE) facility and four open top chambers are available to study possible impact of futuristic climate change on crop-weed interactions. In addition to ten dedicated laboratories, one central laboratory is also in place housing all common equipments like ice maker machine, leaf area meter, root scanner, and spectrophotometers etc. The Directorate has a well-developed agricultural engineering workshop with facilities for fabrication, designing and development of weed control tools and implements.


LC-MS/MS System


Lyophilizer


Thermocycler

AKMU, Library and Information centre

Agriculture Knowledge Management Unit (AKMU) is well equipped with computers, LAN facilities, color xerox-cum-printer and plotter, and specialized software like ARCInfo for GIS analysis, and ERDAS Imagine for satellite imaze analysis. All the scientists have been provided with internet connection. Library has a total collection of 5059 books pertaining to weed science, 60 Indian and 20 foreign-journals in its subscription, membership of Consortium for e-Resources in Agriculture (CeRA) under NAIP (ICAR), modern facilities such as CAB-PEST and CAB-SAC CD-ROMs and Current Contents on Diskette (CCOD) on biological sciences, software for library automation and information retrieval. Reprographic and documentation facilities have also been created for the preparation of documents and reports. One information centre has been developed to display the latest information on weed science and management technologies.


Agriculture Knowledge Management Unit


Library


Information Centre

Networking and Collaboration

Directorate implements its 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 in addition, 8 volunteer centres in other agricultural universities participating in the network programme. Currently, six network programmes (viz. weed surveillance, weed biology and physiology, weed management in crops and cropping systems, management of problematic / invasive / parasitic / aquatic weeds, herbicide residues and environmental quality, and transfer of Technology) are in operation. The Directorate also collaborates with local educational and research institutions, viz., Jawaharlal Nehru Krishi Vishva Vidyalaya, Jabalpur, Rani Durgawati Vishva Vidyalaya, Jabalpur and other colleges from different universities for M.Sc./Ph.D. research work. Active collaboration has been developed with several ICAR Institutes and other research organizations, herbicide industries, NGOs and KVKs. In addition, the Directorate has initiated a significant step towards more effective collaboration with ICAR institutes and state agricultural universities, and nominated five nodal scientists to look after this and to avoid duplication of research in weed management. In addition, two adhoc projects are also in operation in collaboration with universities and institutes like IARI. The scientists of DWSR delivered several lectures in training programmes organized at different institutes / universities. Besides, several lectures by distinguished speakers have been organized during the year.

Farm/ Research / Other facilities

The Directorate possesses 61.5 ha well laid out laser-leveled fully-irrigated experimental farm well connected with approach roads and drainage systems. Farm is equipped with modern farm machineries like high power tractors, small tractor, power-weeders, tractor-driven sprayers, laser land-leveler, happy seeder, no-till seed drill, multi-crop seed drill, multi-crop threshers, tube wells, underground irrigation pipelines and sprinkler system. In addition, Directorate also has containment facility, net houses, lysimeters, phytoremediation unit, set-up to evaluate management practices for aquatic weeds, runoff tank for studies on herbicide toxicity to non-target organisms, biomass composting unit, weed cafeteria for *in situ* demonstration and conservation of weed germplasm, and newly developed technology park.


Containment facility


Weed cafetaria and germplasm conservation unit


Technology park

Staff position (as on 31.3.2014)

Particulars	Sanctioned	Filled	Vacant
Research management position	1	1	-
Scientist	27	17	10
Technical	23	21	02
Administrative	13	08	05
Supporting	22	21	01

Discipline wise staff position (as on 31.3.2014)

Disciplines	Sanctioned			In Position			Vacant		
	PS	SS	S	PS	SS	S	PS	SS	S
Agricultural Biotechnology	-	1	1	-	1	-	-	-	1
Agricultural Chemicals	1	1	1	-	1	1	1	-	-
Agricultural Economics	-	-	1	-	-	-	-	-	1
Agricultural Entomology	-	1	-	-	1	-	-	-	-
Agricultural Extension	-	1	1	-	1	-	-	-	1
Agricultural Microbiology	-	-	1	-	-	1	-	-	-
Agricultural Statistics	-	-	1	-	-	1	-	-	-
Agronomy	2	1	3	2	1	1	-	-	2
Economic Botany & Plant Genetic Resources	-	1	1	-	-	-	-	1	1
Farm Machinery and Power	-	-	2	-	-	1	-	-	1
Plant Pathology	-	1	-	-	1	-	-	-	-
Plant Physiology	1	1	-	1	1	-	-	-	-
Soil Science	-	1	1	-	1	1	-	-	-
Plant Biochemistry	-	-	1	-	-	-			1
Total	**4**	**9**	**14**	**3**	**8**	**6**	**1**	**1**	**8**

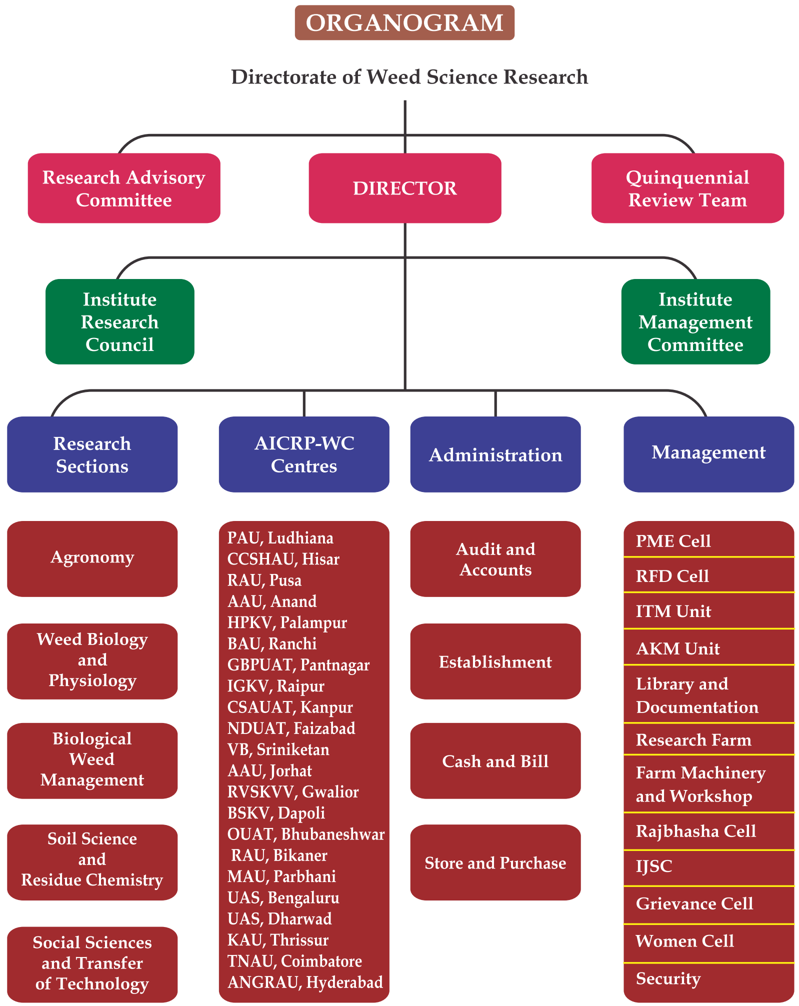
PS – Principal Scientist, SS – Senior Scientist, S – Scientist

Budget during 2013-14 (₹ in lakhs)

Particulars	Plan		Non-Plan		Network project	
	Receipt	Expenditure	Receipt	Expenditure	Receipt	Expenditure
(A) Recurring						
Establishment expenses	0	0	493.00	492.98	640.00	624.38
Pension	0	0	13.25	13.24	0	0
P-Loan & advances	0	0	0	0	0	0
Travelling allowances	5.00	4.99	1.39	1.34	0	0
HRD/IT	5.00	4.97	0	0	0	0
Research and operational expenses	99.00	95.75	122.61	122.18	173.00	188.20
Miscellaneous expenses	1.00	3.97	8.00	7.88	0	0
Tribal Sub-Plan	0	0	0	0	0	0
Total (A)	110.00	**109.68**	**638.25**	**637.62**	**813.00**	**812.58**
(B) *Non-recurring*						
Equipment	20.00	22.82	2.00	1.67	0	
Works	0	0	0	0	2.00	2.00
Library	5	2.50	0	0	0	0
Land	0	0	0	0	0	0
Vehicle	0	0	0	0	0	0
Livestock	0	0	0	0	0	0
Others	5.00	2.29	0	0	0	0
Total(B)	**30.00**	**27.61**	**2.00**	**1.67**	**2.00**	**2.00**
Grand total (A+B)	**140.00**	**137.29**	**640.25**	**639.29**	**815.00**	**814.58**

Resource generation (₹ in lakhs)

Particulars	Amount
Contract research	6.67
Consultancy services	10.50
Sale of farm produce	34.25
Others (auction, guest house, use of transport, tender paper, RTI, interests, license fee, water charges, dissertation fees, etc.)	4.97
Total	**56.39**



2 RESEARCH PROGRAMME - 1

DEVELOPMENT OF SUSTAINABLE WEED MANAGEMENT PRACTICES IN DIVERSIFIED CROPPING SYSTEMS

Despite development of effective weed management practices over the years, weed problems have increased with high-input agriculture and growing of high-yielding dwarf varieties. These necessitate continuous monitoring and upscaling of weed management strategies on a long-term basis. Conservation agriculture is being talked of as a new paradigm in resource management research but weeds are a serious problem in such a system. Diversification and continuous cropping have largely changed the weed communities and, in some cases, these become resistant to commonly used herbicides. Therefore, use of the herbicides has to be investigated in a system perspective. Weed population density and biomass production may be markedly reduced using crop rotation (temporal diversification) and intercropping (spatial diversification) strategies. Weed management practices strongly influence use efficiency of other production factors like water, nutrients etc. Further, herbicide use efficiency is also influenced by adjuvants as well as other pesticides. In recent years, several low dose high potency herbicide molecules have become available, for which, spraying machines and techniques need to be standardized. Hence, this research programme has been initiated since 2012 to address these issues and develop sustainable weed management practices in diversified cropping systems.

Sub-programmes	Experiments	Associates
1.1. Weed management under long term conservation agriculture systems	1.1.1. Long-term impact of herbicides in rice-wheat-green gram sequence under conservation agriculture systems	V.P. Singh, K.K. Barman, Raghwendra Singh, Dibakar Ghosh, P.P. Choudhury, C. Sarathambal, Yogita Gharde and A.R. Sharma
	1.1.2. Long-term impact of weed control measures in DSR-based cropping systems under conservation agriculture	V.P. Singh, K.K. Barman, Raghwendra Singh, Dibakar Ghosh, P.P. Choudhury, C. Sarathambal, Yogita Gharde and A.R. Sharma
	1.1.3. Influence of continuous use of herbicides on weed seed bank, weed dynamics and crop productivity in DSR rice-wheat cropping system	V.P. Singh, K.K. Barman and Shobha Sondhia
	1.1.4. Influence of continuous use of herbicides on weed seed bank, weed dynamics and crop productivity in DSR rice-chickpea cropping system	V.P. Singh, K.K. Barman and Shobha Sondhia
	1.1.5. Long-term impact of herbicides in soybean-wheat-greengram sequence under conservation agriculture systems	V.P. Singh, K.K. Barman, Raghwendra Singh, Dibakar Ghosh, P.P. Choudhury, C. Sarathambal, Yogita Gharde and A.R. Sharma
	1.1.6. Long-term impact of weed control measures in maize-wheat cropping systems under conservation agriculture	R.P. Dubey, K.K. Barman, C. Sarathambal and P.P. Choudhury

Sub-programmes	Experiments	Associates
	1.1.7. Long-term impact of weed control measures in maize-chickpea cropping systems under conservation agriculture	Dibakar Ghosh, V.P. Singh, Raghwendra Singh, P.P. Choudhury, C. Sarathambal and K.K. Barman
	1.1.8. Long-term impact of weed control measures in cotton-wheat cropping systems under conservation agriculture	Raghwendra Singh, Dibakar Ghosh,V.P. Singh, P. P. Choudhury K. K. Barman and C. Sarathambal
1.2. System-based approach to weed management	1.2.1. Effect of organic weed management practices on weeds and crop productivity in rice-wheat cropping system	R.P. Dubey, K.K. Barman and P.P. Choudhury
	1.2.2. Effect of organic weed management practices on weeds and crop productivity in soybean-wheat cropping system	R.P. Dubey, K.K. Barman and P.P. Choudhury
	1.2.3. Effect of organic weed management practices on weeds and crop productivity in okra-tomato cropping system	R.P. Dubey, K.K. Barman and P.P. Choudhury
	1.2.4. Effect of crop establishment techniques and weed management practices on growth and yield of rice under rice - wheat cropping system	Raghwendra Singh, V P Singh, Dibakar Ghosh and K K Barman.
	1.2.5. Long-term effect of weed management practices on weed dynamics and crop productivity in soybean-wheat cropping system	R.P. Dubey, K.K. Barman, P.P. Choudhury and C. Sarathambal
	1.2.6. Cropping systems approach for weed management in mango orchard	R.P. Dubey, K.K. Barman, P.P. Choudhury and C. Sarathambal
1.3. Improving input use efficiency through efficient weed management	1.3.1. Weed management studies in soybean	Dibakar Ghosh, V.P. Singh, Raghwendra Singh, P.P. Choudhury and K.K. Barman
	1.3.2. Screening of different mustard varieties against glyphosate	Dibakar Ghosh, V.P. Singh, Raghwendra Singh and P.P. Choudhury
	1.3.3. Evaluation of nitrogen fertilizer and weed management practices in zero-till transplanted rice	Dibakar Ghosh, Raghwendra Singh, K.K. Barman and A.R. Sharma
	1.3.4. Integrated weed management in summer greengram	Dibakar Ghosh, V.P. Singh, Raghwendra Singh and A.R. Sharma
	1.3.5. Effect of post-emergence herbicides on purple nut sedge in summer greengram	Dibakar Ghosh, V.P. Singh, Raghwendra Singh and A.R. Sharma
	1.3.6. Effect of weed management practices in sesame	Raghwendra Singh, Dibakar Ghosh, C. Sarathambal and A.R. Sharma
	1.3.7. Deciding optimum dose of herbicides in mixture using dose response curve	Yogita Gharde and Dibakar Ghosh
1.4. Standardization of spraying techniques and mechanical tools for weed management	1.4.1. Evaluation of spray application techniques for weed management in crops	H.S. Bisen , V.P. Singh and Dibakar Ghosh

1.1. Weed management under longterm conservation agriculture systems

1.1.1. Weed management in rice-wheat-greengram cropping system under conservation agriculture

Weeds are major constraints in conservation agriculture. The composition of weed species and their relative time of emergence differ between conservation agriculture system (CAs) and soil inverting conventional tillage system (CTs). Keeping in view of these facts, a long-term experiment on the effect of crop establishment techniques and weed control measures under conservation agriculture system has been initiated from 2012 to monitor weed dynamics, crop productivity, herbicide residues, and to study C-sequestration, changes in physico-chemical and biological properties of soil health under rice-based and non-rice-based cropping systems. Total eight treatments consisting of five establishment methods, viz. (i) CT(DSR)+S-CT(Wheat)-ZT(greengram), (ii) CT(DSR)+S+R-CT(wheat)+R-ZT(greengram)+R, (iii) ZR(DSR)+S-ZT(wheat)-ZT(greengram), (iv) ZT(DSR)+S+R-ZT(wheat)+R-ZT(greengram)+R, (v) CT(TPR)-CT(wheat) and three weed control measures viz., continuous use of bispyribac-sodium+pre-sowing non-selective herbicides in ZT, rotational use of herbicides + pre-sowing non selective herbicides in ZT, and unweeded (control) as sub plots were laid out in split plot design with three replications.

Rice

Dominant weed flora in rice were: *Echinochloa colona, Cyperus iria, Physalis minima, Ceasulia axillaris* and *Dinebra retroflexa*. Different crop establishment techniques significantly influenced the emergence of different weed flora, except *E. colona* and *D. retroflexa,* as well as total weed population and dry matter accumulation at 60 days after sowing (DAS) (Table 1). Significantly lower density of *C. iria* was recorded under ZT (DSR)+S with and without retention of previous season crop residue compared to CT (DSR) or CT (TPR). Whereas, ZT (DSR)+S ± crop residue recorded higher population of *C. axillaris*. CT (TPR) recorded lowest population of *P. minima* and *D. retroflexa* during rice. Lowest total weed density was recorded with ZT (DSR)+S without residue retention, but it was statistically at par with CT (TPR). However, CT (DSR) being at par with ZT (DSR) without retention of residue of previous season crop recorded significantly lower weed dry matter production. Amongst the weed control measures, continuous use of bispyribac + pre-sowing non-selective herbicides in ZT recorded significantly lower weed population and weed dry matter over weedy check.

Table 1: Weed density and weed dry matter production in rice as influenced by different tillage systems and weed management measures (2013)

Treatment	Density (no./m²)						Weed dry weight (g/m²)
	E. colona	*C. iria*	*P. minima*	*C. axillaris*	*D. retroflexa*	Total	
Tillage and crop establishment							
CT (DSR) + S – CT (wheat) – ZT (greengram)	1.1 (0.7)	3.8 (13.9)	1.5 (1.7)	1.3 (1.3)	0.9 (0.4)	5.0 (24.3)	3.4 (10.7)
CT (DSR) + R + S – CT (wheat) + R –ZT (greengram) + R	1.2 (0.9)	3.8 (13.9)	1.3 (1.1)	1.2 (0.7)	0.8 (0.1)	4.5 (19.7)	5.8 (31.9)
ZT (DSR) + S – ZT (wheat) – ZT (greengram)	1.1 (0.7)	2.6 (5.7)	0.9 (0.3)	1.6 (1.7)	0.8 (0.2)	3.3 (10.3)	4.3 (17.9)
ZT (DSR) + R + S – ZT (wheat) + R –ZT (greengram) + R	1.0 (0.5)	2.9 (7.9)	1.5 (1.7)	2.0 (3.1)	0.9 (0.3)	4.2 (17.1)	5.4 (28.6)
CT(TPR) – CT (wheat)	0.9 (0.3)	3.3 (10.3)	0.7 (0.4)	1.9 (3.1)	0.7 (0.4)	3.9 (14.7)	5.0 (24.5)
SEm±	**0.16**	**0.17**	**0.13**	**0.20**	**0.15**	**0.28**	**0.33**
LSD (P=0.05)	**0.54**	**0.56**	**0.43**	**0.64**	**0.48**	**0.90**	**0.10**
Weed management							
Weedy check	1.1 (0.7)	6.4 (40.4)	0.9 (0.1)	2.6 (5.7)	0.9 (0.3)	7.3 (52.7)	10.2 (103.5)
Continuous bispyribac + pre-sowing non-selective herbicides in ZT	1.3 (0.9)	1.0 (0.5)	1.6 (2.0)	1.0 (0.4)	0.9 (0.2)	2.3 (4.7)	2.4 (5.2)
Herbicide rotation	0.8 (0.1)	2.5 (5.7)	1.1 (0.7)	1.2 (0.9)	0.7 (0.4)	3.0 (7.9)	3.5 (11.7)
SEm±	**0.13**	**0.14**	**0.10**	**0.18**	**0.10**	**0.16**	**0.30**
LSD (P=0.05)	**0.37**	**0.43**	**0.29**	**0.53**	**0.21**	**0.47**	**0.82**

DSR – direct-seeded rice, TPR – transplanted rice, S – *Sesbania* brown manuring, CT – conventional tillage, ZT – zero tillage and R – residue. Data subjected to $\sqrt{x+0.5}$ transformations. Figures in parentheses are original values

Significantly higher plant height and panicles per running m row were recorded with ZT (DSR) ± previous crop residue. However, highest grain yield of rice was recorded with CT-TPR (3.42 t/ha) which was statistically at par with ZT-DSR (3.11 t/ha). Amongst weed control treatments, continuous use of bispyribac-sodium @ 25 g/ha at 25 DAS being at par with rotational use of herbicides, recorded significantly higher grain and straw yield of rice compared to weedy check (Table 2).

Table 2: Crop growth and grain yield of rice as influenced by different tillage systems and weed management measures (2013)

Treatment	LAI	Plant height (cm)	Panicle length (cm)	Panicles/ running m row	Grain yield (t/ha)	Straw yield (t/ha)
Tillage and crop establishment						
CT (DSR) + S – CT (wheat) – ZT (greengram)	1.6	86.8	22.4	57.8	2.34	4.91
CT (DSR) + R + S – CT (wheat) + R - ZT (greengram) + R	1.6	89.0	23.0	58.7	2.96	5.68
ZT (DSR) + S – ZT (wheat) – ZT (greengram)	1.6	94.0	22.4	65.2	3.08	5.72
ZT (DSR) + R + S – ZT (wheat) + R -ZT (greengram) + R	1.5	95.2	22.5	60.3	3.14	6.56
CT(TPR) – CT (wheat)	1.5	94.6	22.2	50.0	3.42	5.05
SEm±	**0.01**	**3.4**	**0.2**	**0.9**	**0.17**	**0.37**
LSD (P=0.05)	**0.04**	**7.5**	**0.5**	**2.1**	**0.39**	**0.85**
Weed management						
Weedy check	1.5	94.8	22.5	48.4	2.41	5.24
Continuous bispyribac + pre-sowing non-selective herbicides in ZT	1.6	92.3	22.8	64.1	3.35	6.15
Herbicide rotation	1.5	88.6	22.1	62.7	3.20	5.36
SEm±	**0.01**	**2.6**	**0.1**	**1.0**	**0.09**	**0.28**
LSD (P=0.05)	**0.03**	**5.4**	**0.2**	**2.1**	**0.19**	**0.58**

Wheat

Dominant weed flora in wheat were: *Phalaris minor* and *Avena ludoviciana* among grasses, and *Medicago denticulata, Chenopodium album* and *Lathyrus aphaca* amongst broad-leaved weeds. Significantly lower population of *P. minor* and *C. album* was noticed in ZT (DSR)-ZT (wheat), statistically it was at par with CT (TPR)-CT (wheat) over CT (DSR)-CT (wheat). On the other hand, there was lower population of *A. ludoviciana* in CT (TPR)-CT (wheat) and CT (DSR)-CT (wheat), respectively. However, CT (DSR)-CT (wheat) recorded significantly lower population of *M. denticulata*. Whereas significantly lower weed population and weed dry matter was recorded with CT (wheat) sown after CT (TPR/DSR). Amongst weed control measures, significantly lower population and weed dry biomass were recorded with recommended herbicide + pre-sowing non-selective herbicide in ZT (Table 3).

Significantly higher plant height was recorded with CT (wheat) compared to ZT (wheat). Similar trend was also noticed in respect to spikes per m row length (Table 4). The wheat grown after direct seeded rice combined with either crop residue incorporation or retention significantly produced higher grain yield of wheat in both CT/ ZT (wheat). However, highest grain yield of wheat was recorded in CT (TPR)-CT (wheat). Amongst weed control treatments, application of recommended herbicides with and without manual weeding produced significantly higher grain yield over weedy check.

Table 3 : Weed density and weed dry matter production in wheat as influenced by different tillage systems and weed management measures (2012-13)

Treatment	Weed density (no./m²)						Weed dry weight (g/m²)
	M. denticulata	*L. aphaca*	*P. minor*	*C. album*	*A. ludoviciana*	Total	
Tillage and crop establishment							
CT (DSR) + S – CT (wheat)– ZT (greengram)	9.3 (85.9)	1.9 (3.1)	6.4 (40.4)	3.9 (14.7)	1.7 (2.3)	12.4 (153.2)	8.2 (66.7)
CT (DSR) + R + S – CT (wheat) + R – ZT (greengram) + R	10.5 (109.7)	1.9 (3.1)	6.0 (35.5)	2.6 (6.2)	2.0 (3.5)	12.8 (163.3)	8.0 (63.5)
ZT (DSR) + S – ZT (wheat) – ZT (greengram)	21.1 (444.7)	2.7 (6.7)	2.5 (5.7)	1.2 (0.9)	2.8 (7.3)	24.6 (604.6)	8.6 (73.4)
ZT (DSR) + R + S – ZT (wheat) + R – ZT (greengram) + R	22.5 (505.7)	5.1 (25.5)	1.6 (2.0)	0.9 (0.3)	2.6 (6.2)	23.3 (542.3)	12.1 (145.9)
CT(TPR) – CT (wheat)	8.2 (66.7)	5.8 (33.1)	3.8 (13.9)	3.8 (13.9)	1.6 (2.0)	12.0 (143.5)	6.8 (45.7)
SEm±	**0.8**	**0.6**	**0.4**	**0.6**	**0.5**	**1.1**	**2.3**
LSD (P=0.05)	**1.8**	**1.5**	**1.0**	**1.4**	**1.1**	**2.60**	**5.4**
Weed management							
Weedy check	19.41 (375.8)	3.08 (8.5)	4.5 (19.7)	3.0 (8.5)	2.0 (3.5)	21.1 (444.7)	14.7 (215.5)
Recommended herbicide + pre - sowing non-selective herbicides in ZT	10.59 (109.7)	3.1 (9.1)	3.9 (14.7)	2.8 (7.3)	2.3 (4.7)	13.2 (173.7)	4.2 (17.1)
Recommended herbicide + manual/mechanical weeding	12.9 (165.9)	4.3 (17.9)	3.7 (13.1)	1.7 (2.3)	2.0 (3.5)	16.7 (278.3)	7.3 (52.7)
SEm±	**0.51**	**0.51**	**0.4**	**0.26**	**0.36**	**0.6**	**1.3**
LSD (P=0.05)	**1.07**	**1.06**	**1.0**	**0.55**	**0.74**	**1.15**	**3.9**

Data subjected to $\sqrt{x+0.5}$ transformations. Figures in parentheses are original values

Table 4 : Yield attributes and grain yield of wheat as influenced by different tillage systems and weed management measures (2012-13)

Treatment	Plant height (cm)	Spikes/m row length	100-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Tillage and crop establishment					
CT (DSR) + S – CT (wheat) – ZT (greengram)	95.6	57.0	4.40	3.1	4.7
CT (DSR) + R + S – CT (wheat) + R - ZT (greengram) + R	94.3	52.8	4.30	3.7	4.3
ZT (DSR) + S – ZT (wheat) – ZT (greengram)	91.1	51.7	4.30	3.1	3.7
ZT (DSR) + R + S – ZT (wheat) + R – ZT (greengram) + R	93.0	53.6	4.70	3.5	4.7
TPR – CT (wheat)	94.4	58.1	4.50	4.0	5.3
SEm±	**0.4**	**0.7**	**0.04**	**0.1**	**0.2**
LSD (P=0.05)	**0.9**	**1.5**	**0.09**	**0.2**	**0.6**
Weed management					
Weedy check	94.7	44.0	4.50	2.4	3.8
Recommended herbicide + pre - sowing non-selective herbicides in ZT	93.1	59.5	4.60	3.9	4.9
Recommended herbicide + manual / mechanical weeding	93.2	60.6	4.60	4.0	4.9
SEm±	**0.4**	**0.7**	**0.03**	**0.9**	**0.1**
LSD (P=0.05)	**0.9**	**1.4**	**0.07**	**1.2**	**0.2**

DSR – direct-seeded rice, TPR – transplanted rice, S – *Sesbania* brown manuring, CT – conventional tillage, ZT – zero tillage, and R – residue

The effect of tillage practices, crop residue recycling and weed control measures were studied in terms of soil respiration rate during *Rabi* (wheat) 2012-13. It was noted that in absence of crop residue recycling, the rate of soil respiration was significantly higher in ZT-ZT than in CT-CT and puddle-CT systems. Crop residue recycling increased soil respiration rate in both ZT-ZT and CT-CT systems; and the tillage systems did not differ significantly in terms of soil respiration rate when crop residues were recycled (Figure 1). There was no effect of weed control measures on rate of soil respiration.

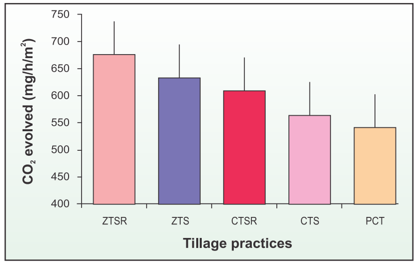


Figure 1: Effect of crop residues and tillage practices on soil respiration under wheat (CT - conventional tillage, ZT - zero tillage, S - *Sesbania* brown manuring, R - crop residue recycling and PCT - puddled/conventional tillage)

Soil samples were collected from 0-15, 15-30 and 30-50 cm depths after completion of one cropping cycle, i.e. rice-wheat-greengram sequence. The mean organic carbon content of the different soil layers decreased significantly with increasing depth. The highest organic carbon (OC) content value of 0.56% was recorded in 0-15 cm layer followed by 0.45 and 0.42 % in 15-30 and 30-50 cm soil layers, respectively (Figure 2(A)). The tillage and crop residue management practices significantly affected the OC content of soil profile (Figure 2(B)). The highest value of the mean OC content at 0-50 cm soil profile was 0.51% under ZTSR followed by 0.49, 0.48, 0.45 and 0.43% under ZTS, CTSR, CTS and PCT treatments, respectively. Although the magnitude of OC content increased with the addition of preceding crop residues, the differences between ZTSR and ZTS, and between CTSR and CTS were not significant. Similarly, no difference in this regard was noticed between CTSR and ZTSR treatments. However, there was significant difference between ZTSR and CTS treatments. This indicated that, compared to conventional practice, there was significant gain in soil organic carbon pool only when the complete conservation package of ZT along with crop residue recycling was adopted. Simply shifting the practice from CT to ZT, or mere recycling of crop residue under conventional tillage system may not provide the desired benefit in short term. However, it was noted that such increase in soil organic carbon pool was restricted only up to 0-30 cm depth, at 30-50 cm depth there was no effect of the tillage/crop residue management practices followed during first year of cropping sequence.

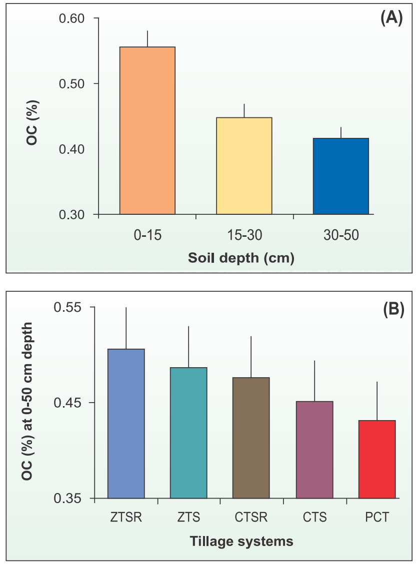
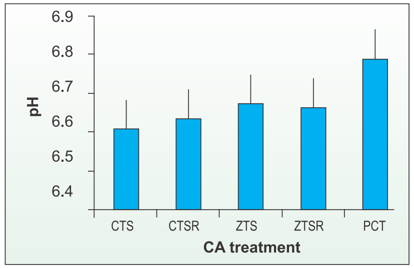


Figure 2: Organic carbon content in the soil as influenced by (A) soil depth, and (B) tillage and residue recycling practices (CT - conventional tillage, ZT - zero tillage, S - *Sesbania* brown manuring, R - crop residue recycling, PCT - puddled/conventional tillage)

The effect of conservation tillage and residue management practices was also noticed on soil pH and EC (Figure 3). The pH and EC values of the soil under puddled-CT treatment was significantly higher than that recorded under ZT the treatments.



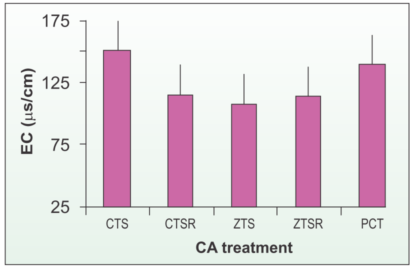


Figure 3: Effect of CA treatments on soil pH and EC (CT - conventional tillage, ZT - zero tillage, S - *Sesbania* brown manuring, R - crop residue recycling and PCT - puddled/conventional tillage)

1.1.2. Weed management in direct seeded rice-based cropping systems under conservation agriculture

Total fifteen treatments consisting of five establishment methods viz., (i) CT(DSR) CT (mustard/chickpea/winter maize–ZT (greengram), (ii) CT(DSR)+R–ZT+R (mustard/chickpea/winter maize)–ZT+R (cowpea/greengram), (iii) ZT (DSR)–CT (mustard/chickpea/winter maize)–ZT (greengram), (iv) ZT(DSR)+R–ZT+R (mustard/chickpea/winter maize)–ZT+R (greengram), and (v) CT(TPR)–CT (mustard/chickpea/winter maize), as main plots; three cropping systems viz., DSR-mustard, DSR-chickpea and DSR-winter maize as sub plot treatments; and three weed control measures *viz.*, recommended herbicides, integrated weed management (herbicide + mechanical/manual weeding) and unweeded (control) as sub-sub plots were laid out in split-split plot design with three replications.

Predominant weeds in rice were *Echinochloa colona, Cyperus iria, Caesulia axillaris* and *Ammannia baccifera*. Significantly lowest *E. colona* was recorded with transplanted rice. Whereas, adoption of conventional / zero tillage for direct-seeded rice recorded lower population of *C. iria* and *A. baccifera* compared to adoption of conventional tillage for transplanting. Similar observation was also noticed in total weed population (Table 5). However, significantly lower weed dry matter production and high grain yield of rice were recorded with adoption of conventional tillage for transplanting. Amongst direct-seeding of rice, adoption of zero tillage for seeding of rice produced higher grain yield than conventional tillage. Different cropping systems also significantly influenced the weed dry matter production and grain yield of rice. Significantly lower weed biomass and higher grain yield of rice was recorded under DSR – mustard, which were statistically at par with DSR – winter maize. Amongst weed control treatments, post-emergence application bisphyribac-sodium @ 25 g/ha followed by 1 HW at 40 DAS recorded lowest weed growth and highest grain yield of rice, which was statistically at par with application of recommended herbicide (Table 5).

Dominant weed flora in chickpea, mustard and winter maize were: *Phalaris minor* and *Avena ludoviciana* among grasses, and *Medicago denticulata, Lathyrus sativa* and *Chenopodium album* among broadleaved weeds. Significantly lower population *M. denticulata, L. sativa* and *P. minor* as well as total weed production and weed dry biomass were recorded with adopting conventional tillage for sowing of *Rabi* crops without previous season crop residues. However, adoption of zero tillage recorded lower population of *A. ludoviciana* and *C. album*. Significantly highest rice equivalent yield (4.6 t/ha) was obtained with adoption of conventional tillage in the absence of previous season crop residues over rest of the crop establishment techniques. Amongst cropping systems, significantly lower population of *M. denticulata*, *P. minor, A. ludoviciana* and *C. album* were recorded under DSR – winter maize cropping system, which was at par with DSR – mustard system, except *M. denticulata*. However, different cropping systems did not influence significantly the total weed population and weed dry biomass production. So far rice equivalent yield is concerned; significantly higher

Table 5: Weed growth and grain yield of rice as influenced by different crop establishment techniques and weed management measures (2013)

Treatment	Weed population (no./m^2)					Weed dry biomass (g/m^2)	Grain yield of rice (t/ha)
	E. colona	*C. iria*	*C. axillaris*	*A. baccifera*	Total		
Tillage and crop establishment							
CT (DSR) + S–CT (mustard/chickpea/ winter maize) – ZT (greengram)	1.6 (2.1)	3.3 (10.4)	1.2 (0.9)	1.1 (0.7)	4.5 (19.8)	5.4 (28.7)	2.6
CT(DSR) + R +S – CT (mustard / chickpea / winter maize) – ZT (greengram) + R	1.5 (1.8)	3.4 (11.1)	1.3 (1.2)	1.3 (1.2)	4.2 (17.1)	5.3 (27.6)	2.9
ZT (DSR) + S – ZT (mustard/chickpea/ winter maize) – ZT (greengram)	1.2 (0.9)	3.3 (10.4)	1.3 (1.2)	1.1 (0.7)	4.2 (17.1)	1.5 (1.8)	3.4
ZT(DSR) + R + S – ZT (mustard / chickpea / winter maize) - ZT (greengram) + R	1.1 (0.7)	3.1 (9.1)	1.4 (1.5)	1.3 (1.2)	4.0 (15.5)	4.8 (22.5)	3.3
TPR – CT (mustard / chickpea / winter maize)	0.8 (0.1)	4.6 (20.7)	1.3 (1.2)	2.1 (3.9)	5.6 (30.9)	2.8 (7.3)	4.2
SEm±	**0.2**	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**	**0.5**
LSD (P = 0.05)	**0.4**	**0.6**	**0.5**	**0.8**	**0.7**	**1.0**	**1.3**
Cropping systems							
DSR – chickpea	1.3 (1.2)	3.9 (14.7)	1.3 (1.2)	1.3 (1.2)	5.0 (24.5)	5.4 (28.7)	3.8
DSR – mustard	1.2 (0.9)	3.3 (10.4)	1.3 (1.2)	1.7 (2.4)	4.8 (22.5)	4.3 (18.0)	3.8
DSR – maize	1.2 (0.9)	3.3 (10.4)	1.3 (1.2)	1.2 (0.9)	4.3 (18.0)	4.4 (18.9)	3.2
SEm±	**0.1**	**0.3**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**
LSD (P = 0.05)	**0.2**	**0.6**	**0.3**	**0.3**	**0.5**	**0.6**	**0.8**
Weed management							
Weedy check	1.3 (1.2)	7.9 (61.9)	2.2 (4.3)	2.4 (5.3)	9.2 (84.1)	9.8 (95.5)	2.8
Recommended herbicide + pre-sowing non - selective herbicides in ZT	1.1 (0.7)	1.2 (0.9)	0.8 (0.1)	0.9 (0.3)	2.3 (4.8)	2.3 (4.8)	3.5
Recommended herbicide + manual/ mechanical weeding	1.4 (1.5)	1.5 (1.8)	0.9 (0.3)	0.8 (0.1)	2.1 (3.9)	1.9 (3.1)	3.7
SEm±	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**	**0.3**	**0.4**
LSD (P = 0.05)	**0.3**	**0.4**	**0.3**	**0.3**	**0.5**	**0.6**	**0.8**

DSR – direct-seeded rice, TPR – transplanted rice, S – *Sesbania* brown manuring, CT – conventional tillage, ZT – zero tillageand R – residue. Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values

yield was recorded under DSR – winter maize cropping system over rest of the cropping system (Table 6). Amongst weed control treatments integrated weed management produced significantly higher rice equivalent yield (4.5 t/ha) than weedy check (3.0 t/ha).

The available soil nitrogen content was significantly higher in the treatment receiving ZT+sesbania brown manuring + crop residue recycling (ZTSR) under DSR-chickpea-greengram system (Figure 4). However, such observation was not recorded under DSR-mustard-greengram and DSR-winter maize- greengram systems (data not shown). Soil organic carbon content of different soil layers in the DSR-chickpea-greengram system significantly decreased with increasing soil depth (Figure 5). Similar observations were also recorded under DSR-mustard-greengram and DSR-winter maize-greengram systems (data not shown). However, unlike under the DSR-wheat-greengram system (vide 1.1.1), the tillage and residue management practices did not show any significant effect on soil respiration and available soil organic carbon content of the surface soils after completion of one cropping sequence under these systems (data not shown).

Table 6: Weed growth and grain yield of rice as influenced by different crop establishment techniques and weed management measures (2012-13)

Treatment	Weed population (no./m^2)						Weed dry biomass (g/m^2)	Rice equivalent yield (t/ha)
	M. denticulata	*L. sativa*	*P. minor*	*A. ludoviciana*	*C. album*	Total		
Tillage and crop establishment								
CT (DSR) + S – CT (mustard / chickpea / winter maize) – ZT (greengram)	11.0 (120.5)	2.0 (3.5)	2.9 (7.9)	1.9 (3.1)	2.2 (4.3)	12.1 (145.9)	12.0 (143.5)	4.59
CT(DSR) + R +S – CT (mustard/chickpea/ winter maize) – ZT (greengram) + R	13.0 (168.5)	3.6 (12.5)	3.8 (13.9)	1.6 (2.1)	2.0 (3.5)	37.2 (1383.3)	12.0 (143.5)	3.68
ZT (DSR) + S – ZT (mustard / chickpea / winter maize) - ZT (greengram)	20.8 (432.1)	7.0 (48.5)	3.6 (12.5)	1.5 (1.8)	1.1 (0.7)	23.0 (528.5)	17.0 (288.5)	3.61
ZT(DSR) + R + S –ZT (mustard / chickpea / winter maize) - ZT (greengram) + R	16.6 (275.0)	5.7 (32.0)	3.7 (13.1)	1.3 (1.1)	0.7 (0.0)	18.0 (323.5)	14.0 (195.5)	3.37
TPR – CT (mustard/chickpea/winter maize)	11.3 (127.1)	5.8 (33.1)	4.0 (15.5)	0.8 (0.1)	1.7 (2.4)	14.0 (195.5)	12.5 (155.8)	3.33
SEm±	**0.6**	**0.5**	**0.5**	**0.3**	**0.4**	**1.4**	**0.71**	**0.16**
LSD (P = 0.05)	**1.4**	**1.1**	**1.1**	**0.8**	**0.9**	**3.3**	**1.63**	**0.36**
Cropping systems								
DSR – chickpea	14.6 (212.7)	3.5 (11.8)	5.0 (24.5)	2.1 (3.9)	1.9 (3.1)	16.5 (271.8)	15.0 (224.5)	2.44
DSR – mustard	15.7 (246.0)	4.3 (18.0)	2.4 (5.3)	1.0 (0.5)	1.4 (1.5)	16.5 (271.8)	12.3 (150.8)	2.27
DSR – maize	13.3 (176.4)	6.8 (45.7)	3.0 (8.5)	1.2 (0.9)	1.4 (1.5)	15.7 (246.0)	13.0 (168.5)	6.45
SEd±	**0.5**	**0.4**	**0.3**	**0.2**	**0.3**	**1.1**	**0.5**	**0.09**
LSD (P = 0.05)	**1.1**	**0.9**	**0.6**	**0.5**	**0.6**	**2.3**	**1.05**	**0.18**
Weed management								
Weedy check	17.2 (295.3)	5.6 (30.9)	4.2 (17.1)	1.8 (2.7)	2.4 (5.3)	32.9 (1081.9)	16.4 (268.5)	3.00
Recommended herbicide + pre-sowing non-selective herbicides in ZT	13.4 (179.1)	5.3 (27.6)	3.6 (12.5)	1.1 (0.7)	1.0 (0.5)	15.5 (239.8)	13.4 (179.1)	3.68
Recommended herbicide + manual/mechanical weeding	13.0 (168.5)	3.7 (13.2)	2.5 (5.8)	1.2 (0.9)	1.3 (1.2)	14.2 (201.1)	10.5 (109.8)	4.48
SEm±	**0.5**	**0.4**	**0.3**	**0.2**	**0.3**	**1.1**	**0.5**	**0.09**
LSD (P = 0.05)	**1.0**	**0.7**	**0.7**	**0.4**	**0.6**	**2.2**	**1.0**	**0.18**

DSR – direct-seeded rice, TPR – transplanted rice, S – *Sesbania* brown manuring, CT – conventional tillage, ZT – zero tillage and R – residue. Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values

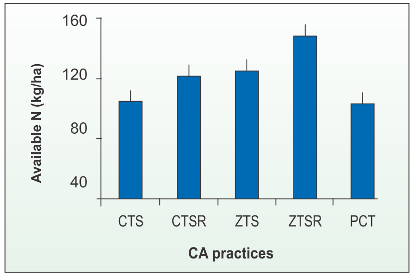


Figure 4: Effect of CA treatments on available N content under DSR-chickpea-greengram system (CT - conventional tillage, ZT - zero tillage, S - *Sesbania* brown manuring, R - crop residue recycling and PCT - puddled/ conventional tillage)

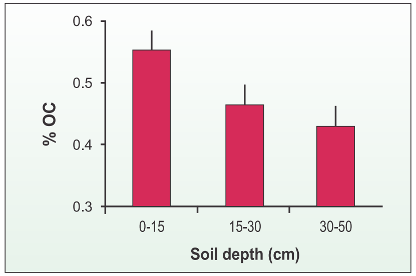


Figure 5: Soil organic carbon (OC) content of different soil layers in a DSR-chickpea-greengram system under CA

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

A field trial initiated in June 2010 was continued in 2012-13 to evaluate continuous use of commonly-applied herbicides in direct-seeded rice-wheat cropping system. Treatments consisted of bispyribac-sodium @ 25 g/ha as post-emergence (20 DAS), cyhalofop-butyl @ 90 g/ha as pre-emergence and one HW at 30 DAS along with weedy check in direct-seeded rice (DSR) as main plot treatments, which were superimposed by post-emergence application (25 DAS) of isoproturon @ 1500 g/ha, sulfosulfuron @ 25 g/ha and clodinafop @ 60 g at 25 DAS *fb* 2,4-D @ 500 g/ha at 30 DAS, one hand weeding (HW) at 30 DAS and weedy check in wheat as sub-plot treatments (Table 7). The experiment was laid out in split-plot design with an aim to study the long-term impact of continuous use of herbicides on weed seed bank, weed dynamics and crop productivity. The treatments employed in the experiment on continuous use of herbicides were bispyribac-sodium (T_1), cyhalofop-butyl (T_2), one HW at 20 DAS (T_3), weedy check (T_4) in rice and sulfosulfuron (T_1), clodinafop fb 2,4-D (T_2), isoproturon (T_3), one HW at 20 DAS (T_4), and weedy check (T_5) in wheat.

Dominant weed flora in the fourth cycle of experimentation was: *Echinochloa colona* and *Ischaemum rugosum* among grasses; *Alternanthera sessilis*, *Commelina communis*, and *Caesulia axillaris* among broadleaved weeds; and *Cyprus iria* among sedges during rainy season. Application of bispyribac-sodium @ 25 g/ha significantly reduced the population by more than 95% of *E. colona*, *C. iria*, and *C. communis* over weedy check. However, application of cyhalofop-butyl failed to reduce the density of *C. iria*, *A. sessilis*, *C. communis*, and *I. rugosum*, the population of these weeds were 94, 79, 98, and 97% higher over bispyribac-sodium, respectively. But it significantly reduced the population of *E. colona* by 96% over weedy check (Table 7). Amongst herbicides, applications of bispyribac-sodium significantly reduced the weed density (89%) and weed biomass (82%) over cyhalofop-butyl (Figure 6).

Significantly higher plant height and leaf area index were recorded in bispyribac-sodium treated plots, followed by plots under hand weeding once at 20 DAS. Similarly, the higher effective tillers/m row length and grain yield of rice were obtained in the bispyribac-sodium treated plots, which were 11% and 121% over weedy check. Pre-emergence application of cyhalofop-butyl produced 42% lesser grain yield of rice than bispyribac-sodium treated plots (3.1 t/ha).

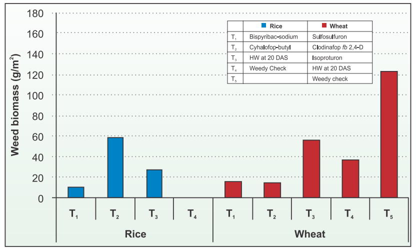


Figure 6: Weed biomass as influenced by continuous use of herbicides under direct-seed rice-wheat cropping system

Table 7: Weed density (no./m^2) dynamics in rice as influenced by continuous use of herbicides under direct seeded rice-wheat system (2013)

Treatment (applied to rice)	*C. iria*	*E. colona*	*A. sessilis*	*C. communis*	*I. rugosum*	*C. axillaris*	Total
Bispyribac-sodium	1.7 (2.4)	1.8 (2.7)	1.0 (0.5)	0.7 (0.0)	0.8 (0.1)	0.7 (0.0)	2.8 (7.3)
Cyhalofop-butyl	6.3 (39.1)	1.0 (0.5)	1.7 (2.4)	2.7 (6.8)	3.7 (13.2)	1.6 (2.1)	8.3 (68.4)
Hand weeding	5.6 (30.9)	3.5 (11.8)	1.1 (0.7)	0.7 (0.0)	1.9 (3.1)	0.9 (0.3)	7.1 (50.0)
Weedy check	7.0 (48.5)	7.5 (55.7)	0.8 (0.1)	3.7 (13.2)	3.6 (12.5)	1.3 (1.2)	11.9 (141.1)
SEd±	**0.47**	**0.4**	**0.3**	**0.1**	**1.0**	**0.4**	**0.8**
LSD (P=0.05)	**1.1**	**0.9**	**0.8**	**0.2**	**2.5**	**0.9**	**2.0**

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

The lowest grain yield of rice (2.8 t/ha) was obtained under weedy check (Table 8). Presence of weeds throughout growing season caused 55% reduction in grain yield. The preceding treatments applied in wheat did not influence the weed flora distribution and weed biomass production in rice.

Dominant weeds in the field were: *Avena ludoviciana* and *Phalaris minor* among grassy weeds, and *Chenopodium album*, *Medicago hispida, Physalis minima* and *Cichorium intybus* among broadleaved weeds in wheat during winter season of 2012-13. Application of clodinafop @ 60 g/ha at *fb* 2,4-D @ 500 g/ha caused significant reduction in *A. sterilis, P. minor, C. album* and *C. intybus*, whereas the lowest populations of *M. denticulata* was recorded with sulfosulfuron. Application of isoproturon failed to check growth of *A. sterilis* and *P. minor* over rest of the herbicides, but was very effective against *C. intybus* and *C. album*. All the weed control treatments significantly reduced the total density and weed dry biomass over weedy check. Post-emergence application of clodinafop *fb* 2, 4-D at 25 and 30 DAS caused 87 and 88% reduction in total weed population and weed dry biomass, respectively over weedy check. This was followed by application of sulfosulfuron. Both the herbicide treatments, viz. sulphosulfuron and clodinafop + 2,4-D were effective in reducing population of almost all weed species and weed biomass production, except *C. intybus* in sulfosulfuron treated plots (Table 9). Presence of weeds throughout the growing season caused 66% reduction in yield. The grain yield recorded with application of sulfosulfuron was 31 and 51% higher than isoproturon and weedy check, respectively. Application of clodinafop *fb* 2, 4-D at 25 and 30 DAS was also equally effective as sulfosulfuron in terms of yield attributes and grain yield of wheat. Preceding treatments applied to rice did not influence the weed distribution, crop growth, yield attributes and grain yield of wheat (Table 10).

Table 8: Growth and yield of rice as influenced by continuous use of herbicides under direct seeded rice-wheat system (2013)

Treatment (applied to rice)	Plant height (cm)	LAI (Without weed)	Panicles /m row	Grains/ panicle	Grain weight/ panicle (g)	100-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium	125.9	3.1	49.5	147.8	3.9	2.7	4.5
Cyhalofop-butyl	119.8	2.8	45.5	131.6	3.5	2.7	3.2
Hand weeding	122.7	2.1	48.0	141.8	3.7	2.6	4.0
Weedy check	119.2	1.8	40.5	139.0	3.6	2.6	2.8
SEd±	**1.4**	**0.1**	**2.7**	**7.0**	**0.2**	**0. 2**	**0.1**
LSD (P=0.05)	**3.4**	**0.2**	**6.8**	**NS**	**NS**	**NS**	**0.4**

Table 9: Weed density (no./m^2) in wheat as influenced by continuous use of herbicides under direct-seeded rice-wheat system (2012-13)

Treatment (applied to wheat)	*A. ludoviciana*	*P. minor*	*C. intybus*	*M. denticulata*	*C. album*	Total
Sulfosulfuron	5.5 (29.7)	0.9 (0.3)	2.6 (6.3)	1.1 (0.7)	1.2 (0.9)	6.5 (41.7)
Clodinafop *fb* 2,4 -D	5.4 (28.7)	1.2 (0.9)	0.8 (0.1)	2.2 (4.3)	0.7 (0.0)	6.0 (35.5)
Isoproturon	9.4 (87.7)	1.4 (1.5)	0.7 (0.0)	1.4 (1.5)	0.7 (0.0)	9.7 (93.6)
Hand weeding	7.7 (58.8)	2.3 (4.8)	1.3 (1.2)	1.7 (2.4)	1.0 (0.5)	8.7 (75.2)
Weedy check	15.1 (227.5)	3.9 (14.7)	1.3 (1.2)	4.5 (19.7)	0.9 (0.3)	16.7 (278.4)
SEd±	**0.8**	**0.5**	**0.3**	**0.3**	**0.1**	**0.7**
LSD (P=0.05)	**1.7**	**1.0**	**0.7**	**0.6**	**0.3**	**1.5**

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

The long-term impact of weed control measures were evaluated after harvest of wheat during *Rabi* 2012-13. The effect of main plot treatments (*Kharif* season) and also of the sub-plot treatments (*Rabi* season) were not significant in terms of soil pH. Similar observation was also recorded in respect to EC of the soil. The interaction of the *Kharif* and *Rabi* treatments were significant on all the soil parameters evaluated, i.e. pH, EC, organic C and available N content. However, magnitude of these parameters as recorded in the plots receiving continuous herbicide applications were statistically similar to that noted in the plots receiving continuous hand weeding (Table 11). This indicated that chemical weed control measures did not affect soil fertility parameters vis-à-vis traditional practice of manual weeding.

Table 10: Yield performance of wheat as influenced by continuous use of herbicides under direct seeded rice-wheat system (2012-13)

Treatment (applied to wheat)	Spike length (cm)	Spikes/m row	Grains/ spike	Grain weight/ spike(g)	100-grain weight (g)	Grain yield (t/ha)
Sulfosulfuron	71.6	10.0	50.5	2.0	4.1	4.8
Clodinafop + 2,4-D	66.5	9.8	51.5	2.1	4.1	4.5
Isoproturon	50.6	9.8	51.5	2.1	4.1	3.6
Hand weeding	57.4	9.2	50.0	2.0	4.1	3.9
Weedy check	46.2	9.5	49.9	1.8	4.0	2.8
SEd±	**0.2**	**0.2**	**0.7**	**1.9**	**0.1**	**0.9**
LSD (P=0.05)	**1.9**	**0.1**	**1.9**	**0.8**	**0.1**	**0.2**

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

A field experiment was conducted during 2012-13 to investigate the impact of continuous use of the same herbicide over a period of time on weed dynamics and soil health in direct-seeded rice-chickpea cropping system. The experiment comprised of treatment combinations consisting of bispyribac-sodium @ 25 g/ha as post-emergence (20 DAS), fenoxaprop @ 60 g fb 2,4-D @ 500 g/ha as post-emergence (20 and 30 DAS) and one hand weeding at 30 DAS along with weedy check in direct-seeded rice (DSR) as main plot treatments. These treatments were superimposed with pendimethalin @ 1250 g/ha as pre-emergence, oxyfluorfen @ 200 g/ha as pre-emergence, quizalofop @ 60 g/ha as post-emergence, one hand weeding at 30 DAS and weedy check in chickpea, laid out with three replications in split-plot design.

Dominant weeds in the third cycle of the experimentation were: *Echinochloa colona* and *Ischaemum rugosum* among grasses; *Commelina communis, Caesulia axillaris, Physalis minima,* and *Phyllanthus niruri* among broadleaved; and *Cyperus iria* among sedges in rice. All weed control treatments influenced density and distribution of weed flora, except *P. niruri, C. axillaris* and *P. minima*. Continuous use of bispyribac-sodium and fenoxaprop + 2,4-D caused significant reduction in density of most of the weed species over weedy check. However, application of fenoxaprop + 2,4-D failed to reduce the population of *C. iria*. The lowest weed density and weed biomass were recorded with bispyribac-sodium, which caused 94 and 90% reduction in total weed density and biomass production, respectively over weedy check (Table 12, Figure 7). Similarly, post-emergence application of fenoxaprop @ 60 g/ha at 20 DAS *fb* 2,4-D @ 500 g/ha at 30 DAS were as effective as bispyribac-sodium in reducing weed growth.

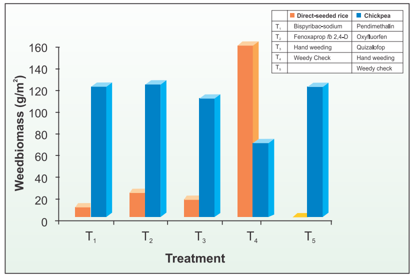


Figure 7: Weed biomass as influenced by continuous use of herbicides under direct-seeded rice - chickpea cropping system

Table 11: Long-term impact of weed control measures on pH, EC, available N and organic carbon content of soil under DSR-wheat system

Kharif (Main plot) treatment	*Rabi* (sub-plot) treatments					
	Sulfosulfuron	Clodinafop *fb* 2,4-D	Isoproturon	HW	Weedy	Mean
(a) pH						
Bispyribac-sodium	6.7	6.7	6.6	6.6	6.7	6.7
Cyhalofop-butyl	6.7	6.6	6.7	6.7	6.6	6.7
HW	6.7	6.7	6.7	6.7	6.7	6.7
Weedy	6.7	6.8	6.7	6.8	6.7	6.7
Mean	6.7	6.7	6.7	6.7	6.7	
LSD (P=0.05)	***Kharif*: NS; *Rabi*: NS; *Kharif* x *Rabi*: 0.12**					
(b) EC (µS/cm)						
Bispyribac-sodium	115	137	133	152	137	135
Cyhalofop-butyl	148	138	152	154	155	149
HW	128	124	142	142	125	132
Weedy	132	117	133	127	138	129
Mean	131	129	140	144	139	
LSD (P=0.05)	***Kharif*: NS; *Rabi*: NS; *Kharif* x *Rabi*: 31**					
(c) Soil organic C (%)						
Bispyribac-sodium	0.48	0.59	0.63	0.63	0.60	0.59
Cyhalofop-butyl	0.46	0.55	0.48	0.60	0.58	0.53
HW	0.49	0.46	0.53	0.52	0.58	0.52
Weedy	0.57	0.55	0.60	0.56	0.51	0.56
Mean	0.50	0.54	0.56	0.58	0.57	
LSD (P=0.05)	***Kharif*: NS; *Rabi*: 0.06; *Kharif* x *Rabi*: 0.12**					
(d) Available N (kg/ha)						
Bispyribac-sodium	163	151	154	157	176	160
Cyhalofop-butyl	182	169	182	176	176	177
HW	166	163	144	154	157	157
Weedy	138	147	138	147	147	144
Mean	162	158	154	158	164	
LSD (P=0.05)	***Kharif*: 23; *Rabi*: NS; *Kharif* x *Rabi*: 32**					

Table 12: Weed density (no./m^2) in rice as influenced by continuous use of herbicides under direct-seeded rice-chickpea system (2013)

Treatment (applied to rice)	*E. colona*	*C. iria*	*P. niruri*	*C. communis*	*I. rugosum*	*C. axillaris*	*P. minima*	Total
Bispyribac-sodium	1.5 (1.8)	1.0 (0.5)	0.7 (0.0)	0.9 (0.3)	0.7 (0.0)	0.7 (0.0)	1.0 (0.5)	2.0 (3.5)
Fenoxaprop *fb* 2,4-D	1.7 (2.4)	3.2 (9.7)	1.1 (0.7)	1.2 (0.9)	1.7 (2.4)	0.8 (0.1)	1.1 (0.7)	4.7 (21.6)
Hand weeding	2.7 (6.8)	2.8 (7.3)	0.9 (0.3)	0.7 (0.0)	0.8 (0.1)	0.8 (0.1)	0.7 (0.0)	4.0 (15.5)
Weedy check	5.6 (30.9)	3.7 (13.2)	0.7 (0.0)	2.0 (3.5)	1.9 (3.1)	0.8 (0.1)	0.7 (0.7)	7.7 (59.9)
SEd±	**1.2**	**0.5**	**0.3**	**0.4**	**0.8**	**0.1**	**0.3**	**1.0**
LSD (P=0.05)	**2.9**	**1.1**	**0.8**	**0.9**	**1.8**	**0.2**	**0.7**	**2.4**

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

The reduction in leaf area index of rice due to weeds was higher under weedy check as compared to bispyribac-sodium treated plots. Maximum number of effective tillers/m row (58), grain weight/panicle (3.7 g) and grain yield (3.70 t/ha) were recorded with bispyribac-sodium. Similar observations were also recorded in fenoxaprop + 2,4-D treated plots. Both the herbicides resulted in higher grain/panicle and grain

Table 13: Growth and yield of rice as influenced by continuous use of herbicides under direct-seeded rice chickpea system (2013)

Treatment (applied to rice)	Plant height (cm)	LAI (with weed)	LAI (without weed)	Panicles/ m row	Grains/ panicle	Grain weight/ panicle (g)	100-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium	124	3.0	2.9	58	139	3.7	2.69	4.2
Fenoxaprop fb 2,4-D	129	3.0	2.7	56	136	3.7	2.74	4.0
Hand weeding	123	3.0	2.4	51	130	3.5	2.75	3.7
Weedy check	119	3.5	2.2	52	126	3.5	2.71	2.9
SEd±	**1.5**	**0.1**	**0.1**	**1.3**	**11.7**	**0.4**	**0.06**	**0.1**
LSD (P=0.05)	**3.7**	**0.1**	**0.3**	**3.1**	**29.0**	**0.9**	**0.15**	**0.2**

yield of rice by 9 and 33% respectively than weedy check (Table 13). Presence of weeds throughout growing season caused 35% reduction in grain yield of rice.

Avena ludoviciana among grassy weeds, and *Medicago hispida*, *Chenopodium album* and *Cichorium intybus* among broadleaved weeds were dominant in chickpea. Amongst herbicides, pendimethalin being at par with oxyfluorfen caused significant reduction in density and dry matter production of all weed species. However, post-emergence application of quizalofop failed to check emergence of *M. hispida*, *C. album, C. intybus* and *A. ludoviciana* compared to pendimethalin and oxyfluorfen. Significantly lower population of *M. hispida*, *C. album* and *C. intybus* were recorded with pendimethalin and oxyfluorfen over quizalofop (Table 14). Hand weeding resulted in the lowest total weed population and dry biomass, which was significantly lower than rest of the treatments. Presence of weeds throughout the growing season caused 84% reduction in seed yield of chickpea. The highest yield attributes, viz. pods/plant, 100-seed weight, seed weight/plant and seed yield of chickpea was recorded with hand weeding, which were significantly higher over quizalofop treated plots and weedy check, respectively. Application of oxyfluorfen and pendimethalin resulted in higher pods/plant (46%) and seed yield (80%) of chickpea over weedy check (Table 15).

Observations on nodulation in chickpea were recorded at 50 DAS. No significant residual effect of the weed control treatments given to the preceding rice was noticed on nodulation in chickpea grown during subsequent winter season. However, significant differences among the weed control treatments given to the chickpea were noticed in terms of nodule count and nodule dry matter production. Both these parameters were depressed due to pendimethalin application as compared to hand weeding. Compared to hand weeding, application of quizalofop, however, did not show any adverse effect on chickpea nodulation (Table 16).

Table 14: Weed density (no./m^2) in chickpea as influenced by continuous use of herbicides under direct-seeded rice-chickpea system (2012-13)

Treatment (applied to chickpea)	*A. ludoviciana*	*P. minor*	*M. hispida*	*C. album*	*C. intybus*	Total
Pendimethalin	16.3 (265.2)	0.8 (0.1)	6.9 (47.1)	1.5 (1.7)	2.3 (4.7)	18.9 (376.7)
Oxyfluorfen	18.4 (338.0)	0.8 (0.1)	4.9 (23.5)	3.2 (9.7)	2.7 (6.7)	20.0 (399.5)
Quizalofop	29.2 (852.1)	0.8 (0.1)	14.0 (195.5)	13.3 (176.4)	5.3 (27.6)	36.2 (1309.9)
Hand weeding	8.8 (76.9)	3.0 (8.5)	3.7 (13.2)	9.6 (91.7)	2.7 (6.8)	14.9 (221.5)
Weedy check	35.0 (1224.5)	0.8 (0.1)	6.9 (47.1)	1.4 (1.5)	2.1 (3.9)	35.9 (1288.8)
SEd±	**1.5**	**0.4**	**1.3**	**1.7**	**0.6**	**1.5**
LSD (P=0.05)	**2.0**	**0.9**	**2.7**	**3.4**	**1.2**	**2.9**

The results in respect to soil fertility parameters revealed that the soil organic carbon content value of 0.54% as recorded under the treatment combination of HW-HW was statistically similar to the values noted under all the remaining treatment combinations. This indicated that there was no effect of the chemical weed control measures on the available soil organic carbon as compared to the traditional practice of hand weeding. Similar observations were also recorded in terms of pH, EC and available N content of soil.

Table 15 : Growth and yield of chickpea as influenced by continuous use of herbicides under direct seeded rice-chickpea system (2012-13)

Treatment (applied to chickpea)	Plant height (cm)	Branches/ plant	Pods/ plant	Seeds/ pod	Seed weight/ plant (g)	100-seed weight (g)	Seed yield (t/ha)
Pendimethalin	41.9	2.8	39.5	1.6	6.4	15.8	1079
Oxyflorfen	42.3	3.6	42.2	1.5	6.8	16.2	1047
Quizalofop	44.8	3.2	27.7	1.6	5.0	14.9	672
Hand weeding	45.6	4.8	44.4	1.5	6.7	15.4	1384
Weedy check	47.7	2.8	21.9	1.7	4.2	14.9	211
SEd±	**1.5**	**0.2**	**3.2**	**0.2**	**0.3**	**0.3**	**99**
LSD (P=0.05)	**2.9**	**0.3**	**6.6**	**0.4**	**0.5**	**0.6**	**201**

Table 16: Long-term impact of weed control measures on (a) nodule count and (b) nodule dry matter of chickpea, and soil organic carbon content under DSR-chickpea system

Kharif (Main) treatment	*Rabi* (sub) treatments					
	Pendimethalin	**Oxyfluorfen**	**Quizalofop**	**HW**	**Weedy**	**Mean**
(a) Nodule count/plant						
Bispyribac-sodium	26	34	40	39	30	34
Fenoxaprop *fb* 2,4 -D	25	35	35	36	31	32
Hand weeding	31	34	35	43	32	35
Weedy	27	28	39	38	26	32
Mean	27	33	37	39	30	
LSD (P=0.05)	*Kharif*: NS; *Rabi*: 5; *Kharif* x *Rabi*: 10					
(b) Nodule dry matter, mg/plant						
Bispyribac-sodium	43	60	66	66	48	57
Fenoxaprop *fb* 2,4-D	45	58	61	72	45	56
Hand weeding	45	54	57	65	45	53
Weedy	44	50	63	73	39	54
Mean	44	56	62	69	44	
LSD (P=0.05)	*Kharif*: 6.19; *Rabi*: 5.27; *Kharif* x *Rabi*: 10.54					
(c) Soil organic C (%)						
Bispyribac-sodium	0.53	0.66	0.58	0.55	0.69	0.60
Fenoxaprop *fb* 2,4 -D	0.60	0.56	0.62	0.69	0.55	0.61
Hand weeding	0.59	0.47	0.55	0.56	0.51	0.54
Weedy	0.67	0.64	0.62	0.55	0.53	0.60
Mean	0.60	0.58	0.60	0.59	0.57	
LSD (P=0.05)	*Kharif*: NS; *Rabi*: NS; *Kharif* x *Rabi*: 0.14					

1.1.5. Weed management in soybean-wheat-greengram cropping system under conservation agriculture

A long-term field experiment on the effect of crop establishment techniques and weed management under conservation agriculture was initiated from April, 2013 with the objectives to monitor weed dynamics, crop productivity, herbicide residues, C-sequestration, physico-chemical and biological properties of soil under soybean-wheat cropping system. Total fifteen treatment combinations consisting of five establishment methods viz., (i) CT(soybean)-CT (Wheat), (ii) CT(soybean)-ZT (Wheat)-ZT (greengram), (iii) ZT

(Soybean)+R -ZT (wheat)-ZT (greengram), (iv) ZT (soybean)-ZT (wheat)+R-ZT (greengram), (v) ZT (soybean) +R-ZT (wheat)+R-ZT (greengram) + R and three weed control measures viz., weedy check, pendimethalin fb imazathapyr and metribuzin + 1 hand weeding laid out in split-plot design with three replications. Dominant weed flora were: *Echinochloa colona, Digera retroflexa, Cyperus eragrastis, Cyperus iria, Eclipta alba,* and *Mecardonia procumbens (*Table 16*).* Different tillage practices did not have any significant difference on weed dry biomass. Both the weed management treatments significantly reduced the weed density and dry biomass as compared to unweeded control (Table 17). Due to heavy and continuous rains soybean crop had failed.

Table 17: Weed density and weed dry matter production in soybean as influenced by different tillage systems and weed management measures (2013)

Treatment	Weed population (no./m²)									Total weed dry matter (g/m²)
	E. colona	*D. retroflexa*	*C. eragrastis*	*C. iria*	*E. alba*	*M. procumbens.*	*A. arvensis*	*P. niruri*	Total	
Tillage practice										
CT(soybean)-CT(wheat)	1.2 (1.5)	7.6 (58.1)	1.9 (3.7)	1.4 (2.0)	3.0 (9.0)	2.1 (4.4)	1.3 (1.7)	0.9 (0.9)	9.5 (91.3)	7.8 (60.7)
CT(soybean)-ZT(wheat)	2.0 (4.2)	7.0 (50.2)	2.5 (6.3)	2.0 (4.2)	4.8 (23.6)	0.9 (0.8)	1.0 (1.1)	1.5 (2.4)	10.7 (115.3)	8.7 (75.6)
ZT(soybean)+R-ZT(wheat)-ZT(greengram)	1.61 (2.5)	7.1 (50.5)	1.0 (0.9)	2.2 (5.1)	3.0 (8.9)	3.5 (12.7)	1.9 (3.7)	0.8 (0.5)	9.9 (98.5)	8.5 (72.7)
ZT(soybean) -ZT(wheat) +R -ZT(greengram)	2.1 (4.5)	9.4 (89.2)	1.8 (3.3)	2.8 (7.9)	3.9 (15.3)	2.4 (5.7)	1.3 (1.8)	1.2 (4.5)	9.9 (89.2)	7.3 (53.2)
ZT(soybean) +R -ZT(wheat) +R -ZT(greengram) +R	1.3 (1.6)	5.8 (34.6)	0.8 (0.6)	2.5 (6.4)	3.8 (14.5)	2.9 (8.7)	1.8 (3.1)	1.2 (1.6)	9.2 (34.6)	7.3 (53.2)
SEm±	**0.45**	**0.54**	**0.26**	**0.31**	**0.14**	**0.33**	**0.19**	**0.27**	**0.49**	**0.37**
LSD (P=0.05)	**1.03**	**1.25**	**1.02**	**1.29**	**0.46**	**1.07**	**0.63**	**0.88**	**1.59**	**1.21**
Weed control measure										
Weedy check	2.4 (5.9)	11.0 (121.8)	3.5 (12.4)	3.3 (10.9)	3.5 (12.2)	1.6 (2.5)	1.4 (1.9)	1.2 (1.5)	13.5 (182.7)	14.6 (215.7)
Pendimethalin *fb* imazathapyr	0.8 (0.6)	1.5 (2.2)	0.7 (0.4)	1.3 (1.7)	4.2 (18.0)	0.8 (0.7)	0.7 (0.4)	0.7 (0.4)	5.0 (25.5)	4.2 (17.6)
Metribuzin + 1 hand weeding	1.7 (3.1)	7.6 (57.7)	0.8 (0.6)	20.4 (416)	3.4 (11.5)	4.6 (21.8)	2.3 (5.5)	1.5 (2.3)	11.0 (121.4)	4.8 (23.1)
SEm±	**0.29**	**0.39**	**0.18**	**0.30**	**0.27**	**0.32**	**0.18**	**0.14**	**0.42**	**0.28**
LSD (P=0.05)	**0.62**	**1.71**	**0.53**	**0.89**	**0.79**	**0.93**	**0.54**	**0.4**	**1.25**	**0.81**

1.1.6. Weed management in maize-wheat-greengram cropping system under conservation agriculture

A field experiment was initiated in rainy season 2013 to study the long term effects of conventional tillage, zero tillage with and without crop residues and weed management on weeds and crop productivity in maize-wheat-green gram cropping system.

Maize

The major weed flora observed in the maize crop grown in rainy season 2013, comprised of *Echinochloa colona, Dinebra retroflexa, Cyperus iria, Eclipta alba, Oldenlandia corymbosa, Phyllanthus niruri, Mollugo* sp. and *Physalis minima.* Being the first season of experimentation, there was no significant difference due to different tillage methods on weed dry biomass (Table 18). However, both the weed management treatments significantly reduced the weed density and dry biomass as compared to unweeded control. The grain yield of maize was significantly higher under ZT treatment compared to CT (Table 18). The treatment, atrazine+ pendimethalin (0.5+0.5 kg/ha) PE *fb* 1 hand weeding 25 DAS recorded significantly higher yield than atrazine+ pendimethalin (0.5 + 0.5 kg/ha) PE *fb* 2,4-D (0.5 kg/ha) (3.43 t/ha) and unweeded control (1.81 t/ha).

Table 18: Weed growth and grain yield of maize as influenced by different tillage systems and weed management methods (rainy season, 2013)

Treatment	Weed population (no./m²)	Weed dry biomass (g/m²)	Plant height (cm)	Grain yield (t/ha)
Tillage				
CT (maize) – CT (wheat)	12.1(186.0)	6.8(61.7)	155	2.58
CT (maize) – ZT (wheat) –ZT (greengram)	8.6(86.8)	6.9(63.3)	165	2.49
ZT+R (maize) – ZT (wheat) – ZT+R (greengram)	8.3(71.7)	6.7(61.8)	156	3.46
ZT (maize) – ZT+R (wheat) –ZT+R (greengram)	7.8(70.0)	6.6(61.0)	156	3.55
ZT+R (maize) – ZT+R (wheat) –ZT+R (greengram)	8.6(106.0)	6.2(60.9)	178	3.48
LSD (P=0.05)	**1.20**	**NS**	**18.6**	**0.36**
Weed management				
Unweeded	13.7(203.0)	12.8(161.6)	145	1.81
Atrazine+pendimethalin(0.5+0.5 kg/ha) PE *fb* 2,4-D (0.5 kg/ha)	7.3(53.8)	4.5(22.3)	173	3.43
Atrazine+pendimethalin(0.5+0.5 kg/ha) PE *fb* 1 hand weeding 25 DAS	6.3(40.4)	3.1(9.1)	169	4.10
LSD (P=0.05)	**0.84**	**0.59**	**14.6**	**0.19**

CT – conventional tillage, ZT – zero tillage and R – residue

1.1.7. Long-term impact of herbicides in maize-chickpea cropping system under conservation agriculture systems

A long-term field experiment on the effect of crop establishment techniques and weed management under conservation agriculture was initiated from April, 2013 with the objectives to monitor weed dynamics, crop productivity, physico-chemical and biological properties of soil, and herbicide residues under maize-chickpea cropping systems. The experiment was laid out in bigger plots with five tillage methods and three weed management practices as main- and sub-treatment, respectively (Table 19).

The major dominating weeds were: *Echinochloa colona*, *Cyperus tenuispica*, *Dinebra retroflexa*, *Phyllanthus niruri* and *Physalis minima*. Among the tillage practices lesser weed density and dry biomass were recorded under zero-tillage as compared to conventional tillage, and weed management practices significantly reduced the weed density and dry biomass accumulation at different crop growth stages as compared to un-weeded situation. Among weed management practices higher grain yield was recorded under zero-tillage than conventional tillage, and atrazine+pendimethalin (PE) *fb* 1 hand weeding (HW) at 25 DAS recorded maximum grain yield among weed management practices. One hand weeding at 25 DAS performed better role to reduced the weed dry matter accumulation at 60 DAS and harvest as compare to 2,4-D application (Table 19).

Residue analysis of herbicide applied to maize

Soil and grain samples were collected after harvest of maize. Samples were extracted and cleaned up by standard methods. The extracts were analysed by LC-MS/MS. The residues of pendimerthalin and 2,4-D were not detected in any soil and grain samples. But the residues of atrazine were found in all soil samples from treated plots. Four degraded products of atrazine were also detected (Figure 8).

1.1.8. Impact of conservation tillage and weed management practices on growth and yield under cotton-wheat cropping system

A long term field trial was initiated from June 2013 to study the growth and yield of cotton with respect to different crop establishment methods and weed management practices and to monitor weed flora, C-sequestration, physico-chemical and biological properties of soil under cotton-wheat cropping system in vertisol of central India. The experiment was laid out in non replicated split plot

Table 19: Weed growth and grain yield of maize as influenced by different crop establishment techniques and weed management measures (2013)

Treatment	Weed density (no./m²) at 60 DAS	Weed dry biomass (g/m²) at 60 DAS	Weed dry biomass (g/m²) at harvest	Grain yield (t/ha)
Tillage				
CT- CT	8.9 (80.2)	80.0	146	2.54
CT- ZT- ZT	8.8 (78.3)	81.0	147	2.69
ZT + R- ZT- ZT + R	8.2 (68.4)	62.2	125	4.07
ZT- ZT + R- ZT + R	8.1 (66.1)	57.8	123	3.74
ZT + R- ZT + R- ZT + R	8.0 (64.7)	67.3	128	3.81
LSD (P=0.05)	**NS**	**17.5**	**22.8**	**0.43**
Weed management				
Weedy	11.1 (124.8)	151.6	207	2.02
Atrazine+pendimethalin (PE) *fb* 2,4-D at 30 DAS	7.2 (53.6)	39.8	114	3.72
Atrazine+pendimethalin (PE) *fb* 1 HW at 25 DAS	6.8 (47.0)	17.5	80.1	4.37
LSD (P=0.05)	**0.65**	**10.4**	**16.2**	**0.28**

Weed density data were subjected to $\sqrt{x + 0.5}$ transformation. Original values are shown in parentheses

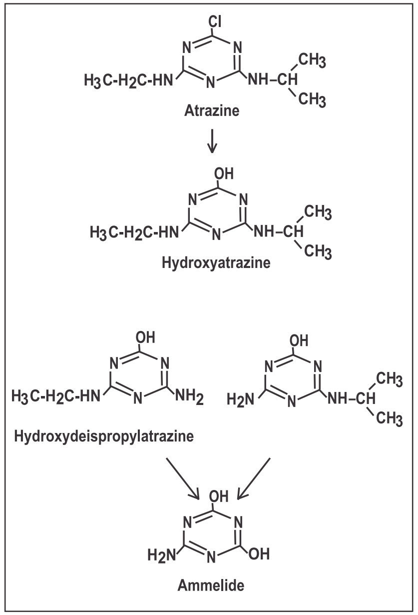


Figure 8: Degradation of atrazine in the soil of maize crop

design with bigger plot size (18 x 9 m). The main treatment consists of five main treatments (raised bed (T_1), permanent raised bed (T_2), convetional tillage (CT) + *Sesbania* (T_3), zero tillage(ZT) + residue (T_4), and conventional tillage (CT) (T_5). The sub plot treatment comprises 4 treatments (unweeded control (S_1), 2 hand weeding (2 HW) (S_2), pendimethalin *fb* 1 HW (S_3) and pendimethalin *fb* directed spray of glyphosate.

Dominant weeds in the field were: *Echinochloa colona, Cyperus* spp. *Phyllanthus* spp. and *Commelina communis* during rainy season. The results revealed that the crop establishment techniques and weed management practices significantly affected the population of different weed species. Significantly lower population of *Echinochloa colona* was recorded with convetional tillage (CT) + *Sesbania* than convetional tillage (CT) alone. Significantly higher population of *Phyllanthus spp* was recorded with raised bed treatments. However, the total weed dry weight did not differ significantly among different crop establishment methods (Table 20). The sub treatments had significant effect on different weed species and weed dry weight at 60 days after sowing (45 DAS). Significantly lower weed count and weed dry weight (7.8 g/m²) was recorded with the application of pendimethalin *fb* directed spray of glyphosate (Table 20).

The main treatments have significant effect on seed cotton yield. Significantly higher seed cotton yield (SCY) was found with raised bed treatments. Among weed management practices significantly higher SCY (608 kg/ha) was recorded with pendimethalin *fb* directed spray of glyphosate (Table 21).

Table 20 : Effect of treatments on different weed species no./m^2 in cotton

Treatment	*Echinochloa*	*Cyperus*	*Phyllanthus*	*Commelina*	Total weed dry (g/m²)
Crop stablishment					
Raised bed	11.0	18.6	29.3	6.0	16.7
Permanent Raised bed	10.9	19.4	20.8	7.0	14.9
CT+ Sesbania	5.7	17.2	7.5	4.5	22.5
ZR+ R	10.3	20.8	11.7	5.2	19.8
CT	17.6	16.5	9.83	4.58	18.9
LSD (P=0.05)	6.58	NS	6.37	1.88	NS
Weed management					
Weedy Check	22.2	35.4	29.0	8.6	36.7
Two HW	13.4	10.7	14.7	2.4	15.8
Pendimethalin+ one HW	5.4	21.0	14.4	5.1	14.0
Pendimethalin + protected application of glyphosate	3.5	6.2	5.1	5.8	7.8
LSD (P=0.05)	4.84	4.71	5.15	2.05	4.07

Table 21: Effect of treatments on yield attributes and seed cotton yield

Treatment	Bolls/plant	Lint weight/boll	Seed cotton weight/boll	Seed yield (kg/ha)
Crop establishment techniques				
Raised bed	11.1	1.16	3.27	613
Permanent Raised bed	11.6	1.01	2.83	595
CT+ Sesbania	8.1	0.72	2.79	423
ZR+ R	8.2	0.97	2.95	455
CT	8.94	0.84	2.82	391
LSD (P=0.05)	**2.91**	**0.41**	**0.49**	**128.9**
Weed control				
Weedy Check	6.6	0.76	2.74	343
Two HW	8.2	0.92	2.91	428
Pendimethalin+ one HW	10.3	0.96	2.93	542
Pendimethalin + protected application of glyphosate	13.2	1.12	3.15	608
LSD (P=0.05)	**2.48**	**0.17**	**NS**	**138.2**

1.2.1. Effect of organic weed management practices in rice–wheat cropping system

Wheat

In winter season (2012–13), wheat was grown in sequence after rice. Major weed flora observed were: *Medicago denticulata, Phalaris minor* and *Chenopodium album, Cichorium intybus* and *Vicia sativa.* Application of FYM @ 10 t/ha + 2 hand weeding at 25 and 45 DAS recorded the lowest weed density and weed dry biomass at 60 DAS followed by the treatment 50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS. (Table 22). Wheat grain yield was significantly higher (3.393 t/ha) under NPK + herbicide (T_6) than other treatments. Treatments T_3, T_7 and T_5 resulted in grain yield at par with each other but higher than T_1, T_2, T_4 and control. The unweeded control recorded 62.3% less grain yield than recommended NPK (120-60-40) kg/ha + herbicide.

Table 22 : Effect of treatments on weed density, weed dry biomass at 60 DAS, spikes/m^2 and yield of wheat (2012-13)

	Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Spikes/m^2	Grain yield (t/ha)
T_1	FYM @ 10 t/ha + stale seedbed *fb* 1 HW at 25 DAS	7.8 (63.2)	2.3 ((5.1))	162	1.62
T_2	FYM @ 10 t/ha + stale seedbed *fb* reduced spacing (15 cm)	11.3 (132.0)	6.7 (46.5)	165	1.26
T_3	FYM @ 10 t/ha + berseem intercropping	6.0 (37.0)	2.3 (5.6)	148	2.33
T_4	FYM @ 10 t/ha + mechanical weeding 25 and 45 DAS	8.8 (78.0)	4.9 (24.4)	136	1.58
T_5	FYM @ 10 t/ha + 2 hand weeding at 25 and 45 DAS	3.4 (11.0)	0.15 (0.4)	186	2.24
T_6	Recommended NPK (120-60-40) kg/ha + herbicide	8.2 (70.2)	3.8 (15.1)	237	3.39
T_7	50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS	5.7 (33.2)	1.4 (1.7)	174	2.31
T_8	Unweeded / unfertilized control	22.2 (494.2)	9.9 (97.4)	98	1.27
	LSD (P=0.05)	**1.96**	**1.24**	**67.1**	**0.409**

Weed data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses

1.2.2. Effect of organic weed management practices in soybean–wheat cropping system

Wheat

Wheat was grown during winter season (2012-13) in sequence after soybean (rainy season 2012). Major weed flora recorded were: *Medicago denticulata, Cichorium sp., Lathyrus sativa* and *Chenopodium album.* The lowest weed population was recorded under 50% NPK + 50% FYM and herbicide + 1 hand weeding (16.0/m^2) followed by the treatment of FYM @ 10 t/ha + berseem intercropping and FYM + stale-seedbed and 1 hand weeding as compared to unweeded control. Wheat grain yield was significantly higher (4.080 t/ha) under NPK + herbicide (T_6) than other treatments. Treatments T_7, T_3 and T_5 resulted in grain yield at par with each other but higher than T_1, T_2, T_4 and control (Table 23).

Table 23: Effect of treatments on weed density and biomass at 60 DAS, spikes/m^2 and yield of wheat (2012-13)

	Treatment	Weed density (no./m²)	*Weed dry biomass (g/m²)	Spikes /m²	Grain yield (t/ha)
T_1	FYM @ 10 t/ha + stale seedbed *fb* 1 HW at 25 DAS	6.2(42.0)	2.0(3.9)	228	2.20
T_2	FYM @ 10 t/ha + stale seedbed *fb* reduced spacing (15 cm)	11.7(136.0)	5.4(35.6)	181	1.68
T_3	FYM @ 10 t/ha + berseem intercropping	4.3(18.2)	2.3(4.7)	202	2.98
T_4	FYM @ 10 t/ha + mechanical weeding 25 and 45 DAS	9.2(120.5)	3.8(16.2)	237	1.98
T_5	FYM @ 10 t/ha + 2 hand weeding 25 and 45 DAS	6.9(50.0)	2.5(5.9)	238	2.65
T_6	Recommended NPK (120-60-40) kg/ha + herbicide	7.0(51.2)	2.8(7.7)	290	4.08
T_7	50% FY M + 50% NPK+ herbicide *fb* 1 hand weeding at 25 DAS	4.0(16.0)	1.4(1.4)	292	3.30
T_8	Unweeded / unfertilized control	19.6(387.0)	9.9(100.6)	226	1.61
	LSD (P=0.05)	**3.25**	**2.11**	**36.2**	**0.48**

Weed data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses

1.2.3. Effect of organic weed management practices in okra–tomato cropping system

Tomato

Tomato crop grown during winter season 2012–13 was infested with weed flora comparising mainly of *Medicago denticulata, Avena ludoviciana, Cichorium intybus, Anagallis arvensis* and *Phalaris minor*. Results revealed that the lowest weed density and biomass were recorded under FYM + black polythene mulch (Table 24). The highest tomato yield was also recorded under FYM with black polythene mulch (37.65 t/ha), which was at par with FYM @ 10 t/ha + 2 hand weeding (20.20 t/ha), as compared to unweeded control (1.55 t/ha. The loss in yield under unweeded control was 95.8% as against the black polythene mulch treatment.

Table 24: Effect of treatments on weed density and biomass at 60 DAS and yield of tomato (2012-13)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Fruit yield (t/ha)
T_1	FYM @ 10 t/ha + stale seedbed	15.0(229.0)	8.7(77.5)	3.18
T_2	FYM @ 10 t/ha + black polythene mulch	0.7(0.0)	0.7(0.0)	37.65
T_3	FYM @ 10 t/ha + straw mulch	13.2(179.6)	5.8(34.2)	5.91
T_4	FYM @ 10 t/ha + radish intercrop	18.5(345.0)	8.8(81.9)	5.88
T_5	FYM @ 10 t/ha + 2 hand weeding at 25 and 45 DAS	5.1(25.4)	3.6(13.5)	20.20
T_6	Recommended NPK (120-60-40) kg/ha + herbicide	11.8(147.0)	7.9(64.2)	7.66
T_7	50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding at 45 DAS	6.8(43.3)	4.1(21.2)	18.45
T_8	Unweeded / unfertilized Control	22.1(493.0)	11.7(137.5)	1.55
	LSD (P=0.05)	**4.13**	**2.14**	**7.45**

Weed data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses

1.2.4. Effects of crop establishment tillage and weed management practices on yield of wheat

Wheat

After harvest of rice, wheat was grown during *rabi* 2012-13 to study the effect of crop establishment methods practiced in rice on ZT and CT wheat under different weed management practices. The experiment was designed in spilt spilt plot, comprised of main treatments (transplanting, TP), puddled broadcast sowing with sprouted seed (PBSR), direct seeded rice (DSR) and system of rice intensification (SRI) during *kharif* season, sub-treatment (conventional tillage CT) and zero tillage (ZT) in wheat and sub sub treatment (mesosulfuron + iodosulfuron, sulfosulfuron + metsulfuron, clodinafop + 2,4-D and weedy check).

The field was infested with *Phalaris minor*, *Medicago hispida*, and *Chenopodium album*. Preceding treatments of crop establishment during *kharif* season did not have any significant effect on wheat yield and infestation of weeds. Whereas, tillage practices in wheat- zero tillage ZT) and conventional tillage (CT) resulted in significant effect on weed population and weed dry weight. Significantly higher population of *Medicago hispida* was recorded with ZT while CT recorded significantly higher population of *Chenopodium album*. Both the tillage practices were significantly similar for the population of *Phalaris minor*. Higher weed dry weight was recorded with ZT as compared to CT (Table 25). Among weed management treatments, sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron significantly reduced the population of *Phalaris minor* as compared to clodinafop + 2,4-D. All the weed management techniques significantly reduced the population of *Medicago hispida* and *Chenopodium album*.

Table 25: Effect of crop establishment practices of rice and tillage and weed management practices in wheat on dominant weed flora in wheat

Treatment	Weed count (no./m²)			Total weed dry weight (g/m²)
	Phalaris	*Medicago*	*Chenopodium*	
Treatment to rice				
DSR	6.3	38.7	1.1	17.0
Transplanting	5.2	48.6	2.3	17.5
SRI	9.6	51.5	2.5	19.0
PBSR	8.9	50.3	2.2	17.1
LSD (P=0.05)	**NS**	**NS**	**1.1**	**NS**
Treatment to wheat				
Weedy check	13.0	85.1	3.5	40.3
Sulfosulfuron + metsulfuron	4.0	34.4	1.0	8.3
Clodinafop +2,4-D	9.0	34.4	1.5	12.9
Mesosulfuron + iodosulfuron	4.1	35.2	2.2	9.1
LSD (P=0.05)	**3.22**	**9.3**	**1.43**	**5.96**
Treatment to wheat				
ZT	7.3	54.0	1.4	21.7
CT	7.7	40.6	2.7	13.6
LSD (P=0.05)		**5.4**	**1.20**	**4.98**

Different crop establishment practices of rice did not affect the yield and yield attributing characters of wheat.the tillage treatments in wheat also had no effect on yield and yield attributing characters. However, the weed and management techniques differ significantly for yield and yield attributing characters. Significantly higher number of spike/m² and yield was observed with all the weed management techniques as compared to unweeded control (Table 26).

Table 26 : Effect of crop establishment practices of rice and tillage and weed management practices in wheat on yield and yield attributing characters of wheat

Treatment	Spike length (cm)	Plant height (cm)	Spike/m²	Grains/spike	Grain yield (t/ha)
Treatments to rice					
DSR	11.1	78.9	265	61.2	5.11
Transplanting	10.9	79.2	259	59.6	4.92
SRI	11.0	78.6	257	57.6	4.66
PBSR	11.2	80.7	259	58.5	5.00
LSD (P=0.05)	**11.2**	**78.9**	**265**	**58.5**	**NS**
Treatments to wheat					
Weedy check	11.2	79.8	247	58.5	4.50
Sulfosulfuron+ metsulfuron	10.9	78.6	263	58.8	5.13
Clodinafop +2,4-D	11.2	82.3	263	57.2	5.04
Mesosulfuron +iodosulfuron	11.1	76.7	267	62.1	5.01
LSD (P=0.05)	**NS**	**2.27**	**12.2**	**NS**	**0.35**
Treatments to wheat					
ZT	11.1	79.4	257.9	58.1	4.85
CT	11.0	79.3	263.0	60.3	4.99
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**

Rice

An experiment was initiated in *kharif* 2011 and continued in 2013 to study the effect of crop establishment methods and weed management techniques on weeds and productivity of rice wheat system. The experiment was laid out in split plot design the main treatments consisted of four rice cultures viz. transplanting (TP), puddled broadcast sowing with sprouted seed (PBSR), direct seeded rice (DSR) and system of rice intensification (SRI) and the sub treatment comprises four weed management practices i.e. weedy check, herbicide alone (bispyribac-sodium 25 g/ha), herbicide (bispyribac-sodium 25 g/ha) + 1 hand weeding (20 DAS DAT/DAS) and 2 hand weeding (20 and 45 DAS/DAT) .

The dominant weed flora of the field were *Echninochloa colona, Cyperus* spp. *Eclipta alba* and *Caesulia axillaris*. Different crop establishment practices significantly affected the weed population of different species. Significantly higher population of *Echninochloa colona* was recorded under DSR while lowest population of *Cyperus* spp. was observed with DSR. Significantly lower population of *Echninochloa colona* was recorded with SRI, TP and PBSR. Significantly higher population of *Cyperus* spp. was observed with PBSR as compared to DSR. The PBSR also accounted for higher weed dry weight (Table 27). Under weed management practices bispyribac alone and bispyribac + 1 HW significantly reduced the population of *Echninochloa colona* and *Cyperus* spp. The close perusal of the data revealed that the bispyribac has lesser impact on controlling *Eclipta alba* and spp. *Caesulia axillaris*. All the weed management practices and 2 HW recorded significantly lower weed dry weight as compared to unweeded control (Table 27).

Crop establishment methods had significant effect on yield and yield attributing characters. Minimum effective tillers per m² were recorded with

Table 27 : Effect of treatments on weed count and dry weight in rice

Treatment	Weed count (no./m²)				Total weed dry weight (g/m²)
	Echinochloa	*Cyperus*	*Eclipta*	*Caesulia*	
Crop establishment methods					
DSR	8.8	5.2	0.2	3.5	56.8
Transplanting	4.0	8.5	1.6	2.3	43.3
SRI	4.1	6.5	0.4	3.5	51.0
PBSR	5.8	10.3	0.3	4.1	68.7
LSD (P=0.05)	**2.60**	**4.3**	**0.81**	**NS**	**NS**
Weed management					
Weedy check	10.2	10.8	1.0	3.0	108.9
Bispyribac	4.6	7.3	0.6	4.0	48.2
Bispyribac + one HW	3.5	5	0.3	2.5	33.6
Two HWs	4.4	7.4	0.5	3.8	28.9
LSD (P=0.05)	**2.12**	**4.45**	**NS**	**NS**	**38.05**

SRI which was at par with TP and significantly lower to PBSR and DSR. The reverse trend was observed for 1000 seed weight, panicle length and plant height. Significantly higher panicle length, 1000 seed weight and plant height were recorded under SRI, leading to significantly higher yield (3.90 t/ha) as compared to other crop establishment practices. Among weed management practices significant difference was observed for plant height, effective tillers/m^2 and grain yield. The highest value for these characters were recorded with 2 HW which was at par with bispyribac + 1 HW and bispyribac alone and all were significantly superior over unweeded control (Table 28).

Table 28: Effect of different crop establishment techniques and weed management on growth and yield of rice

Treatment	Plant height (cm)	Panicle length (cm)	1000-seed weight (g)	Effective tillers/m²	Yield (t/ha)
Crop establishment methods					
DSR	108	20.4	23.9	222	3.05
Transplanting	112	23.3	25.0	189	3.3
SRI	121	24.6	25.7	178	3.9
PBSR	117	21.9	24.8	205B	3.1
LSD (P=0.05)	**6.5**	**0.96**	**1.08**	**26.1**	**0.31**
Weed management					
Weedy check	112	22.4	25.0	170	2.7
Bispyribac-sodium	113	22.1	24.9	197	3.3
Bispyribac-sodium + one HW	118	22.4	24.7	214	3.5
Two HWs	115	23.4	24.8	223	3.7
LSD (P=0.05)	**3.4**	**NS**	**NS**	**24.4**	**0.32**

1.2.5. Long term effect of weed management practices on weed dynamics and crop productivity in soybean-wheat cropping system

Weed management practices influence the weed dynamics and crop productivity of crops in a cropping system. However, these effects are visible only on long term basis. Soybean–wheat is an important cropping system of the country more particularly in Madhya Pradesh. Hence, a field experiment was initiated during rainy season of 2013 in soybean–wheat system to know the effects of various weed management practices on weeds and crop yields.

Soybean

Major weed flora in soybean crop comprised of *Echinochloa colona, Cyperus iria, Phyllanthus niruri, Physalis minima, Portulaca oleracea, Commelina benghalensis* and *Euphorbia geniculata*. Results revealed that application of metribuzin PE *fb* one hand weeding and imazethapyr 20 DAS *fb* one hand weeding reduced the weed biomass to the minimum and were at par with 2 hand weedings (Table 29). The next best treatment was metribuzin PE *fb* imazethapyr 20 DAS. The soybean crop withered out due to continuous rains during the season, hence seed yield could not be obtained.

Table 29: Effect of treatments on weed density and weed dry biomass at 60 DAS in soybean (2013)

Treatment	Weed density (no./m^2)		Weed dry biomass (g/m^2)
	20 DAS	60 DAS	
Metribuzin 500 g/ha PE	7.8(60.3)	8.0(65.0)	9.3(87.7)
Imazethapyr 100 g/ha 20 DAS	10.3(110.3)	7.4(54.7)	6.3(39.0)
Metribuzin 500 g/ha PE *fb* 1 hand weeding 40 DAS	6.9(48.7)	5.8(34.0)	1.9(3.4)
Metribuzin 500 g/ha PE *fb* Imazethapyr 100 g/ha 20 DAS	9.1(88.3)	6.3(39.7)	4.0(16.4)
Imazethapyr 100 g/ha 20 DAS *fb* 1 hand weeding 40 DAS	10.4(111.7)	5.1(26.7)	2.7(8.6)
Reduced spacing (30 cm) + metribuzin 500 g/ha PE	7.7(58.7)	7.8(61.3)	9.5(89.5)
2 hand weedings 20 and 40 DAS	11.8(141.3)	3.8(14.7)	2.3(5.1)
Unweeded	11.8(141.3)	8.4(70.3)	11.8 (142.5)
LSD (P=0.05)	**2.45**	**1.67**	**1.63**

Weed data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses

1.2.6. Cropping system approach for weed management in mango orchard

Weed management in mango orchards can be accomplished by growing weed suppressive intercrops throughout the cropping seasons. Hence, an experiment was initiated in rainy season of 2013 to evaluate various intercrops in sequence for weed suppression in mango orchard. The major weed flora infesting the mango orchard were *Echinochloa colona, Dinebra retroflexa, Cyperus iria, Alternanthera sessilis* and *Oldenlandia corymbosa*. The results revealed that growing sesbania and sunhemp in the inter spaces of mango trees could reduce the weed density at 60 DAS by 94.6 and 94.3%, respectively (Table 30).

Table 30: Effect of treatments on weed density and weed dry biomass at 60 DAS in mango orchard (rainy season, 2013)

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)
Sesbania(R)-pea(W)-cowpea (S)	8.5	2.9
Sunhemp(R)-pea(W)-green gram (S)	9.0	1.7
Soybean(R)-pea(W)-sesbania (S)	65.5	94.9
Sorghum(R)-pea(W)-sunhemp (S)	46.5	80.2
Glyphosate 2.0 kg/ha (R-W-S)	20.5	14.6
Unweeded	159.5	131.8
LSD (P=0.05)	**36.9**	**33.1**

R= Rainy season, W = Winter season, S = summer season

Mango orchard intercropped with sunhemp

1.3.1 Weed management in soybean

Soybean is the most important oilseed crop grown in India. The productivity of soybean is low because of heavy infestations of weeds during the initial slow growth stages of the crop. A field trial on integrated weed management was conducted during rainy season 2013 in randomized complete block design, replicated thrice. Treatments comprised of different pre-emergence (PE) herbicides (pendimethalin 1000 g/ha and metribuzin 500 g/ha); post-emergence (PO) herbicides (imazethapyr 100- and 150 g/ha, and chlorimuron 9- and 13.5 g/ha); hand weeding (25 and 45 DAS) and un-weeded check as control. The post-emergence herbicides chlorimuron-ethyl and imazethapyr were applied at 25 and 30 DAS, respectively.

Major weed floras were: *Cyperus rotundus*, *Echinochloa colona*, *Physalis minima*, *Phyllanthus niruri*, *Dinebra retroflexa*, *Ammannia baccifera*, *Commelina benghalensis*, *Alternanthera sessilis* and *Corchorus* spp.

Among pre-emergence herbicides pendimethalin had better weed suppressing effect as compared to metribuzin. Pendimethalin controlled the germination of small seeded grassy and broad leaved weeds viz., *E. colona*, *D. retroflexa* and *A. baccifera*. Pre-emergence herbicides were not effective to inhibit the germination of purple nut sedge. Pendimethalin *fb* imazethapyr recorded lowest total weed density and dry biomass among the weed management practices at 50 DAS. Sole application of chlorimuron-ethyl (9 and 13 g/ha) was not effective to suppress the weed growth. Due to dominating nature of weeds, plant height observed was minimum in un-weeded plot. Herbicides did not have any negative effect on nodulation in soybean at 45 DAS. From pendimethalin *fb* imazethapyr treated plot, plants accumulated maximum dry biomass as compared to other weed management practices (Table 31). During rainy season the amount of rainfall was ~ 85 % higher than the average annual rainfall and resulted inwater logged condition during initial growth stages, and during latter stage crop was totally damaged by yellow mosaic virus infestation. This resulted total failure of soybean crop.

1.3.2. Screening of different mustard varieties against glyphosate

Orobanche is becoming a major challenge for mustard growers. A group of scientists from Hisar (Haryana) found that the low dose application of glyphosate was an effective measure to manage the weed in mustard. With this background a field experiment was carried out during *rabi* season of 2012-13 with an objective to screen out different mustard varieties for glyphosate resistance. Treatment comprised of six mustard varieties ('NRCHB 101', 'NRCHB 506', 'NRCDR 2', 'Rohini', 'Maya' and 'Laxmi') with different glyphosate doses (control, 40, 50, 60, 80 and 100 g/ha) applied at different crop growth stages (25, 35, 45 and 55 DAS).

During initial growth period (25 and 35 DAS) when glyphosate was applied at higher rate (80 and 100 g/ha), it caused negative effect on mustard plant height, dry biomass accumulation and leaf area. Red pigmentation was observed on mustard leaves due to glyphosate application. Glyphosate applied at latter stage caused yellowing of upper leaves but plant recovered after few days, and no yield penalty was observed. Glyphosate applied at higher rate (80 and 100 g/ha) at 25 and 35 DAS had some detrimental effect on seed yield and yield attributing characters in mustard. Lower doses (40, 50 and 60 g/ha) of glyphosate at 25 and 35 DAS were selective against mustard plant. Glyphosate applied at latter stages did not have any detrimental effect on crop growth, yield and yield attributing characters.

Table 31: Effect of weed management practices on weed and soybean

Treatment	Dose (g/ha)	Weed density (no./m²)		Weed dry biomass (g/m²) at 50 DAS	Plant height (cm)	Nodule count/ plant	Plant shoot dry biomass (g/plant)
		25 DAS	50 DAS				
Pendimethalin *fb* imazethapyr	1000 *fb* 100	9.7 (94.3)	7.3(53.9)	4.3	57.1	18.3	4.8
Pendimethalin *fb* chlorimuron	1000 *fb* 9	10.1 (102.5)	10.2 (103.7)	11.3	57.3	20.9	4.0
Metribuzin *fb* imazethapyr	500 *fb* 100	14.4 (208.9)	9.8(96.7)	10.5	58.8	19.4	4.1
Metribuzin *fb* chlorimuron	500 *fb* 9	13.9 (196.8)	11.21(125.1)	26.5	58.6	18.0	4.1
Imazethapyr	100	17.0 (291.0)	11.1 (123.1)	16.5	56.7	17.7	4.7
Imazethapyr	150	17.3 (301.8)	9.3(87.7)	18.2	56.1	20.0	4.5
Chlorimuron	9	16.6 (277.9)	12.7 (160.9)	40.8	56.9	21.4	4.2
Chlorimuron	13.5	17.2 (296.4)	11.2 (125.1)	32.0	58.5	19.1	4.2
2 hand weedings		18.3 (338.0)	9.9(98.4)	5.2	58.9	21.1	4.71
Weedy check		16.3 (269.2)	13.4 (181.5)	49.7	55.2	17.8	3.6
LSD (P=0.05)		**2.67**	**2.52**	**12.87**	**NS**	**NS**	**1.16**

Weed density data were subjected to $\sqrt{x+0.5}$ transformation. Original values are shown in parentheses

Effect of glyphosate applied at early (a) and later stage (b) on mustard

1.3.3. Evaluation of nitrogen fertilizer and weed management practices in zero-till transplanted rice

An experiment was conducted to evaluate varying levels of N, fertilizer and different weed management practices in zero-till (ZT) transplanted rice. Treatments comprised of different nitrogen levels (0, 40, 80, 120 and 160 kg N/ha) as main factor and weed management practices as sub-factor (Table 32). The post-emergence herbicides were applied at 25 days after transplanting (DAT), and hand weeding was done at 25, 55 and 75 DAT.

There was no significant effect of N application on weed density at different growth stages of rice crop. Application of herbicides effectively reduced the total weed population at 50 DAT as compared to un-weeded check. When N was applied at lower doses (40, 80, 120 and 160 kg N/ha), the weed dry matter accumulation was higher as compared to recommended and higher dose of N application.

Among fertilized plots minimum weed dry weight at 50 DAT was recorded when fertilizers were applied at recommended or higher doses (120 and 160 kg N/ha) rather than lower doses. Among herbicides bispyribac+2,4-D at 25+500 g/ha effectively reduced dry biomass accumulation by weeds at 50 DAT as compared to fenoxaprop 60 g/ha application. Hand weeding treatment significantly reduced total weed dry biomass at harvesting stage as compared to other treatments. Due to severe weed infestation under zero-till transplanted condition and scanty rainfall at latter growth stage, crop performance was poor and resulted lower yield. Application of N fertilizer and weed management practices did not leave any significant effect on plant height. With increasing dose of N fertilizer, tiller number also increased but there was no significant difference of weed management practices on tiller number. Fertilizer applied at recommended or higher doses gave significantly higher yield than lower doses. Among weed management practices maximum yield was recorded from hand weeded pots and it was at par with bispyribac+2,4-D (Table 32).

Table 32: Effect of nitrogen and weed management practices on weed growth and performance of zero-till transplanted rice

Treatment	Weed density (no./m²)		Weed dry biomass (g/m²)		Plant height (cm)	Tillers /m²	Panicles /m²	Grain yield (t/ha)
	25 DAS	50 DAS	50 DAS	Harvest				
Nitrogen level (kg/ha)								
0	12.3 (151)	10.3 (106.7)	182	189	71.5	228	203	1.11
40	12.0 (143)	9.0 (80.5)	221	233	72.2	246	222	1.51
80	12.0 (143)	10.0 (101.0)	275	439	71.8	233	237	1.70
120	12.0 (143)	9.6 (93.0)	181	363	70.8	277	253	1.91
160	13.7 (188)	10.1 (103.3)	194	195	71.6	273	251	1.94
LSD (P=0.05)	**NS**	**NS**	**48.9**	**122.4**	**NS**	**24.28**	**26.55**	**0.16**
Weed management								
Bispyribac+2,4-D (25+500) g/ha	12.7 (160)	8.37 (69.5)	51	318	71.1	249	242	1.91
Fenoxaprop 60 g/ha	11.8 (140)	8.09 (64.9)	321	361	71.3	259	240	1.74
3 hand weedings	13.0 (169)	11.00 (120.5)	114	61	70.9	255	236	1.98
Weedy	12.0 (144)	11.54 (132.8)	356	396	73.1	242	214	0.89
LSD (P=0.05)	**NS**	**1.30**	**66.28**	**94.1**	**NS**	**NS**	**18.27**	**0.17**

Weed density data were subjected to $\sqrt{x+0.5}$ transformation. Original values are shown in parentheses

1.3.4. Integrated weed management in summer greengram

A field experiment was carried out during summer season of 2013 with an objective to identify a judicious combination of pre- and post-emergence herbicides and intercultural operations for managing weeds in greengram. Treatments comprised of pre-emergence (PE) herbicides (pendimethalin 1000 g/ha and imazethapyr 100 g/ha); post-emergence (PO) herbicides (imazethapyr 100 g/ha and quizalofop-p-ethyl 60 g/ha); and hand weeding and hoeing as inter-culture operation. The post-emergence herbicides and intercultural operations were applied at 25 days after sowing (DAS).

Purple nut sedge (*Cyperus rotundus*) was the main dominant weed species found on experimental site. Other weeds were *Echinochloa colona, Paspalidium flavidum*, *Dinebra retroflexa* and *Eleusine indica* among grasses, and *Ipomoea obscura, Commelina diffusa, Euphorbia geniculata*, *Convolvulus arvensis, Physalis minima, Alternanthera sessilis*, *Phyllanthus niruri, Portulaca oleracea* and *Corchorus aestuans* among broad leaved weeds.

Pendimethalin (PE) controlled the germination of grassy weeds. The imazethapyr as PE did not have any effect on the germination of grassy weeds, both the pre-emergence herbicides were not effective to inhibit the germination of purple nut sedge. At 45 DAS, the imazethapyr 100 g/ha (PE) *fb* hoeing at 25 DAS was least effective on grassy weeds. The PO herbicides i.e imazethapyr and quizalofop-p-ethyl, and inter culture operations effectively suppressed the growth of grassy weeds. The growth of purple nut sedge was controlled by the post-emergence application of imazethapyr and quizalofop-p-ethyl. The inter culture operations were most effective to control the broad leaved weeds. The maximum total weed density was recorded from weedy plot. Except pendimethalin (PE) alone and imazethapyr (PE) *fb* hoeing, all the weed management practices performed well to suppress the total weed density. Slight suppressing effect on plant height in greengram was observed with the application of imazethapyr as PO. Among weed management practices, pendimethalin (PE) *fb* quizalofop-p-ethyl (PO) recorded maximum number of branches and pods per plant. Significantly higher seed yield of greengram were recorded from pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of either quizalofop-p-ethyl 60 g/ha or imzethapyr 100 g/ha at 25 DAS (Table 33).

Table 33 : Effect of weed management practices on weed density, growth and seed yield of greengram

Treatment	Weed density (no./m²)		Plant height (cm)	Branches/ plant	Pods/ plant	Seed yield (kg/ha)
	20 DAS	45 DAS				
Pendimethalin 1000 g/ha (PE)	7.2(52.3)	5.9(34.7)	34.9	5.2	17.3	520
Imazethapyr 100 g/ha (PO)	7.8(64.7)	4.1(17.7)	33.8	5.6	20.4	670
Pendimethalin 1000 g/ha (PE) *fb* imazethapyr 100 g/ha (PO)	6.6(44.9)	3.0 (9.1)	33.8	5.6	22.6	750
Pendimethalin 1000 g/ha (PE) *fb* quizalofop 60 g/ha (PO)	6.5(42.8)	3.7(13.5)	39.1	6.0	24.8	750
Pendimethalin 1000 g/ha (PE) *fb* hoeing	6.4(43.9)	3.9(15.0)	35.6	5.6	20.3	570
Imazethapyr 100 g/ha (PE) *fb* hoeing	6.9(54.9)	5.7(32.6)	35.0	5.1	17.4	540
Pendimethalin 1000 g/ha (PE) *fb* HW	6.5(44.3)	4.1(16.6)	38.3	5.4	21.1	660
Weedy check	7.6(57.6)	7.2(51.3)	34.4	4.6	13.7	460
LSD (P=0.05)	**NS**	**1.24**	**4.83**	**0.76**	**4.21**	**227**

HW - hand weeding. Weed density data were subjected to $\sqrt{x+0.5}$ transformation. Original values are shown in parentheses

1.3.5. Effect of post-emergence herbicides on purple nut sedge in summer greengram

Among the pulses, greengram (*Vigna radiata*) is one of the most important and extensively cultivated crops. It is grown during rainy and summer seasons. The productivity of greengram is low because of heavy infestations of weeds including *Cyperus rotundu*. during the initial slow growth stages. With this background, a field experiment was conducted during summer season of 2013 with an objective to evaluate different post-emergence herbicides for managing purple nut sedge in greengram. Treatments comprised of quizalofop-p-ethyl 60 g/ha, imazethapyr 100 and 150 g/ha as post-emergence herbicide, hoeing as non chemical approach and un-weeded check as control. The applications of post-emergence herbicides and hoeing were done at 25 days after sowing (DAS).

Purple nut sedge (*Cyperus rotundu*) was the main dominant weed species found on experimental site. Other weeds were *Echinochloa colona, Paspalidium flavidum*, *Dinebra retroflexa Commelina diffusa, Physalis minima, Alternanthera sessilis*, *Phyllanthus niruri, Parthenium hysterophorus* and *Asphondelus trnuifolius*.

The post-emergence herbicides significantly reduced the density of purple nut sedge at 50 DAS as compared to hoeing and un-weeded situation. Hoeing was not effective against purple nut sedge because purple nut sedge has underground tubers and corms (the "nuts" or "nutlets") which are not controlled by interculture operation as tubers of the weed act as a primary source of its infestations. Imazethapyr at 100 and 150 g/ha effectively reduced the total weed density at 50 DAS, as compared to other treatments. The maximum plant height was observed in hoeing as means of weed management, but there was no significant difference among treatments on number of branches per plant at harvest. All the weed control measure were at par in respect to seed yield, but the maximum yield was recorded from imazethapyr (150 g/ha) treated plot (Table 34).

Table 34 : Effect of weed management practices on weed population, crop growth and seed yield of greengram

Treatments	*Cyperus rotundus* (no./m²)		Total weed (no./m²)		Plant height (cm)	Branches /plant	Seed yield (t/ha)
	25 DAS	50 DAS	25 DAS	50 DAS			
Quizalofop 60 g/ha	7.8 (62.4)	5.6 (32.4)	9.2 (85.6)	10.8 (123.1)	25.1	5.67	0.49
Imazethapyr 100 g/ha	6.6 (43.5)	5.4 (31.4)	7.5 (57.4)	9.0 (81.3)	25.6	6.27	0.53
Imazethapyr 150 g/ha	6.9 (49.4)	3.7 (14.5)	7.8 (61.5)	6.1 (37.8)	29.9	7.40	0.58
Hoeing	7.3 (53.2)	8.9 (80.7)	8.0 (64.9)	10.6 (116.6)	31.5	5.93	0.47
Weedy	7.2 (52.2)	9.5 (91.5)	8.1 (66.5)	11.9 (141.9)	29.7	6.15	0.20
LSD (P=0.05)	**NS**	**2.31**	**1.50**	**3.91**	**5.1**	**NS**	**0.138**

Weed density data were subjected to $\sqrt{x+0.5}$ transformation. Original values are shown in parentheses

1.3.6. Effect of pre-emergence herbicides on weed flora and seed yield of sesame

A field experiment was conducted during summer season of 2013 to find out suitable pre-emergence herbicide for weed control during early growth stages of sesame. The experiment was laid out in randomized block design, replicated thrice, comprised of 8 treatments with different groups of herbicides viz., pendimethalin 750 g/ha (dinitroaniline), oxyfluorfen 150 g/ha (diphenyethers), imazethapyr 60 g/ha (imidazolinone), metribuzin 200 g/ha (triazines), pendimethalin 750 g/ha + imazethapyr 50 g/ha, imazethapyr 35 g/ha + imazamox 35 g/ha (imidazolinone), two hand weedings (15 and 30 DAS) and weedy check.

The most dominant broad leaved weeds were: *Alternanthra philoxeroides, Cichorium intybus* and *Euphorbia geniculata,* and grassy weeds were *Digitaria sanguinalis, Dinebra retroflexa* and *Echinocloa colona*. The pre-emergence herbicides had varied response over broad and narrow leaved weeds. Among the pre-emergence herbicides tried, pendimethalin + imazethapyr showed better control over *Alternanthra philoxeroides* (Table 35) and was at par with pendimethalin alone and other herbicides tried, except imazethapyr + imazemox , which showed that its doses had no impact on *Alternanthra philoxeroides*. Metribuzin controlled *Cichorium intybus* effectively and was statistically similar to oxyfluorfen. Pendimethalin controlled approximately 50% infetstation of *Cichorium intybus* whereas imazethapyr had negligible effect on it. Emergence of *Euphorbia geniculata* was checked by imazethapyr + imazamox followed by oxyfluorfen and imazethapyr. All the broad leaved and narrow leaved weeds were effectively controlled by two handweeding (2 HW) and lowest population of all the weeds (broad and narrow leaved) were observed with this treatment except *Alternanthra philoxeroides*. Significantly higher population of grassy as well as broad leaved weeds were recorded in weedy check. Significantly higher plant height, number of branches per plant, number of capsules and seed yield were recorded with 2 HW, while weedy check yielded the lowest values (Table 36). All the pre-emergence herbicides reduced the plant height of sesame but significantly lower plant height was observed with oxyfluorfen and imazethapyr + imazamox when compared with 2 HW and untreated check. Dinitroanilines were much safer to sesame as compared to imidazolinone, triazines and diphenyethers.

Table 35: Effect of pre-emergence herbicides on density and dry matter of weeds in summer sesame

Treatment	Weed density (no./m²)						Weed dry mass (g/m²)
	A. philoxeroides	*C. intybus*	*E. geniculata*	*D. sanguinalis*	*D. Retroflexa*	*E. colona*	
Pendimethalin 750g/ha	2.0	13.1	9.0	2.8	1.3	5.1	28.7
Oxyfluorfen 150 g/ha	3.4	5.8	1.7	1.2	4.3	11.4	33.6
Imazethapyr 60 g/ha	3.7	18.7	3.4	1.7	1.6	7.0	33.7
Metribuzin 200 g/ha	5.3	3.6	6.6	2.9	4.0	4.5	24.1
Pendimethalin 750 + imazethapyr 50 g/ha	1.7	16.2	4.6	2.2	1.3	4.1	23.0
Imazetha pyr 35 g/ha + imazamox 35 g/ha	9.3	20.4	1.2	1.8	1.3	7.1	26.1
Two hand weedings	3.6	4.6	1.3	1.6	1.0	1.7	16.2
Weedy check	8.6	25.7	6.4	3.84	4.3	12.9	75.4
LSD (P=0.05)	**5.05**	**7.39**	**7.37**	**1.09**	**4.23**	**4.88**	**11.16**

Table 36: Effect of pre-emergence herbicides on seed yield and yield attributing characters of sesame

Treatment	Plant height (cm)	Branches/ plant	No. of capsules/plant	Test weight (g)	Seed yield (kg/ha)
Pendimethalin 750g/ha	105	5.6	55.1	3.1	546
Oxyfluorfen 150 g/ha	80	3.6	31.3	3.1	373
Imazethapyr 60 g/ha	92	3.8	41.8	3.0	411
Metribuzin 200 g/ha	98	4.6	45.8	3.0	459
Pendimethalin 750 + imazethapyr 50 g/ha	104	5.1	52.4	3.0	531
Imazethapyr 35 g/ha + imazamox 35 g/ha	82	3.3	31.7	3.0	342
Two hand weedings	109	7.1	66.7	3.0	682
Weedy check	107	3.2	29.1	3.1	271
LSD (P=0.05)	**23.2**	**1.74**	**15.25**	**NS**	**55.4**

1.3.7. Deciding optimum dose of herbicides in mixture using dose response curve

A field experiment was conducted in *kharif* 2013 to decide optimum dose of herbicides in mixture using dose response curve in rice crop. The experiment comprised of treatment combinations of two herbicides fenoxaprop and metsulfuron at different doses 30, 40, 50, 60 g/ha and 2.5, 3, 3.5, 4 g/ha respectively to control grassy and broad leaved weeds. The experiment was laid out in 2^5 factorial Randomized Block design with 3 replications. There was diverse weed flora in the field. Dominant weeds in the field were: *Echinochloa colona, Alternanthera sessilis, Euclipta alba, Ludwigia adscendenus, Dinebra retroflexa, Cyperus iria, Ammania bacifera* and *Commelina benghalensis.* Fenoxaprop controlled grassy weeds at recommended dose but at lower dose it failed to control the weeds. It reduced the population of *Echinochloa colona* very significantly. On the other hand, metsulfuron controlled all broad leaved weeds significantly even at lower dose than recommended levels. Growth parameters of the rice crop, viz., plant

height and panicle length were not influenced by the herbicides. After 12 days from the application of herbicides, data on % weed control by different doses of two herbicides was observed and dose response models were fitted to the data. Among many models, Dose Response Hill Model was found to be the best fit.

Dose-Response Hill function is given by:

$$y = \delta + \frac{\alpha x^{\theta}}{\varphi^{\theta} + x^{\theta}}$$

where, y is the % weed control, δ is intercept, $\alpha = y_{max}$, x denote the dose, θ is the hill coefficient of sigmoidicity and φ denote the ED_{50} value or the dose with which 50% control was obtained. Before fitting the model, error assumptions (normality, randomness and homogeneity of the error variance) were confirmed with studentized residuals and Shapiro-Wilk normality test. Data were found to be non-normal, therefore arc sine transformation was applied to make it normal. Hill model describes the relationship between the dose and % weed control for the present data. From the investigation of fenoxaprop doses 30, 40, 50 and 60 g/ha, a Hill model was fitted to fenoxaprop alone as well as in mixture data.

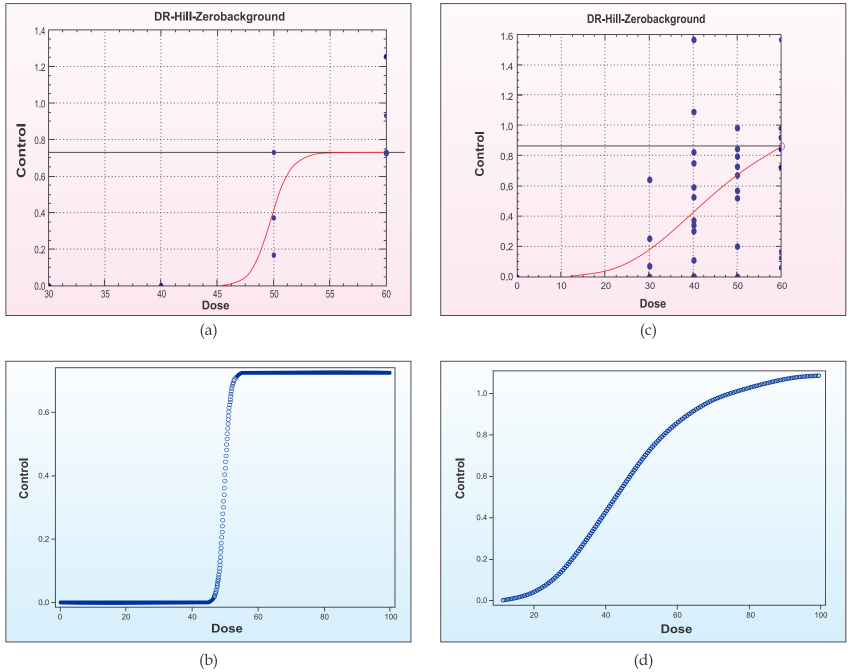


Figure 9: (a) Dose response curve of % weed control (arc sine value) of grassy weeds in rice crop with fenoxaprop alone from 30 to 60 g/ha doses. (b) Fenoxaprop alone dose response curve Hill equation: y=(0.726*dose^57.06)/(49.71^57.06 + dose^57.06). (c) Dose response curve of %weed control (arc sine value) of grassy weeds in rice crop with fenoxaprop in mixture from 30 to 60g/ha doses. (d) Fenoxaprop (in mixture) dose response curve Hill equation: y=(1.13*dose^4.05)/(44.9 ^ 4.05 + dose^4.05)

The figure 9(a) revealed that only 68% of grassy weed control was observed even with full dose of fenoxaprop when applied alone. Its ED_{50} value was estimated as 49.71 g/ha from the fitted model. It was clear from figure 9(c) that when fenoxaprop applied in mixture with metsulfuron, its control increased from 68 to 73%. Its ED_{50} value was lower dose i.e. 44.9g/ha as compared to fenoxaprop alone.

For fitting the data of metsulfuron at different doses, hill model was used for both metsulfuron alone as well as in mixture data.

It was clear from figure 10 (a) that when metsulfuron was applied alone, it controled all broad leaved weeds even at lower doses than recommended levels. Its ED_{50} value was obtained as 1.68 g/ha when applied alone but it increases to 2.94 g/ha when applied with fenoxaprop in mixture. Hence, it can be inferred from this data that fenoxaprop had some antagonistic effect on metsulfuron when applied in mixture. However it needed to be confirmed. It was found that, 52.81 g/ha of fenoxaprop and 2.73 g/ha of metsulfuron should be used to get the maximum control of broad and grassy weeds, when applied in mixture.

1.4 Standardization of spraying techniques and mechanical tools for weed management

1.4.1 Evaluation of spray application techniques for weed management in crops

Spray application techniques viz. medium low volume (MLV), low volume (LV), medium high volume (HV) and very low volume (VLV) were evaluated in wheat and soybean crops during *Rabi* 2012-13 and *Kharif* 2013. The herbicide was applied at different spray volumes according to the spray application techniques with the help of selected hydraulic nozzles using knapsack sprayer. The spinning disc CDA atomizer was used for very low volume spray application. The spray volumes applied in treatments have been detailed (Table 37).

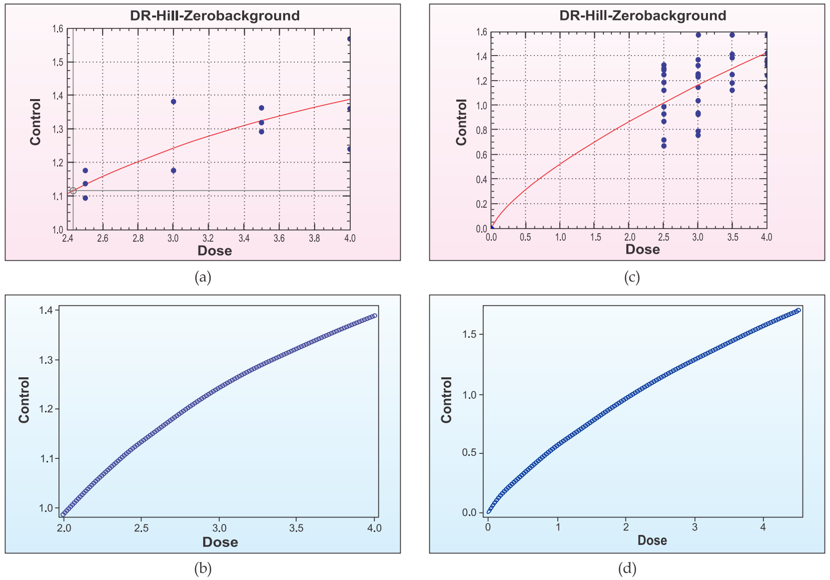


Figure 10: (a) Dose response curve of % weed control (arc sine value) of broad leaved weeds in rice crop with metsulfuron alone from 2.5 to 4g/ha doses. (b) Metsulfuron alone dose response curve Hill equation: y=(1.74*dose^1.58)/(1.68^1.58+ dose^1.58). (c) Dose response curve of % weed control (arc sine value) of broad leaved weeds in rice crop with metsulfuron in mixture from 2.5 to 4 g/ha doses. (d) Metsulfuron in mixture dose response curve Hill equation: y=(0.821*dose^5.28)/(2.94 ^ 5.28+ dose^5.28)

Laboratory tests of selected fan nozzles were carried out to determine their discharge rate, operating pressure, swath width covered and speed of operation (Table 38). The spray volume was calculated from the values of operating parameters obtained from laboratory tests for fan type, flat fan nozzles and spinning disc atomizer to be used for herbicide application. The fan nozzles were selected to get the required spray volume as per treatments of the experiment. The field calibrations of selected nozzles were done prior to actual application of herbicide in spray treatments.

Table 37: Different spraying application techniques (spray volume) applied in experiment

Spraying technique	Spray Volume (L/ha)	Nozzle used
Medium low volume	100	Flat fan nozzle (hdp, red tip)
Low volume	200	Fan nozzle (brass, 60675)
Medium high volume	300	Fan nozzle (hdp, blue tip)
High volume	400	Fan nozzle (brass, WFN 78)
Very low volume	40	Spinning disc (CDA) atomizer
-	Weed free	Hand weeding
-	Weedy	No weed control measures

The field experiment with seven treatments and three replications was carried out in RBD in wheat crop during *Rabi* 2012-13. The herbicide mesosulfuron + iodosulfuron @ 1.0 kg/ha was applied in wheat. The experimental plot size was 9 x 6 m. The data have been shown in Table 39.

The weeding efficiency based on dry weight were non-significant among different spray volume treatments but were significantly different when compared with weed free and weedy plots. The weeding efficiencies based on weed count were non-significant in treatments of medium low volume (T_1), low volume (T_2), very low volume (T_5) and medium high volume (T_3). The weeding efficiency based on weed count were also non-significant in treatments of high of volume (T_4), medium high volume (T_3) and very low volume (T_5). The weeding efficiency on weed count attained in different spraying treatments were significantly different when compared with weed free and weedy plots. The grain yield of wheat crop in different spraying treatments were non-significant but were significantly different when compare with weed free and weedy plots.

Table 38: Discharge rate, operating pressure, swath width and speed of operation and application rate attained with different spray nozzles during spraying operation

Nozzle Type	Discharge rate (mL/min)	Liquid pressure (kg/cm²)	Swath width (cm)	Speed of operation (m/min)	Applica tion rate (L/ha)
Fan nozzle (HDP) red tip	270	1.5	69	38.8	100.8
Fan nozzle (brass) 60675	684	1.5	80	42.0	203.6
Fan nozzle (HDP) blue tip	1038	1.5	80	42.0	308.9
Flat fan nozzle (brass) WFN 78	1408	1.5	80	42	419.0
Spinning disc atomizer	43	Atmospheric pressure	40	35.0	30.7

Table 39: Weed control efficiency and seed yield of wheat in different spraying treatments (*Rabi* 2012-13).

Treatment	Spray volume (L/ha)	Weed control efficiency (%)		Seed yield (t/ha)
		Weed count	Dry weight	
Medium Low Volume (MLV)	100	6.8 (50.1)	7.1 (51.1)	3.44
Low Volume (LV)	200	7.1 (53.5)	7.2 (54.2)	2.69
Medium High Volume (MLV)	300	7.7 (60.1)	7.5 (57.2)	3.30
High Volume (H.V)	400	8.2 (68.8)	7.7 (59.6)	3.76
Very LowVolume (VLV)	40	7.4 (55.0)	7.1 (51.2)	3.02
Weed free	Weed free	9.3 (87.5)	9.2 (84.9)	4.38
Weedy	No weed control	0.00 (0.70)	0.0 (0.7)	2.22
LSD (P=0.05)		**0.86**	**0.99**	**0.349**

High Volume

Medium High Volume

Low Volume

Medium Low Volume

Very Low Volume

Weed control attained in different spray treatments in wheat

Field experiment was carried out to evaluate different spray volume (l/ha) for application of herbicide imazethapyr in soybean crop during *Kharif* 2013. The experimental plot size was 4.5 X 6 m. The data have been shown in Table 40.

Variations of weed control efficiencies based on weed count were non-significant in low volume (T_2) and medium high volume (T_3) and also non-significant in low volume (T_2) and very low volume (T_5). The weeding efficiencies based on weed count

Table 40: Weed control efficiencies attained in different spraying treatments in soybean (*Kharif* 2013)

Treatment	Spray volume (L/ha)	Weeding efficiency (%) (weed count)	Weeding efficiency (%) dry weight
Medium Low Volume (MLV)	100	60.7	1.88 (47.8)
Low Volume (LV)	200	68.5	2.15 (50.0)
Medium High Volume (MHV)	300	69.8	2.37 (52.4)
High Volume (HV)	400	73.8	1.88 (58.6)
Very Low Volume (VLV)	40	66.7	2.22 (52.8)
Weed free	Weed free	92.5	2.30 (89.9)
Weedy	No weed control measures	0.0	1.91)(0.0)
LSD (P=0.05)		**0.16**	**0.18**

and dry weight achieved in high volume (T_4), medium low volume (T_1), weed free (T_6) and no control (T_7) treatments, were significantly different. The weeding efficiencies based on dry weight attained in low volume (T_2), medium low volume (T_1), medium high volume (T_3) and very low volume (T_5) spray treatments were non-significant. The crop established and grows well during July month. The soybean crop failed in *kharif* 2013 due to continuous rains in August and September months.

3 RESEARCH PROGRAMME – 2

WEED DYNAMICS AND MANAGEMENT UNDER THE REGIME OF CLIMATE CHANGE AND HERBICIDE RESISTANCE

Behaviour of invasive and agronomic weeds with changing climatic regimes is poorly understood, though it is of potential importance for production and protection of agriculture and, for human and animal health, environment and natural biodiversity. Greater genetic variability and/or sustained selection pressures due to repeated use of herbicides and herbicides with similar sites of action may prompt recurrence of herbicide resistances in weeds. Changing climatic factors further complicate the puzzle of crop-weed interaction and hence effectiveness of weed management practices. Thus, understanding behaviour of weeds and development of herbicide resistance under the regime of climate change is an urgent need for the development of weed management strategies. Weed risk analysis and weed seed/seedling identification are crucial for the seed producers, scientists, farmers and policymakers. In order to make weed seed identification user-friendly for stakeholders, it is desirable to develop interactive software for identification of weed seeds/seedlings. Keeping in view these aspects, the research programme has been focused on understanding complex behaviour of crops and weeds and development of herbicide resistance in weeds under the regime of climate change.

Sub-programme	Experiments	Associates
2.1. Effect of climate change on crop-weed interactions, herbicide efficacy and bioagents	2.1.1. Effect of elevated CO_2 on physiological, biochemical and molecular aspects in chickpea and dominant weed species	Bhumesh Kumar, Meenal Rathore and Raghwendra Singh
	2.1.2 Effect of elevated CO_2 on rice and weedy rice biotypes	Meenal Rathore, Bhumesh Kumar, Raghwendra Singh and Dibakar Ghosh
	2.1.3. Effect of elevated CO_2 on herbicidal activity of parthenium leaves on aquatic weeds	D.K. Pandey
	2.1.4. Performance of major aquatic weeds under elevated CO_2	D.K. Pandey
	2.1.5. Performance of major invasive aquatic weeds under temperature regimes	D.K. Pandey
	2.1.6. Herbicidal activity of parthenin under temperature regimes	D.K. Pandey
2.2. Physiological and molecular basis of herbicide resistance development in weeds and evaluation of herbicide - tolerant crops	2.2.1. Screening of herbicide resistance in different biotypes of *Phalaris minor*	Bhumesh Kumar , Meenal Rathore and Raghwendra Singh
	2.2.2. Response of broadleaf weeds to 2,4-D dimethylamine salt	D.K. Pandey
	2.2.3. Status of bispyribac-sodium tolerance in *Echinochloa* sp.	D.K. Pandey
2.3. Development of weed seed identification tools and weed risk analysis	2.3.1. Development of weed seed identification tools	Bhumesh Kumar, Meenal Rathore and Raghwendra Singh
	2.3.2. Weed spread risk potential of seeds of some of the important weeds	D.K. Pandey
2.4. Others	2.4.1. Spinach (*Spinacia oleracea*) leaf herbicidal to noxious aquatic weed water hyacinth	D.K. Pandey

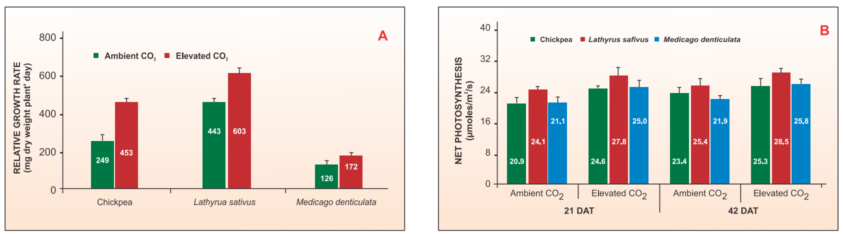
2.1. Effect of climate change on crop-weed interactions, herbicide efficacy and bioagents

2.1.1. Effect of elevated CO_2 on physiological, biochemical and molecular aspects in chickpea and dominant weed species

Effect of elevated CO_2 on chickpea and weed species (*Lathyrus sativus* and *Medicago denticulata*) was studied in open top chambers (OTCs). Chickpea (cv. JG-16) was sown following recommended practices. Weed population was maintained 20 plants/m^2 (10 of each species). Plants of the above three species were exposed to ambient CO_2 (385±5 ppm) and elevated CO_2 (550±50 ppm) from emergence to physiological maturity of chickpea. Salient findings of the experiment are given below.

Enrichment of atmospheric CO_2 had a positive effect on overall growth of chickpea plants as well as weed species (*L. sativus* and *M. denticulata*). Promotion in growth at elevated CO_2 was evident from higher relative growth rate (RGR) at elevated CO_2 as compared to that at ambient CO_2 in all the three species under study (Figure 1A). At ambient CO_2, RGRs/ were calculated as 249, 448 and 126 mg dry weight/plant/day in chickpea, *Lathyrus* and *Medicago*, respectively. At elevated CO_2, RGRs were 453, 603 and 172 mg dry weight/plant/day in chickpea, *Lathyrus* and *Medicago*, respectively (Figure 1A). Rate of photosynthesis increased in all the three species when plants were exposed to elevated CO_2 (Figure 1B). At 21 DAT, elevated CO_2 treatment resulted an increase in photosynthesis by 17.5, 15.0 and 18.2% in chickpea, *Lathyrus* and *Medicago*, respectively, while, at 42 DAT, increase was 8.3, 12.3 and 17.8% in chickpea, *Lathyrus* and *Medicago*, respectively. On the other hand, decrease in stomatal conductance was observed in all the three species irrespective of sampling stages (Figure 1C). At 21 DAT, elevated CO_2 treatment resulted a decrease in stomatal conductance by 18.2, 19.4 and 18.9% in chickpea, *Lathyrus* and *Medicago*, respectively, while, at 42 DAT, decrease was 16.5, 16.2 and 17.1% in chickpea, *Lathyrus* and *Medicago*, respectively. Similarly, rate of transpiration also decreased in chickpea, *Lathyrus* and *Medicago* at elevated CO_2 as compared to that at ambient CO_2 irrespective of sampling stage (Figure 1D). At 21 DAT, elevated CO_2 exposure led a decrease in transpiration by 16.6, 13.8 and 12.0% in chickpea, *Lathyrus* and *Medicago*, respectively, while, at 42 DAT, decrease was 8.8, 9.8 and 9.8% in chickpea, *Lathyrus* and *Medicago*, respectively as compared to ambient CO_2. In general, exposure to elevated CO_2 brought about 10 days advancement of reproductive stage in all the three species (data not given).

Exposure of plants to elevated CO_2 had a positive effect on activity of carbonic anhydrase in all the three species (chickpea, *Lathyrus* and *Medicago*) at both the sampling stages. however, increase in carbonic anhydrase activity at elevated CO_2 was more in two weed species as compared to chickpea (Figure 1E) and may be a contributing factor to the observed higher rates of photosynthesis at elevated CO_2. Similarly, activity of nitrate reductase increased in all the three species when plants were exposed to elevated CO_2 (Figure 1F). At 21 DAT, exposure to elevated CO_2 resulted an increase in activity of nitrate reductase by 6.6, 10.8 and 10.5% in chickpea, *Lathyrus* and *Medicago*, respectively, while, At 42 DAT, increase was 5.3, 9.3 and 11.6% in chickpea, *Lathyrus* and *Medicago*, respectively.



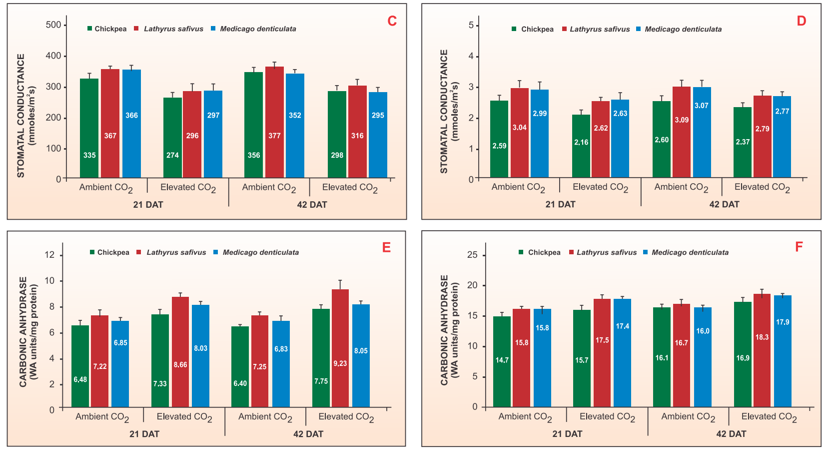


Figure 1: **Effect of elevated CO_2 on relative growth rate (A), net photosynthesis (B), stomatal conductance (C), transpiration (D), activity of carbonic anhydrase (E) and activity of nitrate reductase (F) in chickpea and associated weeds (*L. sativus* and *M. denticulata*) at 21 and 42 days after treatment**

Isoenzymes activity profile (native PAGE) of antioxidant enzymes [superoxide dismutase (SOD), guaiacol peroxidase (POX) and glutathione reductase (GR)] depicts differential regulation as well as induction of new iso-forms in response to elevated CO_2 at 21 DAT (Figure 2). Weed species especially *Lathyrus* exhibited stronger antioxidant defence as compared to chickpea pointing towards an involvement of antioxidant defence system in adaptation to climate change condition.

Expression of genes involved in antioxidant defence pathway altered in chickpea at elevated CO_2 at 21 DAT (Figure 3). DHAR showed down-regulation while CAT2, chloroplastic CuZnSOD, APX1 and

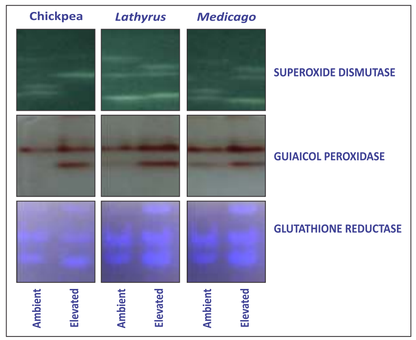


Figure 2: **Effect of elevated CO_2 on isoenzymes of superoxide dismutase, guaiacol peroxidase and glutathione reductase in chickpea and associated weeds (*L. sativus* and *M. denticulata*) at 21 days after treatment. (Colour was reverted in case of glutathione for better visibility of bands)**

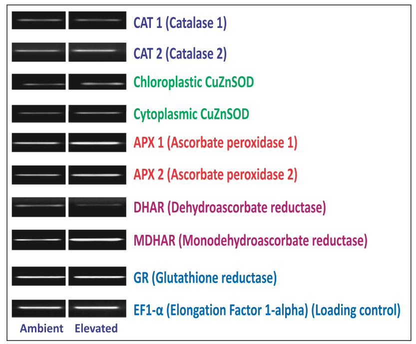


Figure 3: **Effect of elevated CO_2 on transcript level of genes involved in antioxidant defence pathway in chickpea at 21 DAT**

APX2 and showed up-regulation at elevated CO_2. A marked up-regulation was noticed in transcript level of MDHAR when plants were exposed to elevated CO_2, however, transcript level of cytoplasmic CuZnSOD and GR was unaffected. Differential regulation of genes involved in antioxidants defence pathways pointed towards involvement of these genes in adaptation to high CO_2 environment.

2.1.2. Effect of elevated CO_2 on rice and weedy rice biotypes

Weedy rice is expected to be a more severe problem in the future regime of climate change. Hence, the effect of elevated CO_2 (550 ± 50 ppm) on growth of weedy rice was studied using open top chambers. Two weedy rice accessions along with cultivated rice were germinated and grown in the OTC's maintained at elevated and ambient CO_2 concentrations. No significant variation was observed in germination percent and germination index amongst the lines tested (Figure 4).

Elevated CO_2 had significant effect on total leaf area, number of tillers/plant, net photosynthesis and transpiration in cultivated rice and weedy rice biotypes used in the experiment. Real-time PCR of ascorbate peroxidase reveal variations in expression levels amongst weedy rice themselves and with cultivated rice (Figure 5). The expression levels of *APX* decreased in weedy rice biotypes but increased in cultivated rice at elevated CO_2 as compared to that at ambient CO_2 suggesting possible role of this enzyme in adaptation to high CO_2 environment.

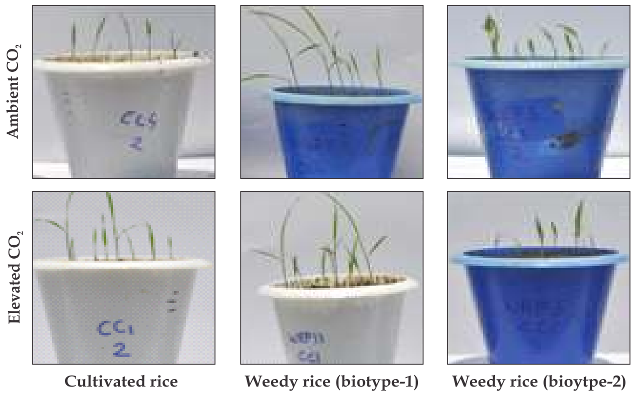


Figure 4: Effect of elevated CO_2 on germination of cultivated and weedy rice

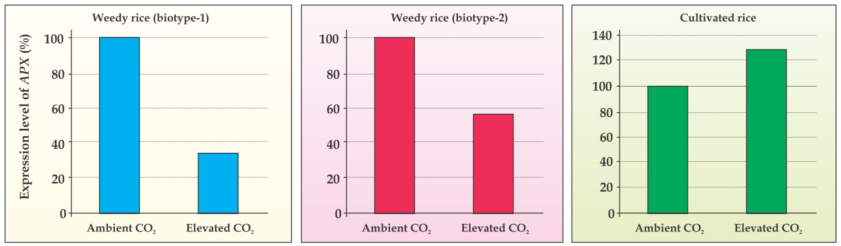


Figure 5: Variation in expression levels of ascorbate peroxidase (APX) in cultivated and weedy rice biotypes at elevated CO_2

2.1.3. Effect of elevated CO_2 on herbicidal activity of *Parthenium* leaves on aquatic weeds

Herbicidal activity of *Parthenium* leaves obtained from ambient and elevated CO_2 (550±50 ppm) grown stands of the weed on representative floating and submerged aquatic weeds was investigated. Preweighed aquatic weeds were placed in Parthenium leaf residue suspensions obtained from stands of the weed grown at ambient and elevated (550±50 ppm) CO_2 in the OTC. Biomass and toxicity symptoms were monitored. The results showed that there was no distinct trend of the herbicidal activity in the leaves obtained from the plants grown in different CO_2 regimes. The ambient CO_2 grown leaf residue levels lethal for the aquatic weeds *Eichhornia crassipes*, *Pistia stratiotes*, *Lemna pausicostata*, *Spirodella polyrhiza*, *Hydrilla verticillata*, *Ceratophyllum demersum*, *Potamogeton crispus* and *Chara zeylanica* were 0.5, 0.25, 0.5, 0.5, 0.25, 0.25, 0.5 and 0.1% (dry weigh / volume), respectively against corresponding lethal levels of 0.5, 0.5, 0.5, 0.5, 0.25, 0.1, 0.5 and 0.05% in the elevated CO_2 grown leaf residue. However, phenolics in the leaves of elevated CO_2 grown plants had higher (>60.6%) phenolics than the leaves of ambient CO2 grown plants ($P<0.05$).

2.1.4. Performance of major aquatic weeds under elevated CO_2

Major invasive floating aquatic weeds *Eichhornia crassipes*, *Pistia stratiotes*, *Spirodella polyrrhiza*, *Lemna pausicostata* and *Azolla pinnata*, and submerged aquatic weeds *Hydrilla verticillata*, *Ceratophylum demersum*, *Najas graminea*, *Potamogeton crispus* and *Chara zeylanica* were grown in 25% nutrient medium at ambient and elevated (550±50 ppm) CO_2 in open top chambers and their performance was compared. Elevated CO_2 did not show distinct effect on performance of the weeds over a short period.

2.1.5. Performance of major invasive aquatic weeds under temperature regimes

Major invasive floating aquatic weeds *Eichhornia crassipes*, *Pistia stratiotes*, *Lemna pausicostata*, *Spirodela polyrrhiza* and *Azolla nilotica*, and submerged aquatic weeds *Hydrilla verticillata*, *Ceratophylum demersum* and *Potamogeton crispus* were allowed to grow in 25% nutrient medium at 25 and 30°C in containment of the Directorate. Performance of the weeds were monitored as change in biomass over initial values and compared.

2.1.6. Herbicidal activity of parthenin under temperature regimes

Parthenin was tested at 10, 15 and 20 ppm for herbicidal activity on pondweed (*Potamogeton crispus*) at 20, 27 and 35°C under illumination (photosynthetic photon flux density of about 200 $\mu Em^2/g$) and toxicity and biomass were monitored. Herbicidal activity of parthenin on the weed was more prominent at 35^{0}C proving lethal as compared to showing toxicity but not proving lethal at 20 and 27^{0}C.

2.2. Physiological and molecular basis of herbicide resistance development in weeds and evaluation of herbicide-tolerant crops.

2.2.1. Screening of herbicide resistance in different biotypes of *Phalaris minor*

Different biotypes of *Phalaris minor* were collected from Pantnagar, UP, Delhi, MP, Punjab and Haryana and tested against different herbicides (isoproturon, pinoxaden, Atlantis (mesosulfuron + iodosulfuron) and total (sulfosulfuron + metsulfuron) at recommended doses for resistance.

Biotypes of *P. minor* from Pantnagar, Faizabad (U.P.), IARI and Jabalpur showed no or very low degree of resistance against isoproturon (Figure 6). Biotypes from Punjab showed medium (Talwandi) to high (Rajpura and Barnala) resistance against Isoproturon while biotypes from Haryana (Pipli, Panipat and Narwana) showed very high resistance against isoproturon. Biotypes from Haryana and Punjab also showed resistance against Pinoxaden, Atlantis, and Total in addition to Isoproturon.

2.2.2. Response of broadleaf weeds to 2,4-D dimethylamine salt

Herbicide 2,4-D dimethylamine salt at x (750 g/ha), 2x and 3x was tolerated by some of the plants of some major broad leaf weeds of Rabi season. Some of the sprayed plants recovered and were able to flower and formed seeds as well. The weeds which showed tolerance in the initial evaluation include *Convolvus arvensis*, *Melilotus alba*, *Cichorium intybus*, *Solanum surattense*, *Lathyrus sativa*, *Medicago denticulate*, *Solanum viarum*, *Chenopodium album*, *Lathyrus aphaca* and *Euphorbia geniculata*. Seeds form the plans that recovered were collected and will be investigated

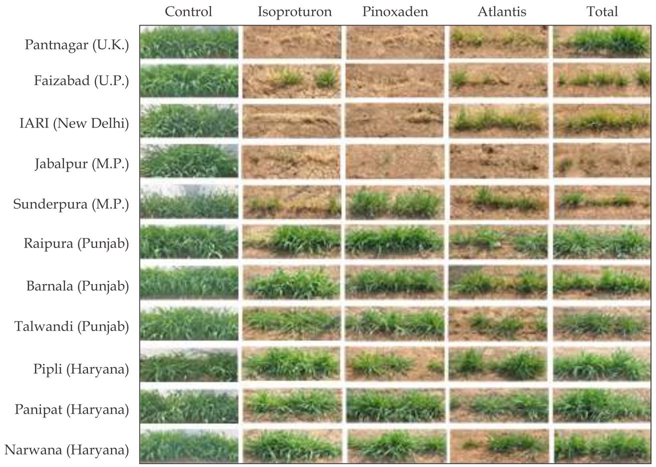


Figure 6: Evaluation of different biotypes of *Phalaris minor* for resistance against different herbicides

further for ascertaining status of the herbicide tolerance.

2.2.3. Status of bispyribac-sodium tolerance in *Echinochloa* species

Bispyribac-sodium tolerance was evaluated in *Echinochloa crusgalli*, *Echinochloa colona* and *Echinochloa glabrescens* lines collected locally and those obtained from Pantnagar and Hyderabad. Some of the lines showed tolerance to the herbicide. The experiment was repeated at another site and the herbicide tolerance by some of the lines was established. Seeds were obtained from the plants withstanding x (25 g/ha), 2x and 4x levels of the herbicide.

2.3. Development of weed seed identification tools and weed risk analysis

2.3.1. Development of weed seed identification tools

Images of different weeds at different stages (i.e. seeds, imbibed seeds, and their reproductive parts) have been taken for the purpose develop weed identification software and weed atlas. Information regarding 16 weeds has been compiled for weed atlas. Images of few weeds at different stages are given in Figure 7.

2.3.2. Weed spread risk potential of seeds of some of the important weeds

Spread of weeds through viable seeds is one of the primary mechanisms of infestations. Thus, it is necessary to know viability of seeds of the weeds at or near ambient environment to predict their weed spread risk potential when such seeds are contaminants or trapped in diverse niches like food grains and their raw products, crop seed lots and in transported and transportable packaging and packaged materials. At present, such valuable information on the extent of viability of weed seeds at or near ambient conditions is rare in the scientific literature. Hence, investigations were undertaken to find out longevity of weed seeds at ambient temperature with a view to assess weed spread risk potential of some of the important weeds.

Seeds of weeds were collected from their stands since 1992. The seeds were allowed to dry at ambient conditions, moisture contents measured, and kept in glass containers at ambient temperature (30±15°C). Viability (germination) of the seeds was tested at yearly intervals. The tests were repeated at least thrice in each case and the data were done mean plus minus standard deviation.

Figure 7: Images of weeds (seeds, germinating seeds and reproductive structure) at different stages

Different weeds have species specific temperatures facilitating germination. Some of the seeds had hard seed coat requiring wearing out of the coat naturally or scarification for facilitating for germination testing in the laboratory. The weed seeds lost viability almost abruptly as is evident from years to 50% germination were close to the years to lose viability, except in *Phalaris minor* (Table 1). The weed seeds included in the study had viability extending from 6-13 years depending on the species.

Table 1: Viability of weed seeds at ambient condition

Weed species	Moisture content (FW)	Germination testing temperature (^{0}C)	Initial germination (%)	Years to 50% germination decline	Years to lose viability
Alternanthera sessilis	9.7	20	96±3	5	8
Asphodelus tenuifolius	9.7	25	56±2	4	6
Avena ludoviciana	9.8	20	95±2	5	6
Cassia sericea	9.8	30 (HSS)	95±4	8	10
Cassia tora	9.4	30 (HSS)	96±2	7	9
Caesulia axullaries	9.9	25	49±3	5	6
Chenopodium album	10.2	15/25	68±5	8	9
Cichorium intybus	10.6	25	92±2	6	9
Echinochloa glabrescens	9.4	30	95±3	9	11
Euphorbia geniculata	10.2	30 (HSS)	95±2	6	7
Ipomoea hederacea	11.4	25	94±2	11	13
Ischaemum rugosum	9.2	20	94±1	9	11
Medicago denticulata	10.5	25 (HSS)	94±3	10	13
Melilotus alba	9.8	15/25 (12 h cycle)	94±3	8	10
Parthenium hysterophorus	9.6	20	98±1	5	7
Phalaris minor	9.8	18	91±4	3	7
Rumex dentatus	9.3	15/25	93±3	7	10
Trifolium flagiferum	10.3	30	92±2	6	8

Values are means ± SD of three replications. FW - Fresh weight basis, and HSS - Hard seeds scarified.

Viability of weed seeds, referred to as weed spread risk potential, was 6 - 10 years in 13 species and 11 - 13 years in remaining 4 species. The seeds of these species trapped in diverse niches sustain risks of infestation for the seed viability durations. Weed seed contamination of these species need to be checked and contaminated seed be destroyed for preventing their infestation to newer areas and to check intensification of infestation to already infested areas.

2.4. Others

2.4.1. Spinach leaf herbicidal to noxious aquatic weed water hyacinth

Though synthetic herbicides have proved to be magic molecules greatly facilitating weed management in crops and reducing labour, yet their use has potential environmental and toxicological costs raising question about our agricultural dependence on these molecules. The natural products and their relatives have been viewed as sources of potential environment-friendly herbicides and offer attractive possibilities for natural molecules derived herbicides. There is rising interest in exploring plant constituents as a source of eco-friendly herbicide formulations. Prompted by these considerations, spinach (*Spinacea oleracea* L.) was evaluated for herbicidal activity on noxious aquatic weed water hyacinth (*Eichhornia crassipes* Mart Solmns.).

The spinach was grown in the field during winter season of 2012-13, leaves were harvested, quickly washed, blot dried and then further dried in the shade, powdered and suspended at different levels in a standardized nutrient medium. Pre-weighed water hyacinth plants were placed with their roots immersed in the medium comprising nutrient medium (controls) or the spinach leaf powder suspended in it at 0.1, 0.25, 0.5, 0.75 and 1% dry w/v in 500 ml volume in plastic containers and kept outdoors during March 2013. Biomass and toxicity symptoms were monitored. Phenolics were estimated in the spinach residue suspensions. Electrical conductivity and pH of the medium were also measured.

The spinach leaf residue showed potential phytotoxicity on water hyacinth at 0.75 -1.0% (Table 2). At low levels of the residue (0.1-0.5%), water hyacinth growth was not conspicuously affected. However, it inhibited the treated plants at and above 0.75% killing them in 10-15 days after initiation of the treatment.

Table 2: Herbicidal activity of spinach leaf residue (SLR) on water hyacinth outdoors

Treatment (SLR % w/v)	Change in biomass over initial value days after initiation of the treatments		
	5	10	15
Control	12±6	27±7	45±10
0.1	8±1	17±3	28±5
0.25	9±1	18±3	35±11
0.5	9±4	8±18	-4±22
0.75	-33±11	-52±8	-100
1.0	-26±2	-64±1	-100

Values are means of three replications ± SD. Hundred % reduction in biomass shows death of the treated plants.

Table 3: Changes in phenolic contents in the medium containing spinach leaf residue at lethal level (0.75%, w/v) without (blank) or with water hyacinth plants (treated) with time outdoors

Treatment	Changes in phenolics (ppm) in the medium days after initiation of the treatments			
	0	5	10	15
Blank	256±6	200±10	159±6	82±4
Treated	261±4	120±5	52±6	32±2

Values are means of three replications ± SD.

The water hyacinth plants caused rapid dissipation of the phenolics in the residue suspensions (Table 3). Further work is necessitated to identify the active constituents and elucidation of mechanism of action of the active molecules. Examination of role of the phytotoxic constituents in competitive and or allelopathic interactions of the species under field conditions with reference to weed management would be interesting.

4 RESEARCH PROGRAMME - 3

BIOLOGY AND MANAGEMENT OF PROBLEMATIC WEEDS IN CROPPED AND NON-CROPPED AREAS

In recent years, some weeds have gained the status of problematic weeds. Weedy rice in rice is the one in many states of India. During last decade, *Orobanche* has emerged as another in mustard and tobacco besides tomato and brinjal. Likewise, *Chromolaena odorata*, which was a menace in North East States, Kerala, Tamil Nadu, and Karnataka, has also now become a common weed in Jagdalpur area of Chhattisgarh. The weed is spreading its tentacles in larger area of Chhattisgarh and it is feared that it may enter into Maharashtra and Madhya Pradesh in due course. Among the aquatic weeds, *Pistia stratiotes* has spread in aquatic ponds in and around Jabalpur where it was not a serious weed in the last decade. The programme has been taken to address biology and management of these problematic weeds.

Sub-programme	Experiments	Associates
3.1. Biology and management of problematic weeds in cropped areas	3.1.1. Characterization of weedy rice biosimilars	Meenal Rathore, Raghwendra Singh, Bhumesh Kumar and Dibakar Ghosh
	3.1.2. Incidence of *Orobanche* on different varieties of mustard	C. Kannan
3.2. Biology and management of problematic weeds in non-cropped areas	3.2.1. Integrated management of *Chromolaena odorata*	Sushil Kumar
3.3. Biology and management of aquatic weeds	3.3.1. Integrated management of *Pistia stratiotes*	Sushil Kumar, Shobha Sondhia and Yogita Gharade
	3.3.2. Effect of inoculation of *Alternaria alternata* and *A. eichhorniae* in water hyacinth on fishes	C. Kannan

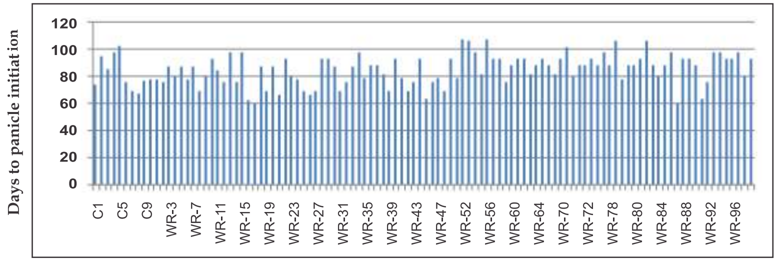
3.1. Biology and management of problematic weeds in cropped areas

3.1.1. Characterization of weedy rice biosimilars

Being a natural hybrid of cultivated and wild rice, weedy rice has properties of both rice types and, as a result, varied properties. The origin of weedy rice varies across geographical regimes, and hence properties also tend to vary. Variations in flowering phenology are expected, and hence a total of 112 weedy rice accessions collected from 8 states of India and 6 lines of wild rice were transplanted in experimental field along with 10 cultivated rice varieties in an augmented block design for documenting the days to panicle initiation (DTPI) and days to 50% flowering from date of transplanting. Statistical analysis revealed significant variation in these parameters amongst test cultivars and weedy rice accessions (Figure 1). The accessions studied could be divided into three groups based on days to panicle initiation - the first having 10 members with panicle initiation 52-65 days after transplanting, the second with 94 members taking 66-87 days for panicle initiation and the third group with only 5 members requiring 88-97 days for panicle initiation.

Earliest 50% flowering was observed in a weedy rice accession from Madhya Pradesh and the latest in weedy rice from West Bengal and Chhattisgarh. Standing water/flooding is known to suppress weedy rice emergence. But still, weedy rice is known to occur. This indicates that weedy rice has capacity to grow in standing waters, though the ability to do so may vary across accessions. Efforts were made to assess existing variability for germination under anaerobic conditions in weedy rice.

Fifty five accessions of weedy rice along with ten varieties of cultivated rice were tested for



Accessions of rice and weedy rice

Figure 1: Significant variations in days to panicle initiation amongst rice cultivars and weedy rice accessions

germination when placed 1 cm below soil surface and covered with 6 cm. standing water. Tetrazolium test was also conducted to assess viability of seeds that had not germinated under anaerobic conditions. Among the sixty five accessions studied, only twenty seven germinated. The 38 accessions that had not germinated included six cultivated rice, and responded positive to the tetrazolium test indicating that the seeds were viable but did not germinate under existing anaerobic conditions

The accessions that germinated included four rice cultivars and 23 weedy rice accessions. Variations were observed in cultivated and weedy rice for the parameters studied. However, there was no significant variation amongst cultivated rice. Amongst weedy rice accessions studied, highest germination (100%) was recorded in accessions from Madhya Pradesh (M.P.) and Kerela (100%) (Table 1). This accession from MP also had the highest vigor index (2928) which was significantly superior over the others. On the other hand, few accessions revealed very poor germination (20%) and vigor indices. Immense variation was found amongst the weedy rice accessions studied for the parameters observed with significant differences in all, except root length.

It is known that seed burial along with flooding can help manage germination of weedy rice in infested fields. Considering the variations in germination evident in weedy rice, a study was conducted to determine the effect of seed burial and flooding depth on emergence of different weedy rice accessions from major rice growing states of India viz., Madhya Pradesh, Jharkhand, Uttar Pradesh, Chhattisgarh, Bihar, and Kerala along with cultivated

Table 1: Germination of rice cultivars and weedy rice accessions under anaerobic conditions

Accessions (T= weedy rice, C=cultivated rice)	Parameters studied		
	Germination (%)	Root Length (cm)	Vigour index
T_1: UP	30	6.0	1040
T_2: UP	20	3.5	392
T_3: UP	40	4.5	888
T_4: UP	20	4.0	614
T_5: UP	53	3.7	1263
T_6: UP	26	5.4	770
T_7: UP	20	9.0	640
T_8: UP	66	4.8	1686
T_1: MP	20	0.5	40
T_2: MP	40	6.7	1442
T_3: MP	60	5.9	1390
T_4: MP	30	8.2	883
T_5: MP	40	4.6	968
T_6: MP	100	4.9	2928
T_7: MP	20	6.3	722
T_1: Kerela	60	2.0	575
T_2: Kerela	93	3.6	2306
T_3: Kerela	100	3.1	2805
T_1: CGH	46	2.6	775
T_1: JKD	93	3.7	2392
T_1: WB	20	6.0	198
T_1: Bihar	73	2.7	2014
C: Jyothi	40	2.5	805
C: Sahbhagi	73	4.2	1718
C: Jaya	20	3.6	658
C: IR64	20	4.4	51
C: P.Basmati	40	2.7	1276
SE(d)±	**20.01**	**1.77**	**590.7**
LSD (P=0.01)	**54.04**	**NS**	**1597**

Vigour index is calculated by germination % X (root length X shoot length) on that day

varieties as check. To evaluate effect of seed burial on seedling emergence, seeds of each weedy rice accession were sown at different depths (0, 2, 4, 6, 8, and 10 cm) in soil, and for anaerobic germination different flooding depth (0, 2, 4, 6, 8, and 10 cm) were maintained. It was observed that few accessions had the ability to germinate even from 10 cm water depth. Accessions from Jharkhand, Kerala, Bihar and Madhya Pradesh (Gwalior) had more potential to germinate under anaerobic situations than others. The effect of seeding depth did not differ significantly upto 8 cm depth, but accessions from Chhattisgarh, Bihar, Madhya Pradesh (Gwalior) and Uttar Pradesh had relatively more potential to emerge from 10 cm seeding depth in comparison to other accessions.

An experiment was also conducted three months after harvesting of weedy rice to study dormancy. Eighteen different accessions of weedy rice from eight states of India were used along with two cultivated varieties as a check. Percent germination of seeds was observed weekly till 35 weeks after sowing. Observations revealed significant variation in germination percentage amongst accessions studied, even amongst those from the same state. Weedy rice accessions from Jharkhand, Bihar, Gwalior (T_1), Kerala (T_1), Madhya Pradesh (T_2, T_3), and Chhattisgarh (T_2) did not have high dormancy, while other accessions from Madhya Pradesh (T_4, T_5), West Bengal, Chhattisgarh (T_1) and Uttar Pradesh revealed dormancy even after six months (Table 2).

Table 2 : Variation in seed dormancy of weedy rice

Treatment	Weeks to 50% germination	Germination (%) after 3 weeks	Germination (%) after 35 weeks	Weeks to maximum germination (%)	Germination Index 27 weeks after sowing
T_1 Madhya Pradesh	8.6	43.33	68.33	14.00	4.25
T_2 Madhya Pradesh	1.0	81.67	81.67	3.00	6.65
T_3 Madhya Pradesh	1.0	88.33	90.00	3.33	7.29
T_4 Madhya Pradesh	Ng	0.00	28.33	25.67	0.32
T_5 Madhya Pradesh	Ng	26.67	38.33	12.00	2.39
T_6 Jharkhand	1.3	95.00	95.00	2.00	9.42
T_1 West Bengal	Ng	0.00	31.67	17.67	0.47
T_1 Chhattisgarh	Ng	0.00	21.67	20.67	0.30
T_2 Chhattisgarh	2.0	85.00	96.67	18.33	7.34
T_1 Gwalior	2.0	93.33	96.67	11.00	8.34
T_2 Gwalior	5.6	33.33	93.33	16.00	4.54
T_1 Bihar	1.3	93.33	98.33	4.00	9.49
T_1 Uttar Pradesh	Ng	6.67	45.00	26.00	0.95
T_2 Uttar Pradesh	13.5	15.00	65.00	19.00	2.39
T_3 Uttar Pradesh	Ng	0.00	46.67	22.33	1.01
T_4 Uttar Pradesh	Ng	0.00	36.67	19.67	0.59
T_1 Kerala	1.6	93.33	98.33	11.33	9.38
T_2 Kerala	3.0	60.00	91.67	10.67	5.79
BPT 5204	1.3	95.00	96.67	3.00	9.40
Pusa Basmati	2.0	80.00	83.33	3.67	7.00
LSD (P=0.05)		**15.0**	**22.4**	**8.25**	**1.17**

Germination index was calculated by the method of AOSA (1983)

3.1.2. Incidence of orobanche on different varieties of mustard

3.1.2.1. Survey of biocontrol agents for *Orobanche*

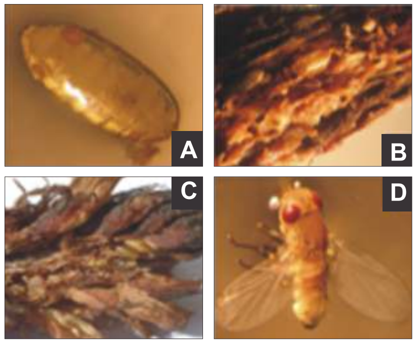
During a survey conducted in *Rabi* 2013 at Khinni, it was observed that in tomato field, some *Orobanche* plants were rotting and at the base of the plants were white mycelia growth. In the infected field, the fungal attack was more on *Orobanche*, though tomato plants were there near place of incidence. This showed that the fungus had preference to *Orobanche* than tomato. The specimens were brought to the laboratory and the fungus was isolated in potato dextrose agar media by standard tissue isolation method. The fungus was identified as *Sclerotium rolsfii* based on morphological characters. *S. rolfsii* is a polyphagous pathogen. It was cultured in 4 litre flasks and cell free extracts were collected. The fungus was applied on *Orobanche* along with other treatments and the emergence and mortality of the parasitic weed were monitored.

Evaluation of effect of different fungal bioagents on emergence of *O. crenata* stalks was undertaken. The stalks of *O. crenata* were sprayed with the spore suspension of four different bioagents viz., *Trichoderma viride, Gliocladium virens, Fusarium* sp. DWSR1, *Fusarium* sp. DWSR 2 and *S. rolfsii* and results indicated that only *S. rolfsii* caused infection on *O. crenata*. The plants showed wet rotting symptoms in the affected portions and the symptoms were progressive upwards. There was no symptom in the associated tomato plants. This showed that the particular isolate of *S. rolfsii* had preference to *O. crenata*. However, more host specific studies have to be conducted since *S. rolfsii* is a polyphagous pathogen.

Sclerotium rolfsii infecting *Orobanche*

3.1.2.2. Collection of *Phytomyza orobanchia* from *Orobanche crenata*

During survey in the Billua village (26^{0}02'59.32"N; 78^{0}17'00.03"E) of Gwalior district in Madhya Pradesh, during January 2013, brinjal (egg plant: *Solanum melongena*) plants with chili pepper (*Capsicum annuum*) as inter crop, were found infested by *Orobanche crenata*. In the same field flowering stalks of some *O. crenata* were found in various stages of drying, while the host was still healthy and alive. Closer observation of the uprooted stalks revealed the bore holes and extensive tunnels with tiny brown pupae and small white maggots, feeding on the capsules, succulent stalk and tubercles. The field was then marked, number of infected *O. crenata* stalks counted and collected in polythene bags for detailed studies in the laboratory. The insects were identified as *Phytomyza* sp., based on their morphology. The insect specimens were sent to National Bureau of Agriculturally Important Insects, Bengaluru, India for identification and accordingly the insects were identifiedas *Phytomyza orobanchia Kal*. The DNA sequences of cytochrome c oxidase subunit I (cox1) gene of the insects were submitted in the gene bank accession (No. KC732453.1, 658 bp*)*. The samples were brought to the laboratory in DWSR, stored in incubator at 26±0.5^{0}C. Observations under stereo binocular microscope of the collected specimens revealed that the maggots were white in colour, without legs and did not have a head capsule (B). Internal skeleton was visible through the transparent body wall and there was no chewing mouthpart on the head region. The adults emerged out at various periods depending upon the stage of the larvae or pupae. Proportion of emergence of adults was more from the soft and succulent flowering stalks (28/43) when compared to the hard tubercles (15/43).



Different stages of the *Phytomyza orobanchia* on *Orobanche crenata:* A. Maggot, B. Maggot feeding on the flowering stalk of *O. crenata*, C. Dried stalk of *O. crenata* with pupae, D. Mature fly

During survey in naturally infested field, observations on total number of brinjal plant, total number of stalks around a single brinjal plant. Per cent incidence, larvae / pupae etc. were taken (Table 3).

Table 3: Natural infestation of *Phytomyba* on *Orobanche crenata* in tomato

Total number of brinjal plants in the identified plot	235
Average number of stalks around a single egg plant	4
Iincidence of *Orobanche crenata* in the identified plot	28%
Incidence of *Phytomyza orobanchia* in the identified field	46%
Larvae/pupae observed in spike	48%
Larvae/pupae observed in flowering stalk	38%
Larvae/pupae observed in tubercle	14%
Infested Orobanche *crenata* plants collected from the field and incubated in the lab at 25^{0}C	25
Total no. of adults emerged from the collected plants	43
No. of adults emerged from the flowering stalks	28
No. of adults emerged from the tubercles	15

3.1.2.3. Management of *Orobanche* through soil solarization

Infested plot was identified in the farmer's field in village Khinni (Jabalpur). The soil was clay loam, the crops cultivated since last 20 years were wheat, rice, tomato and brinjal. A plot (30 m x 27 m) where *Orobanche* infestation was continuously observed over years was marked. Within this plot, sub-plots of size 2.5 m x 4.5 m were marked for the treatments. The plots were first irrigated up to the saturation level and after two days the plastic sheets of 100 micron thickness were laid on them with the sides covered by mud to prevent any loss of heat. The temperature was recorded before covering with the sheets and after a period of 30 days the sheets were removed. Uncovered plots of same size were maintained. The temperatures in the covered (solarized) and uncovered areas of the plots were recorded at different points. On observation, we had recorded maximum of 58^{0}C and minimum 30^{0}C. In the same study, we had observed the microbial population also, where it was found that in solarized plots microbial count was very low whereas in non solarized plot it was high. In addition, soil was collected from infected field and placed in the containment chamber to emulate the field conditions. Accordingly, the soil was irrigated for pre-conditioning of the seeds present in soil and for experiment in the forthcoming *Rabi* season.

Soil solarization at farmers' field for the management of *Orobanche*

3.2. Biology management of problematic weeds in non-cropped area

3.2.1. Integrated management of *Chromolaena odorata*

About a decade back, *Chromolaena odorata*, a problematic weed of Western Ghat, Karnataka and Tamil Nadu was not found in Baster area of Chhattisgarh but in a short span, it has invaded large area of forest, community and waste land in and around Bastar region. In Baster region, all the teak and eucalyptus plantations were severely infested with *C. odorata* Survey made in Raipur and surrounding area revealed its presence first time in Raipur around the campus of Indira Gandhi Krishi Vishwavidyalaya. The weed was not found in other areas of the city as well as along the road side upto the border of Odisha.

To manage this weed, about 3000 galls infested with gall fly (*Cecidocharus connexa*) were collected from Bengaluru and were released in the Jagdalpur area in 2012. Survey done this year did not reveal the establishment of bioagents in any of the released sites. Therefore, again 1500 infested galls were collected from Bengaluru and released in the three different sites of Jagdalpur area in September 2013. Survey done during 2013 revealed the presence of gall fly at one site indicating start of establishment process.

Severe infestation of *Choromolaena odorata* on road side and vacant land

3.3. Biology and management of aquatic weeds

3.3.1. Integrated management of *Pistia stratiotes*

Pistia stratiotes, often called water cabbage, water lettuce, floats on lakes, streams, and stagnant waters throughout India. It propagates by seeds or more rapidly by stolons and causes serious clogging on water ways. It forms a dense mat on water surface in the pond. This weed was recorded only in small patches in corners of the pond but never found in abundance during last 20 years. In India, no work has been done on management of *Pistia* by herbicides in context to water quality, residue and fish mortality. Its management by biological means has also not investigated. Therefore, study was initiated to find out potential native bioagents for biological control and suitable herbicides for chemical control in contest to water quality and effect on non-target organisms. This weed is increasing day by day in the aquatic bodies.

Survey done during 2013 revealed its spread in more aquatic bodies. Earlier *P. stratiotes* used to be confined in low intensity in a few aquatic bodies in Jabalpur but now its spread was noticed in 12 vacant land filled with water. Four more ponds were found severely infested with *Pistia stratiotes* in and around Jabalpur.

Glyphosate, 2,4-D and metsulfuron-methyl were tested on *P. stratiotes*. The herbicides were sprayed with the help of knapsack spray with flat fan nozzle calculating amount of herbicides and water based on the surface area. Among these herbicides, metsulfuron-methyl 6 g/ha was found most effective followed by glyphosate 2.kg/ha. 2,4-D was not effective even at 2.9 kg/ha.

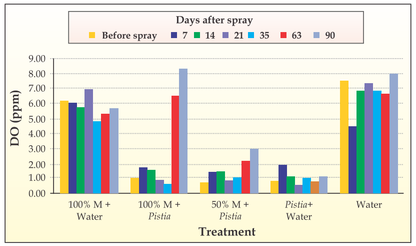
Water quality parameters were recorded before and after spray of herbicides at different intervals. Water quality parameter dissolve oxygen decreased from 14 to 35 days after spray of 2,4-D and glyphosate. This decrease in dissolved oxygen was coincided with decomposition of the weed. After killing the weed, DO increased due to clearing of water surface. Dissolved oxygen was recorded lowest in the tanks having *Pistia* cover over the entire water surface. This might be due to non-contact of water with air. Dissolved oxygen was fairly good (> 5) in tanks having water only (Table 4).

Table 4 : Effect of herbicides on dissolved oxygen (DO) at different intervals

Treatment	DO days after spray (DAS)								
	BS	0-25	14	21	28	35	42	63	90
100% glyphosate + water	4.16 ±2.87	4.55 ±2.20	6.31 ±2.16	5.52 ±0.25	4.49 ±0.13	5.61 ±0.29	6.65 ±0.36	7.51 ±0.60	6.01 ±0.50
100% glyphosate + *Pistia*	3.20 ±0.44	1.11 ±0.34	2.53 ±2.16	3.46 ±0.79	2.80 ±0.05	1.66 ±0.30	1.22 ±0.30	0.74 ±0.09	1.42 ±0.31
50% glyphosate + *Pistia*	2.75 ±0.10	1.15 ±0.61	1.63 ±1.19	1.46 ±0.08	1.13 ±0.30	0.99 ±0.13	0.91 ±0.02	1.04 ±0.15	0.68 ±0.10
100%2,4-D + water	3.82 ±4.30	6.52 ±2.71	6.25 ±2.33	7.25 ±0.26	5.58 ±0.07	7.64 ±0.24	5.03 ±0.38	6.17 ±0.49	5.70 ±0.23
100%2,4 -D + *Pistia*	3.50 ±1.78	0.71 ±0.15	5.19 ±5.09	3.94 ±0.12	2.05 ±0.00	2.44 ±0.47	1.31 ±0.23	1.08 ±0.16	1.16 ±0.17
50%2,4 -D + *Pistia*	0.96 ±0.92	0.69 ±0.46	0.87 ±0.96	1.73 ±0.90	1.65 ±0.04	1.53 ±0.15	1.02 ±0.21	0.99 ±0.05	0.71 ±0.04
Pistia + water	3.23 ±3.98	4.07 ±3.96	2.03 ±0.34	1.29 ±0.18	1.39 ±0.01	1.22 ±0.19	0.64 ±0.21	0.82 ±0.19	0.99 ±0.24
Only water	7.51 ±2.00	7.48 ±2.19	6.84 ±2.49	7.36 ±0.54	5.57 ±0.22	6.89 ±0.55	5.38 ±0.23	6.73 ±0.09	7.95 ±0.09

BS- Before spray

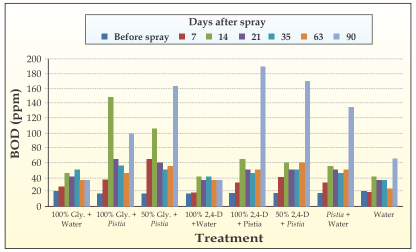
Application of metsulfuron-methyl on water surface did not affect DO which showed that the herbicide alone did not affect DO. Dissolved oxygen was lowest in the tanks covered with *Pistia*. Application of metsulfuron-methyl on 100 % surface of *Pistia* decreased the DO from 21 to 35 days, which coincided with the highest decomposition of *Pisita* biomass in the water result in decrease in the DO. In 100 % treated tank, the DO increased by 63 days after the decomposition and settlement of decomposed biomass. In case of 50% herbicide treated area the DO had not increased significantly by 63 days. This was due to multiplication of the weed from the left part of the tank. Dissolved oxygen was fairly good in the tanks without weed (Figure 2).



M - Metsulfuron-methyl

Figure 2: Effect of metsulfuron-methyl application on dissolved oxygen (DO) at different days intervals

The BOD was also affected due to herbicide treatment. In tanks with water, BOD was low indicating good water quality but it increased with the decomposition of weed after the herbicide treatment. The BOD were maximum in the tanks where entire surface of *Pistia* was treated with glyphosate (Figure 3).



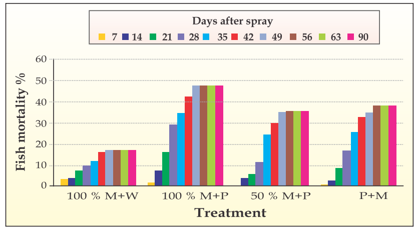
Gly. - Glyphosate

Figure 3: Effect of 2,4-D and glyphosate on biological oxygen demand (BOD) at different days intervals

Fish mortality was recorded lowest in the tanks having water only and was treated with metsulfulra- methyl indicating that applications of herbicide on water surface do not affect fish mortality. Highest fish mortality was observed in the tanks with *Pistia* treated with metsulfuron-methyl coincided with the highest decomposition of weed and reduction of dissolved oxygen. Fish mortality was also observed in the tanks having *Pistia* conver which might be due to less dissolved oxygen (Figure 4).

3.3.2. Effect of inoculation of *alternaria alternata* and *A. eichhorniae* in water hyacinth on fishes

Field demonstrations of application of *A. alternata* in aquatic bodies at Gosalpur, Panagar and Belghadu were done. *Alternaria alternata* strain, which



M - Metsulfuron-methyl, P - *Pistia*, W - Water

Figure 4 : Effect of metsulfuron-methyl on fish mortality (%) at different days intervals

was found to be host specific and very effective on water hyacinth, was mass multiplied using molasses yeast agar medium and talc. The protocol followed for spraying was as follows. One kg talc mixed in 50 liters of water and the contents were filtered to remove talc. Starch solution (rice solution) was added at 250 mL /kg of talc formulated product to improve the sticking quality. The solution was then sprayed at 1 kg/100 m^2 area through large nozzle using knapsack sprayer. Rice solution was prepared by boiling 100 grams rice in one litre water and filtered the contents. This was added at the rate of 250 mL to 1 kg of talc product. The spray was done in the evening to take advantage of the RH that would be available for a whole night to the fungus to establish on the plants.

Observations after 10 days of application indicated that the sprayed biocontrol agent *A. alternata* had established on the water hyacinth plants. There were symptoms of various stages of leaf spot on the sprayed plants. However due to rains, the plants were washed away and further observations could not be taken.

Symptoms of establishment of fungi *Alternaria alternata* on water hyacinth

5 RESEARCH PROGRAMME – 4

MONITORING, DEGRADATION AND MITIGATION OF HERBICIDE RESIDUES AND OTHER POLLUTANTS IN THE ENVIRONMENT

Persistence of herbicide residues is of great concern as their presence in the soil may not only damage the sensitive succeeding crops but also adversely affect human and animal health due to bioaccumulation of residues in crop produce. Due to rain and irrigation, the persisting residues are likely to move towards sub-surface soil and may contaminate ground water. This theme deals with the monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment.

Sub-programmes	Experiments	Associates
4.1. Impact of herbicides in soil, water and non targeted organisms and herbicide mitigation measures	4.1.1. Residues of penoxsulam, pyrazosulfuron-ethyl and pretilachlor in soil of rice field	Shobha Sondhia
	4.1.2. Residues of pretilachlor, penoxsulam and pyrazosulfuron-ethyl on residues and fish mortality in ponds	Shobha Sondhia
	4.1.3. Residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor herbicides on water quality	Shobha Sondhia and P.J. Khankhane
	4.1.4. Residues of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in soil of wheat field	Shobha Sondhia
	4.1.5. Evaluation of major degradation products of pyrazosulfuron, pretilachlor and penoxsulam in field soil by LC-MS/MS	Shobha Sondhia
	4.1.6. Metabolites of pretilachlor in rice field	Shobha Sondhia
	4.1.7. Degradation products /metabolites of pretilachlor in pond water	Shobha Sondhia
	4.1.8. Evaluation of risk of ground water contamination by the continuous use of herbicides	Shobha Sondhia
	4.1.9. Change in pH and EC of leachates after pretilachlor application and following rain in *Kharif* 2013	Shobha Sondhia
	4.1.10. Change in pH and EC of the soil at various depths after pretilachlor application and following rain in *Kharif* 2013	Shobha Sondhia
	4.1.11. Identification of metabolites/transformation products of pretilachlor in soil at various depth in lysemeter of 1-3 meter depths	Shobha Sondhia
	4.1.12. Identification of metabolites/transformation products of pretilachlor in the leachates in lysemeter of 1-3 meter depths	Shobha Sondhia
4.2. Degradation of herbicides in the environment	4.2.1. Photodegradation of bispyribac in soil and water	P.P. Choudhury
4.3. Bio-remediation of pollutants using terrestrial / aquatic weeds	4.3.1. Testing of terrestrial weed based phytoremediation system for waste water treatment for irrigation	P.J. Khankhane
	4.3.2. Evaluation of weedy plants for herbicide tolerance and accumulation	P.J. Khankhane and Shobha Sondhia
	4.3.3. Enhanced accumulation of cadmium in *Arundo donax* by chelating agent	P.J. Khankhane

4.1. Impact of herbicides in soil, water and non-target organisms and herbicide mitigation measures

The contamination of food chain and water with herbicide may lead to some undesirable consequences to non-target organisms. The most obvious effects of herbicides on fish and other wildlife are direct effects of acute poisoning. Herbicides find ways to water sources through drift, runoff, soil erosion, leaching, and occasionally, accidental or deliberate release. Thus herbicide persistence in soil and water and their effect on non-target organisms was evaluated under rice based cropping system.

4.1.1. Residues of penoxsulam, pyrazosulfuron-ethyl and pretilachlor in soil of rice field

Penoxsulam, pyrazosulfuron-ethyl and pretilachlor were applied at 25, 25 and 750 g/ha to the rice crop in *Kharif* 2013 and carfentrazone, pinoxaden and fenoxaprop-p-ethyl at 100, 25 and 100 g/ha, respectively to wheat crop in *Rabi* 2012-13 at recommended doses. Herbicide dissipations in water, soil, rice, wheat and fish were determined by analyzing processed samples with standardized HPLC methods. Initially 0.095, 0.297 and 0.576 µg/g residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor were found in rice soil which dissipated to 0.0088, 0.0176 and 0.0375 at 30 days. At 90 days, residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor were <0.001 µg/g in rice soil (Figure 1). Half-lives of pyrazosulfuron-ethyl, pretilachlor and penoxsulam in soil of rice field was found 9.8, 10.4 and 7.8 days, respectively (Table 1).

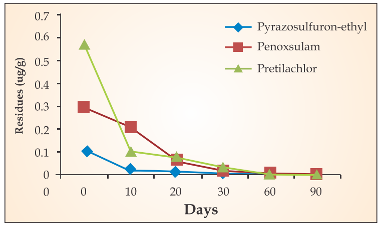


Figure 1: Dissipation of pyrazosulfuron-ethyl, pretilachlor and penoxsulam in soil during *Kharif* 2013

Table 1: Half-lives of pyrazosulfuron-ethyl, pretilachlor and penoxsulum during in soil during *Kharif* 2013

Herbicides	Rate kinetic equation	R^2	Half-life (days)
Pyrazosulfuron-ethyl	y = - 0.018x + 0.455	0.91	9.8
Pretilachlor	y= - 0.027x + 1.511	0.95	10.4
Penoxsulam	y = - 0.026x + 1.397	0.94	7.8

At 10 days, residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor found in pond water respectively were 0.0314, 0.0370 and 0.0113 µg/mL which dissipated to 0.0075, 0.0230 and 0.0047 µg/g, respectively at 30 days. Residues of pyrazosulfuron-ethyl were below <0.001 µg/mL after 60 days. However, pretilachlor residues were 0.0054 µg/mL detected at 60 days which was below <0.001 µg/mL after 60 days in pond water (Table 2).

Table 2: Residues of pyrazosulfuron-ethyl, pretilachlor and penoxsulam in water during *Kharif* 2013

Days	Residues (µg/mL)		
	Pyrazosulfuron	Pretilachlor	Penoxsulam
5	0.0349	0.0132	0.0456
10	0.0314	0.0113	0.0371
20	0.0096	0.0087	0.0042
30	0.0074	0.0047	0.0230
60	<0.001	0.005	<0.001
90	<0.001	<0.001	<0.001

All of the three herbicides were detected in rice green plant even after 60 days of application and in grain and straw after harvest (Table 3).

Table 3: Residues of pyrazosulfuron, pretilachlor and penoxsulam in green rice plant

Days	Residues (µg/g)		
	Pyrazosulfuron	Pretilachlor	Penoxsulam
10	0.2384	1.1247	0.1102
20	0.1630	0.9594	0.0498
30	0.0117	0.0825	0.0223
60	0.0067	0.0651	0.0129
Grain after harvest	0.0030	0.0465	0.0151
Straw after harvest	0.0010	0.0116	0.0101

4.1.2. Residues of pretilachlor, penoxsulam and pyrazosulfuron-ethyl on residues and fish mortality in ponds

Fish mortality and toxicity symptoms were recorded initially in the pond where herbicides were entered through runoff water. In the fish 0.0133, 0.0189 and 0.063 µg/g residues of pyrazosulfuron-ethyl, penoxsulam and pretilachlor were found after 30 days, respectively. At 60 days pyrazosulfuron-ethyl, penoxsulam and pretilachlor residues in fish were <0.001, 0.017 and 0.010, respectively (Table 4).

Table 4: Herbicide residues in fishes in *Kharif* 2013

Days	Residues (µg/g)		
	Pyrazosulfuron	Pretilachlor	Penoxsulam
30	0.0133	0.063	0.0188
60	<0.001	0.010	0.0178
100	<0.001	<0.001	<0.001

4.1.3. Residue of pyrazosulfuron-ethyl, penoxsulam and pretilachlor herbicides on water quality

Overall mean pH of water varied between 7.1 to 8.25 in the corresponding ponds where pyrazosulfuron-ethyl, penoxsulam and pretilachlor were entered through runoff and rain. Changes in pH of soil and water were higher in penoxsulam contaminated soil and water. Similarly pyrazosulfuron -ethyl and pretilachlor did not alter quality of water and soil significantly. Electrical conductivity decreased after application of pretilachlor, penoxsulam and pyrazosulfuron-ethyl, respectively (Table 5).

Table 5: Changes in pH and EC of the soil (S) and pond water (W) due to herbicide application in rice field in *Kharif* 2013

Days	Control				Pretilachlor				Penoxsulam				Pyrazosulfuron-ethyl			
	pH		EC (µS/cm)		pH		EC (µS/cm)		pH		EC (µS/cm)		pH		EC (µS/cm)	
	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
0	7.5	7.4	153	500	7.1	7.3	109	513	7.1	7.6	124	432	7.0	7.1	128	501
5	7.4	7.9	74	485	7.2	7.8	72	510	7.3	7.7	82	448	7.2	7.9	48	504
10	7.4	8.8	123	489	7.0	8.2	52	512	6.6	7.5	70	393	6.8	8.1	69	508
20	7.8	7.7	116	325	7.2	7.4	88	291	6.8	8.1	87	343	6.5	7.5	85	309
30	7.7	7.5	122	358	7.4	7.3	79	341	7.1	9.0	34	182	6.9	7.4	78	379
60	7.7	7.9	126	379	7.3	7.7	94	335	8.0	7.4	34	127	7.0	7.6	101	374
90	7.9	7.9	96	376	7.4	7.3	62	360	8.2	7.0	63	435	7.3	8	69	365
At harvest		6.6		426		7.0		391		7.2		436		7.7		316

4.1.4. Residues of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in soil of wheat field

Initially, residues of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in wheat soil were 0.0434, 0.0888 and 0.1661 µg/g which dissipated to 0.0026 µg/g at 30 days. At 90 days fenoxaprop-p-ethyl, carfentrazone and pinoxaden residue in wheat soil were <0.001 µg/g (Table 6). Half lives of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in the soil of wheat field were 16.6, 9.1 and 8.6 days in *Rabi* 2012-13 (Table 7).

Table 6: Residues of carfentrazone, fenoxaprop-p-ethyl and pinoxaden in soil of wheat field

Days	Residue in soil of wheat (µg/g)		
	Carfentrazone	Fenoxaprop-p-ethyl	Pinoxaden
0	0.0888	0.0434	0.1661
10	0.0518	0.0369	0.0299
20	0.0078	0.0051	0.0196
30	0.0046	0.0026	0.0049
60	<0.001	0.0012	0.001
90	<0.001	<0.001	0.001

Table 7: Rate kinetics, R^2 and half-life of fenoxaprop-p-ethyl, carfentrazone and pinoxaden residues in soil in *Kharif* 2013

Herbicides	Rate kinetics equation	R^2	Half-life (days)
Fenoxaprop-p-ethyl	y = - 0.018x + 0.389	0.777	16.6
Carfentrazone	y = - 0.033x + 0.839	0.924	9.1
Pinoxaden	y = - 0.035x + 0.984	0.944	8.6

4.1.5. Evaluation of major degradation products of pyrazosulfuron, pretilachlor and penoxsulam in field soil by LC/MS/MS

Metabolites of pretilachlor, pyrazosulfuron and penoxsulam were detected from soil and pond water which were identified by LC/MS/MS. Three major products of pyrazosulfuron-ethyl were identified as ethyl-5-[(4, 6-dimethoxypyrimidin-2-ylcarbamoyl) sulfamoyl]-1-methylpyrazole-4-carboxylic acid; ethyl 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylate and 4, 6-dimethoxypyrimidin-2-amine, 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylic acid.

Three major degradation products of penoxsulam in field soil were viz., 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine, 5,8 dicarboxylic acid; 2-(2,2-difluoroethoxy) -6 (triflurомethyl) benzenesulfonamide and 3-[[[2-(2,2-difluoroethoxy)-N-[1,2,4] triazole [1,5c]-6-triflurоmethyl) benzene sulfonamide carboxylate.

4.1.6. Metabolites of pretilachlor in rice field

In the soil of rice field five degradation product were identified by LC/MS/MS as 2',6'-diethyl-N-(propoxyethyl)acetanilide; 2',6'-diethyl-N-(propoxyethyl)aniline; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'(diethyl)-N-(ethyl)aniline; and 2-chloro-2'-)1–hydroxyethyl, 6'ethyl)-N-(2-propoxyethyl acetanilide (Figure 2).

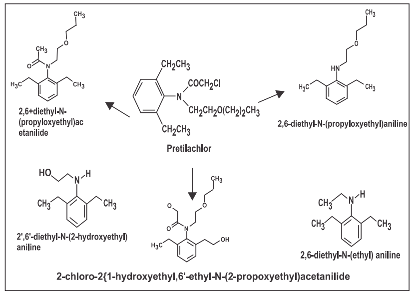


Figure 2: Metabolites of pretilachlor in pond soil

4.1.7. Degradation products/metabolites of pretilachlor in pond water

In pond water seven degradation product were identified by LC/MS/MS as 2',6'-diethyl-N-(propoxyethyl)acetanilide; 2',6'-diethyl-N-(propoxyethyl)aniline; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'(diethyl)-N-(ethyl)aniline; 2-chloro-2'-)1–hydroxyethyl,6'ethyl)-N-(2-propoxyethyl acetanilide; acetanilide and 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone (Figure 3).

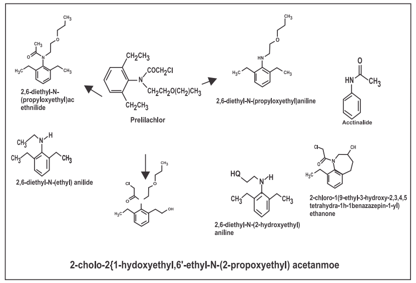


Figure 3: Metabolites of pretilachlor in pond water

Seven major degradation products of pretilachlor in field soil were identified by LC/MS/MS as 2',6'-diethyl-N-(propoxyethyl) acetanilide; 2',6'-diethyl-N-(propoxyethyl)aniline; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'-diethyl-N-(ethyl)aniline; acetanilide; 2-chloro-2',) 1 –hydroxyethyl, 6'ethyl)-N-(2-propoxyethyl acetanilide; and 2-chloro-1 (-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl) ethanone (Figure 3).

4.1.8. Evaluation of risk of ground water contamination by the continuous use of herbicides

Herbicide leaching through soil is particularly important due to environmental and agronomic problems. Leaching is considered as main cause of ground contamination by herbicides. As most of the herbicides are soluble in water and thus may pose the risk of ground water contamination under saturated moisture regime. Thus the experiment was conducted to see the mobility and leaching potential of herbicides under natural rainfall conditions in lysemeter made of cements of 1, 2 and 3 meters.

Pretilachlor was sprayed at 750 and 1500 g/ha dose to the lysemeter of 1.0, 2.0 and 3.0 meters depths under field conditions and allowed to receive natural rain (approximately 1520 mm). Soil samples from up to 0-25, 25-50, 50-75, 75-100, 100-125, 125-150, 150-175, 175-200 and 200-225 cm depths were collected and analyzed by HPLC to see the movement of pretilachlor in soil and to predict possible risk of ground water contamination through herbicides. Residues of pretilachlor were analyzed from the 1.0, 2.0 and 3.0 meter height columns. Leachates were also collected from the column and analyzed to see the movement of pretilachlor.

Pretilachlor residues were detected from the leachates of 1 m column as compared to 2 and 3 meter lysemeter. Residues were higher in surface soil and detected up to lower depths in lysemeters at 10 and 20 days. Pretilachlor metabolites/transformation products were found in soil and water after 10 days. Residue of pretilachlor in 1-meter soil lysemeter at 0-50 cm depths after 1 to 30-days was 87.1 to 93.0 ng/g at surface soil in the lysemeter where rice plants were grown, whereas 54.73 to 48.96 ng/g residues of pretilachlor were found in the surface soil of 1-3 m depth lysimeter where rice plants were not grown (Table 8 and 9). Residue dissipated with passage of time and did not detect in lower depths after 60 days. In general residues of pretilachlor were higher in those lysimeters where rice plant were grown and simultaneously received natural rains. In leachates, a total of approximately 22.4-24.0, 44.4-64.6 and 19.1-43.5 ng/mL residues of pretilachlor were detected in the leachates of 1, 2 and 3 m depth lysimeter.

Table 8: Residues of pretilachlor at 3 and 10 days (D) in the soil of lysimeter at various depths

Depths (cm)	Residues of pretilachlor at various depths (ng/g) days (D) after initiation of the treatment											
	3 D with plant, at lysimeter depth (m)			3 D without plant, at lysimeter depth (m)			10 D with plant, at lysimeter depth (m)			10 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
Upper	87.17	78.56	93.04	54.73	48.96	51.88	74.41	62.04	70.17	34.61	38.96	47.07
0-25	58.35	52.83	43.12	15.64	13.3	19.39	49.68	38.135	19.52	20.50	8.63	2.506
25-50	54.92	16.38	-	12.07	19.63	-	31.99	20.50	-	6.27	8.75	-
50-75	15.82	10.57	21.329	10.77	31.74	20.09	13.57	3.246	8.32	3.93	5.41	4.998
75-100		5.210	3.37		0.0584	1.64		3.847	2.68		4.792	6.652
100-125		-	0.083		-	0.0438		4.71	4.78		6.083	8.73
125-150		-	-		-	0.0562		1.876	4.58		5.34	5.592
150-175			-			-			5.49			4.498
175-200			-			-			0.682			1.844
200-225			-			-			1.01			1.610

4.1.9. Change in pH and EC of leachates after pretilachlor application and following rain in *Kharif* 2013

There was increase in pH 7.5 to 9.4 of leachates after pretilachlor application which showed movement of residues and its major metabolites at various depths. Change in pH and EC of leachates due to pretlachlor application in soil columns and following rain are presented in Table 10 and 11.

Table 9: Residues of pretilachlor at 30 and 60 days (D) in the soil of lysimeter at various depths

Depths (cm)	Residues of pretilachlor at various depths (ng/g) (T2) days after initiation of the treatment											
	30 D with plant, at lysimeter depth (m)			30 D without plant, at lysimeter depth (m)			60 D with plant, at lysimeter depth (m)			60 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
upper	19.49	23.39	31.91	5.058	5.32	5.925	3.978	3.71	7.49	3.43	1.183	0.052
0-25	12.69	14.55	14.624	0.312	3.476	1.294	0.190	0.238	0.264	0.341	0.861	0.0427
25-50	6.25	6.54	-	0.178	3.134	-	0.252	0.059	-	0.031	0.38	-
50-75	1.817	4.389	9.68	0.035	2.845	2.882	0.074	0.075	0.010	0.011	0.076	<0.001
75-100		6.54	6.08		3.586	1.766		<0.001	<0.001		<0.001	<0.001
100-125		3.965	9.016		3.26	1.766		<0.001	<0.001		<0.001	<0.001
125-150		0.0961	1.154		3.85	0.103		<0.001	<0.001		<0.001	<0.001
150-175			4.370			0.017			<0.001			<0.001
175-200			1.090			0.011			<0.001			<0.001
200-225			<0.001			<0.001			<0.001			<0.001

Table 10: Changes in pH of leachates due to pretilachlor application in *Kharif* 2013

Days	pH of leachates					
	Lysimeter with plant at depth (m)			Lysimeter without plant at depth (m)		
	1	2	3	1	2	3
12.7.13	7.7	8.3	NL	7.6	7.9	7.5
15.7.13	7.6	7.8	8.1	7.5	7.8	7.9
18.7.13	8.0	7.7	7.65	7.7	7.7	7.6
19.7.13	8.2	8.4	NL	8	8.2	8.2
27.7.13	8.2	8.4	NL	8.1	8.2	NL
29.7.13	7.8	8.1	NL	NL	8.1	8
2.8.13	9.3	9.3	9.2	9.1	8.9	9.4
7.8.13	8.1	8.2	NL	8.1	8.1	NL
17.8.13	8.6	9.2	NL	8.8	9.3	NL
19.8.13	8.7	8.5	8.4	8.6	8.4	8.2
21.8.13	9.3	9.2	9.1	9.1	8.9	8.6
23.8.13	8.9	8.8	8.6	8.7	8.6	8.3
28.8.13	8.2	8.6	NL	8.2	9.0	9.1
3.9.13	8.2	8.5	NL	8.3	8.2	NL

Table 11: Change in EC in leaches after pretilachlor application in lysimeter in *Kharif* 2013

Days	EC of leachates					
	Lysimeter with plant at depth (m)			Lysimeter without plantat depth (m)		
	1	2	3	1	2	3
12.7.13	871	695	NL	684	777	1178
15.7.13	796	329	1213	594	669	1059
18.7.13	839	614	1123	699	664	1040
19.7.13	780	533	NL	685	668	1012
22.7.13	695	409	NL	657	634	987
27.7.13	633	475	NL	617	597	NL
29.7.13	622	516	NL	NL	643	1220
2.8.13	433	431	856	527	336	722
7.8.13	818	490	NL	610	549	NL
17.8.13	660	533	NL	520	383	NL
19.8.13	724	507	435	452	589	882
21.8.13	524	442	563	381	496	732
23.8.13	259	494	114.5	514	658	825
28.8.13	614	447	NL	391	388	469
3.9.13	482	346	NL	407	427	NL

4.1.10. Change in pH and EC of the soil at various depths after pretilachlor application and following rain in *Kharif* 2013

There was an increase in pH (7.2 to 8.4) of soil after pretlachlor application and EC of leachates decreased with passage of time. Change in physico-chemical parameter due to pretilachlor application in the leachates of soil in lysimeters and are presented in Table 12 -15.

Table 12: Change in pH of soil at various depths at 3-10 days (D) after pretilachlor application in lysimeters in *Kharif* 2013

Depth (cm)	pH of pretilachlor at various depths (µg/g)											
	3 D with plant, at lysimeter depth (m)			3 D without plant, at lysimeter depth (m)			10 D with plant, at lysimeter depth (m)			10 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
Upper	8.4	7.2	7.5	7.3	7.5	7.5	8.1	7.3	7.4	7.5	7.2	7.5
0-25	7.3	7.1	-	7.1	7.4	-	7.6	7	-	7.1	7	-
25-50	7.4	7.1	-	7.3	7.5	-	7.6	7.1	-	7.4	7.2	-
50-75	7.4	7.2	7.6	7.3	7.3	7.6	7.6	7	7.5	7.5	7.1	7.4
75-100		7.5	7.6		7.4	7.6		7.2	7.4		7.3	7.4
100-125		7.5	7.5		7.6	7.6		7.3	7.6		7.4	7.4
125-150		7.4	7.4		7.5	7.5		7.2	7.4		7.4	7.5
150-175			7.5			7.6			7.4			7.5
175-200			7.6			7.5			7.5			7.5
200-225			7.5			7.6			7.4			7.4

Table 13: Change in pH of soil at various depths at 60-90 days (D) after pretilachlor application in lysimeter in *Kharif* 2013

Depth (cm)	pH of pretilachlor leachates											
	60 D with plant, at lysimeter depth (m)			60 D without plant, at lysimeter depth (m)			90 D with plant, at lysimeter depth (m)			90 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
Upper	8	7.8	7.9	7.9	7.9	8.2	8.7	7.5	8.9	7.6	7.4	7.4
0-25	7.6	7.8	-	7.5	8	-	8.5	7.1	-	7.5	7	-
25-50	7.6	8.2	-	8	8.2	-	8.8	7	-	7.7	7.4	-
50-75	8	8.2	8.2	8.2	8.2	8.4	8.8	7.4	8.8	7.7	7.3	7.4
75-100		8.2	8.4		8.2	8.4		7.3	8.4		7.3	7.6
100-125		8.1	8.3		8.2	8.4		7.4	8.2		7.4	7.5
125-150		8	8.2		8.1	8.2		7.2	8		7.1	7.6
150-175			8.4			8.4			7.9			7.5
175-200			8.0			8.3			7.8			7.4
200-225			8			8.2			7.7			7.4

Table 14 : Change in EC of soil at various depths at 3-10 days (D) after pretilachlor application in lysimeters in *Kharif* 2013

Depth (cm)	EC of pretilachlor leachates at various depths											
	3 D with plant, at lysimeter depth (m)			3 D without plant, at lysimeter depth (m)			10 D with plant, at lysimeter depth (m)			10 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
Upper	112.9	170.1	292	96.1	143	231	92.1	77.5	96.6	64.7	88.4	75.8
0-25	92.8	136.6	-	79	148	-	41.3	65.2	-	76.2	54.7	-
25-50	71.1	123.1	-	121.9	130	-	119.7	61.8	-	151.3	70.8	-
50-75	111.1	131.9	181	133	201	211	87.4	117.3	165.4	101.2	98.6	136.7
75-100		127.9	171		175	201		113	151.6		107.8	109.2
100-125		156.9	194		134	227		111.2	132.7		122.7	129.7
125-150		189	182		167	254		124.6	146.4		98.4	96.6
150-175			162			226			145.2			138.5
175-200			167			271			91.5			121.7
200-225			137			246			161.4			132.8

Table 15: Change in EC of soil at various depths at 60-90 days (D) after pretilachlor application in lysimeters in *Kharif* 2013

Depth (cm)	EC of pretilachl or leachates at various depths											
	60 D with plant, at lysimeter depth (m)			60 D without plant, at lysimeter depth (m)			90 D with plant, at lysimeter depth (m)			90 D without plant, at lysimeter depth (m)		
	1	2	3	1	2	3	1	2	3	1	2	3
Upper	165.2	115.6	129.7	137.9	118.8	122.7	100.8	202	62.9	90.2	96.5	70.6
0-25	130.7	148.2	-	120.4	168.4	-	141.5	99.6	-	11.7	97.8	-
25-50	191.6	148.5	-	135.1	147.7	-	136.3	107.2	-	150.8	145.7	-
50-75	132.4	164.1	176.2	135.7	166.7	179.6	221	196.2	123.7	114.5	108.7	152.6
75-100		161.3	171.7		146.6	176.3		186.7	129.4		142.3	126.3
100-125		143.7	167.2		181	165.2		145.3	118.8		139.4	130.6
125-150		142.8	155.1		156.1	165.7		331	165.2		137.9	122.5
150-175			161.2			212			168.3			174.7
175-200			151.4			169.7			117.8			125.3
200-225			161.2			176			161.9			172

4.1.11. Identification of metabolites/ transformation products of pretilachlor in soil at various depth in lysemeter of 1-3 meter depths

Several metabolites/transformation products of pretilachlor were found in soil at various depths. Seven degradation products were found in soil of lysemeter such as, 2',6'-diethyl-N-(propoxyethyl)acetanilide; 2',6'-diethyl-N-(2-hydroxyethyl)aniline; 2',6'-diethyl-N-(ethoxyethyl)aniline; 2',6'-diethyl-N-(ethyl)aniline; acetanilide; 2-chloro-2',6'(diethyl)-N-methyl acetanilide; 2-chloro-2(1-hydroxyethyl,6'-ethyl)-N-(2-propoxyethyl acetanilide; 2-chloro-1-(9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone; (diethyl)-N-methyl acetanilide; and 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone (Figure 4)

4.1.12. Identification of metabolites/ transformation products of pretilachlor in the leachates in lysemeter of 1-3 meter depths

Ten degradation products of metabolites were found in leachates viz. 2',6'-diethyl-N-(propoxyethyl) acetanilide; 2',6'-diethyl-N-(2-hydroxyethyl) aniline; 2',6'-diethyl-N-(ethoxyethyl) aniline; 2',6'-diethyl-N-(ethyl)aniline; 2',6'-diethy-aniline; acetanilide; 2-chloro-2',6'(diethyl)-N-methyl acetanilide; 2-chloro-2',6'-hydroxyethyl)-N-(2-propoxyethyl acetanilide; 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone; (diethyl)-N-methyl acetanilide; and 2-chloro-1(-9-ethyl-3-hydroxy-2,3,4,5-tetrahydro-1H-1benzazapin-1-yl)ethanone (Figure 5).

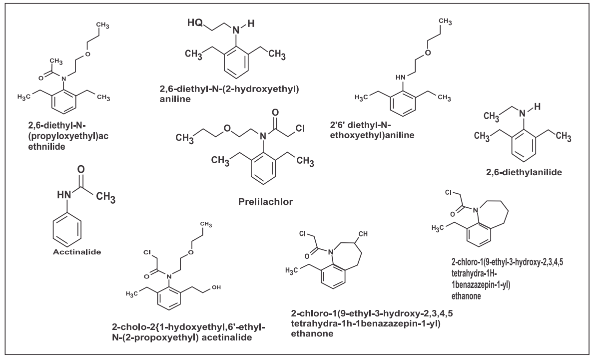


Figure 4: Metabolites of pretilachlor in the soil of lysimeter at various depths

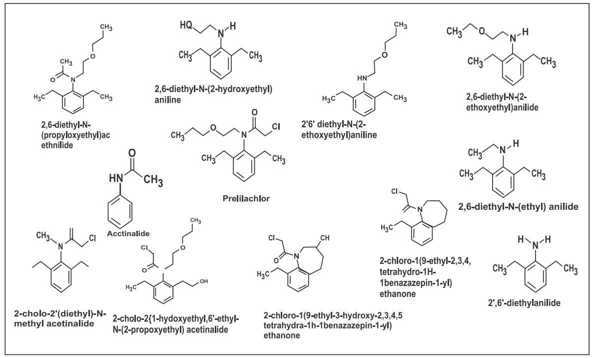


Figure 5: Metabolites of pretilachlor in the leachates of lysimeter

4.2. Degradation of herbicides in the environment

4.2.1. Phototransformation of bispyribac-sodium in soil and water

Bispyribac-sodium [sodium 2, 6-bis [(4, 6-dimethoxypyrimidin-2-yl) oxy] benzoate], a rice herbicide, is highly soluble in water (73.3 g/L at 25^{0}C). Its run off to surface bodies and leaching into groundwater are likely. Therefore, study of its degradation in the environment is essential for safety concern. The degradation of bispyribac may take place either through photochemical reactions or through microbial processes in the biphasic system of rice field.

To investigate the phototransformation of bispyribac-sodium in the rice-environment, a biphasic environment was simulated in plastic containers. A standing water of 5 cm was maintained on the soil layer of 15 cm during the experiment time. The soil and water were being sterilized to avoid any microbial degradation. Bispyribac-sodium solution was applied to this system at the rate of 100 g/ha. Sampling was done at 0, 3, 7, 10, 15 and 15 days after application. After irradiation under sunlight, the degradates were extracted in suitable solvents, processed and analyzed by LC-MS/MS. The photoproducts formed during different phases were: 2-(3-methoxy-phenoxy)-4, 6-dimethoxypyrimidine (I); pyrimidine-2, 4, 6-triol (II);4,6-dihydroxypyrimidinyl phthalate (III); 2-methoxy methyl benzoate (IV); 2-(3-hydroxy-phenoxy)-pyrimidine-4, 6-diol (V);2,4,6-trimethoxy pyrimidine (VI); and 2,6-bis[(4,6-dimethoxy-2-pyrimidinyl) oxy]benzoate (VII) (Figure 6).

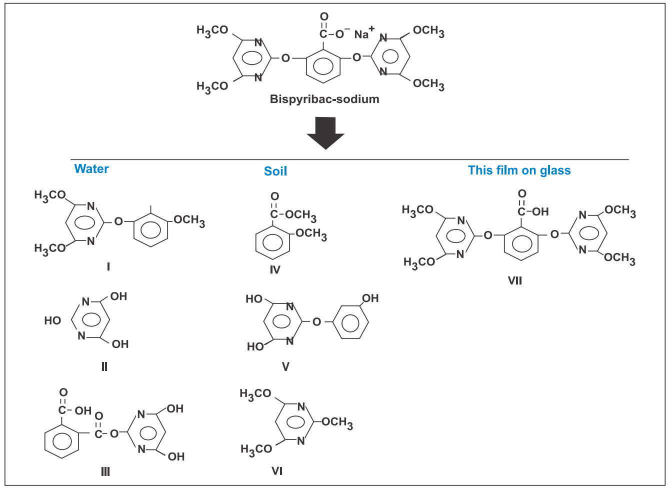


Figure 6: Phototransformation of bispyribac-sodium under sunlight

4.3. Bioremediation of pollutants using terrestrial/aquatic weeds

4.3.1. Testing of terrestrial weed based phyto-remediation system for waste water treatment for irrigation

The municipal and industrial waste water in peri urban areas provides an irrigation source particularly during dry season, which enables farmers to meet the water requirement of vegetable crops. Besides being a source of nutrients these effluents often contain various heavy metals, depending upon the anthropogenic activities from which these are originating. The removal of contaminants by macrophyte treatment of polluted water at source is easier than sites where these get accumulated by adsorption. Investigation was, therefore, carried out to test the efficacy of phytoremediation system using terrestrial weed species for remediation of heavy metals in industrial drain water.

The constructed phytoremediation system consisted of pre-treatment overhead settling zone and treatment zone having three pairs of sequential tanks (3 x 2 x 0.75) m. The fast growing terrestrial weeds such as *Typha latifolia* and *Vetiveria zizinoides* was planted hydroponically in first pair of tanks and in surface and sub-surface tanks filled with porous media. The polluted water from waste water carrying drain is injected into pre-treatment overhead tanks and after settling of solid particles at bottom, 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 outlet point of sedimentation, hydroponics, surface and subsurface tanks after treatment.

It was observed that extensive root system of *Typha* was developed in hydroponically grown tanks. The concentration of iron, copper and cadmium in drain water was 0.3282, 0.0363 and 0.0126 mg/L respectively (Table 16). After its treatment, the

Waste water carrying drain

Extensive growth of *Typha* in hydroponic tank

concentration of iron, copper and cadmium was reduced to 0.1548, 0.0286, 0.0093 mg/L in hydroponic tanks, 0.0356, 0.0276, 0.0106 mg/L in surface tank and 0.0650, 0.016, 0.0106 mg/L in sub-surface tanks of *Typha* based system respectively. Whereas in the *Vetiveria* treatment system, the concentration of iron, copper and cadmium was 0.2443, 0.0256 and 0.0110 mg/L in hydroponic tanks; 0.2453, 0.0226 and 0.0098 mg/L in surface tanks; 0.1033, 0.0199 and 0.0087 in sub-surface tanks of *Vetiveria* system, respectively (Table 17). Higher nutrient removal to the extent of 70.4, 58.8, 80.3 % of nitrate and 42.5, 12.1, 29.5 % of phosphate under hydroponic, surface and sub-surface system was removed by *Typha* system (Table 18).

Table 16: Performance of *Typha* treatment system heavy metal (mg/L) removal

Treatment	Fe (mg/L)	Removal efficiency (%)	Cu (mg/L)	Removal efficiency (%)	Cd (mg/L)	Removal efficiency (%)
Sedimentation	0.2242	31.6	0.0361	0.36	0.0101	19.7
Hydroponics	0.1548	52.8	0.0286	21.0	0.0093	26.3
Surface tank	0.0356	89.1	0.0276	23.7	0.0106	15.7
Sub surface	0.0650	80.1	0.016	56.9	0.0106	15.7
Drain water	0.3282	-	0.0363	-	0.0126	-

Table 17: Performance of *Vetiveria* treatment system for heavy metal removal

Treatment	Fe (mg/L)	Removal efficiency (%)	Cu (mg/L)	Removal efficiency (%)	Cd (mg/L)	Removal efficiency (%)
Sedimentation	0.3080	6.1	0.0288	20.6	0.0110	12.6
Hydroponics	0.2443	25.5	0.0256	29.4	0.0110	12.6
Surface tank	0.2453	25.2	0.0226	37.7	0.0098	22.2
Sub surface	0.1033	68.5	0.0199	45.1	0.0087	30.9
Drain water	0.3282	-	0.0363	-	0.0126	

Table 18: Performance of *Typha* treatment system for heavy metal removal

Treatment	*Typha* system				*Vetiveria* system			
	NO_3 (mg/L)	Efficiency (%)	PO_4 (mg/L)	Efficiency (%)	NO_3 (mg/L)	Efficiency (%)	PO_4 (mg/L)	Efficiency (%)
Hydroponics	0.832	70.4	1.057	42.5	0.840	70.1	1.6661	9.5
Surface tank	1.16	58.8	1.617	12.1	0.552	80.3	1.4933	18.9
Sub surface	0.552	80.3	1.297	29.5	0.576	79.3	1.1352	38.3
Drain water	2.816	-	1.8414	-	2.816	-	1.8414	-

The effect of drain water on soil contamination was assessed after its irrigation to tomato crop. The results indicated that among irrigation water treatments, higher concentration of DTPA extractable heavy metals (cadmium, copper, manganese, nickel, lead were observed in plots irrigated with untreated drain water as compared to tube well water. The sequence of heavy metal accumulation in soil was Cu > Pb >Zn >Ni >Cd.

4.3.2. Evaluation of weedy plants for herbicide tolerance

A pot experiment was carried out to evaluate three plant species viz, *Vetiveria zizinoides, Typha latifolia,* and *Acorus calamus* exposed to three pretilachlor levels (0, 750 and 1500 g/ha) and two doses of NPK levels of 0 and 120 kg N + 60 kg P_2O_5+60 kg K_2O /ha. The experimental results suggested that all the plant species tolerated with optimum pretilachlor levels (750 g/ha). However, among weed species tested, there existed significant variation in the tolerance to pretilachlor affecting growth of *Acorus* and *Typha* at higher dose of pretilachlor. The difference embodied with the plant height, number of tillers, dry weight, chlorophyll and leaf area compared to these plant species *Vetiveria zizinoides* showed tolerance to pretilachlor (Table 19-22).

Table 19: Effect of different levels of pretilachlor on fresh weight (FW) and dry weight (DW) of weed species

Treatment	*Acorus calamus*		*Typha latifolia*		*Vetiveria zizinoides*	
	FW (g/plant)	DW (g/plant)	FW (g/plant)	DW (g/plant)	FW (g/plant)	DW (g/plant)
Pretilachlor (g/ha)						
0	3.96	2.31	2.72	1.62	7.57	4.10
750	3.91	2.30	3.03	1.70	7.20	4.51
1500	3.87	1.87	2.74	1.79	8.05	4.78
SEm±	**0.31**	**0.23**	**0.22**	**0.05**	**0.47**	**0.24**
LSD (P=0.05)	**NS**	**0.50**	**NS**	**0.12**	**1.05**	**0.53**
NPK levels						
No NPK	3.85	2.25	2.69	1.61	7.72	4.16
NPK 120, 60, 60	3.98	2.34	2.97	1.79	7.49	4.76
SEm±	**0.25**	**0.19**	**0.18**	**0.04**	**0.39**	**0.19**
LSD (P=0.05)	**NS**	**NS**	**0.40**	**0.10**	**NS**	**0.43**

Table 20: Effect of Pretilachlor levels and nutrients on root length and its biomass of weed species

Treatment	*Acorus calamus*		*Typha latifolia*		*Vetiveria zizinoides*	
	Root length (cm)	Root biomass (g/plant)	Root length (cm)	Root biomass (g/plant)	Root length (cm)	Root biomass (g/plant)
Pretilachlor (g/ha)						
0	20.05	19.89	20.88	17.76	33.70	18.68
750	19.10	18.85	16.06	14.50	40.18	21.98
1500	16.57	16.85	15.26	11.91	48.68	24.34
SEm±	**0.74**	**1.88**	**1.90**	**3.99**	**2.11**	**1.26**
LSD (P=0.05)	**2.24**	**NS**	**5.7**	**NS**	**4.71**	**2.80**
NPK levels						
No NPK	18.93	12.294	18.02	11.88	38.28	16.47
NPK 120, 60, 60	18.21	21.166	16.78	17.56	43.42	26.87
SEm±	**0.61**	**1.53**	**1.55**	**3.26**	**1.73**	**1.03**
LSD (P=0.05)	**NS**	**3.342**	**NS**	**NS**	**3.85**	**2.29**

Table 21: Effect of pretilachlor and nutrient levels on chlorophyll a and b (mg/g /fresh weight) in weed species

Treatment	*Typha latifolia*		*Acorus calamus*		*Vetiveria zizinoides*	
	Chl a	Chl b	Chl a	Chl b	Chl a	Chl b
Pretilachlor (g/ha)						
0	0.416	0.642	0.696	0.687	0.311	0.290
750	0.296	0.566	0.499	0.509	0.256	0.283
1500	0.209	0.318	0.364	0.498	0.151	0.271
SEm±	**0.018**	**0.061**	**0.030**	**0.030**	**0.013**	**0.022**
LSD (P=0.05)	**0.040**	**0.136**	**0.066**	**0.066**	**0.030**	**NS**
NPK levels						
No NPK	0.277	o.294	0.487	0.509	0.238	0.273
NPK 120, 60, 60	0.337	0.724	0.553	0.621	0.241	0.290
SEm±	**0.015**	**0.050**	**0.024**	**0.024**	**0.011**	**0.018**
LSD (P=0.05)	**0.033**	**0.111**	**0.054**	**0.054**	**0.025**	**0.040**

Chl a-chlorophyll a and Chl b-chlorophyll

Table 22: Effect of different levels of pretilachlor and nutrients on leaf area (cm/m^2) of weed species

Treatment	*Acorus calamus*	*Typha latifolia*	*Vetiveria zizinoides*
Pretilachlor (g/ha)			
0	199.6	142.6	345.6
750	156.8	154.4	364.3
1500	143.3	146.4	424.0
SEm±	**10.64**	**22.27**	**36.82**
LSD (P=0.05)	**23.7**	**NS**	**82.2**
NPK (levels)			
No NPK	129.5	127.79	336.67
NPK 120, 60, 60	150.4	167.90	419.94
SEm±	**8.68**	**18.18**	**30.0**
LSD (P=0.05)	**19.4**	**40.6**	**67.1**

4.3.3. Enhanced accumulation of cadmium in *Arundo donax* by chelating agent

Soil contaminated by metal elements like cadmium which mainly originate from industries such as plastic production units, waste from smelters, re-melting of plated metals and alloys and sewage sludge etc, has become one of the major environmental concerns and has profound effects on health of human beings. In recent times, the phyto-extraction of toxicants from metal contaminated sites has been of prime importance due to its lesser cost of implementation than others and loads of environmental paybacks. More importantly, use of chelating agent is an effective amendment to speed up phytoremediation process. Thus this work was started with the objective to test the potential of *Arundo donax* L. for cadmium (Cd) tolerance and accumulation with or without EDTA.

A pot experiment was carried out in net house facility during *kharif* 2013. *Arundo donax L.* was exposed to different concentrations of Cd: 0, 100, 200, 400, 800 and 1200 mg/L with ethylene diamine tetra-acetic acid (EDTA) concentrations applied at 0, 3 and 6 ppm.

Photoremediation in net house

After harvesting, plant samples were thoroughly washed and dried at 70 °C for 48 hours, ground and mixed thoroughly for cadmium analysis. Plant samples (1g) were digested in concentrated nitric and perchloric acid (3:1) till a clear solution was obtained. The solution was filtered, reconstituted to the desired volume and analyzed for cadmium in di-acid plant extract by atomic absorption spectrophotometer (Thermo Solar- S4 model).

The cadmium accumulation in shoot was increased with increased concentration of cadmium. The higher cadmium accumulation was observed in root than shoot part of *Arundo donax*. The order of cadmium accumulation was root > stem > leaf . The EDTA at 3-6 mg/L enhanced cadmium accumulation in shoot (Figure 7 and 8). The EDTA enhanced Cd accumulation in roos by 2 – 3 folds. There was an increase in accumulation in shoot also.

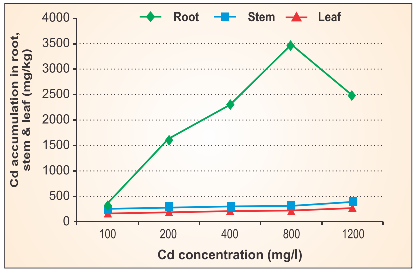


Figure 7 : Accumulation of cadmium in different plant part

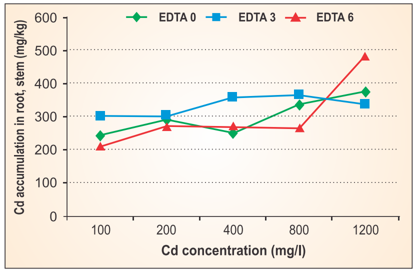


Figure 8 : Cadmium accumulation by *Arundo* with or without EDTA

6 RESEARCH PROGRAMME - 5

ON-FARM RESEARCH AND DEMONSTRATION OF WEED MANAGEMENT TECHNOLOGIES AND IMPACT ASSESSMENT

Appropriate technologies are roots of agrarian development. However, any weed management technology cannot perform equally in every agro-climatic situation. On-farm research (OFR) is aimed at testing new technologies on farmer's field, in participatory mode. It should help to develop innovations consistent with farmers' circumstances compatible with an actual farming system and corresponding to farmers' goal and preferences. The improved weed management technologies are in great demand by the farmers now a days because of the acute labourer scarcity and high cost of manual weeding. Unfortunately, there is not enough awareness among the farmers about IWM practices, even in areas not far away from the research institutions. It is also argued that scientists do their research work without much consideration of the real problems faced by the farming community. Accordingly, the on-farm research programme has been initiated to understand farmers' problems and undertake necessary interventions through farmer participatory approach to develop, test and evaluate cost-effective solutions to their weed related problems.

Sub-programmes	Experiments	Programme Leader	Associates
5.1. On-farm research and demonstration of weed management technologies for higher productivity and income	5.1.1. On-farm research and demonstration of weed management technologies in soybean-based cropping system (Majholi locality)	P.K. Singh	V.P. Singh, P.J. Khankhane and Shobha Sondhia
	5.1.2. On-farm research and demonstration of weed management technologies in direct-seeded rice-based cropping system (Bankhedi locality)		C. Kannan and Meenal Rathore
	5.1.3. On-farm research and demonstration of weed management technologies in rice-based cropping system (Panagar locality)		H.S. Bisen, Dibakar Ghosh and Bhumesh Kumar
	5.1.4. On-farm research and demonstration of weed management technologies in direct-seeded rice-based cropping system (Shahpura locality)		Sushil Kumar, Raghwendra Singh and Yogita Gharde
	5.1.5. On-farm research and demonstration of weed management technologies in rice based cropping system (Gosalpur locality)		D.K. Pandey, R. P. Dubey and P.P. Choudhury
	5.1.6. On-farm research and demonstration of weed management technologies in maize and rice-based cropping system (Kundam locality)		P.K. Singh and K.K. Barman
5.2. Impact assessment of weed management technologies on social upliftment and livelihood security	5.2.1. Impact assessment and adoption of weed management technologies	P.K. Singh	Yogita Gharde and Associates

5.1. On farm research and demonstration of weed management technologies for higher productivity and income

Initially, different localities of Jabalpur district were indentified and surveyed with regard to cropping pattern, location-specific weed problems and management practices being adopted by the farmers. Accordingly, farmers with little technical knowhow in terms of existing weed management practices were selected. Subsequently, 7-8 farmers representing various sections were selected randomly in each locality. The OFRs using IWM technologies were laid out in wheat, chickpea and pea during winter season, and rice, soybean and maize during rainy season, and greengram during summer season. Trials were conducted in a participatory mode with active involvement of the farmers.

5.1.1. On-farm research and demonstration of weed management technologies in soybean-chickpea based cropping system (Majholi locality)

Chickpea (*Rabi* 2012-13)

Five on-farm trials were conducted in the village Pola of Majholi region. In chickpea, treatment consisted of pre-emergence application of pendimethalin (Stomp xtra) @ 750 g/ha. Fields were infested heavily with *Vicia sativa*, *Convolvulus arvensis*, *Chenopodium album* and *Lathyrus sativa*. Results revealed that pendimethalin effectively controlled the weeds and gave higher weed control efficiency and overall average benefit of ₹ 17040/ha with benefit cost (B:C) ratio of 2.93 over farmers practice (Table 1).

Table 1: OFR on improved weed management technologies in chickpea at Majholi locality of Jabalpur

Name of farmer	Treatment	Weed count (no./m^2)	Dry weight (g/m^2)	Grain yield (t/ha)	Economic benefit over FP (₹/ha)	B:C ratio
Lahori Patel	Pendimethalin 750 g/ha	92	35.4	1.19	11648	2.04
	Farmers' practice- no weeding	236	154.0	0.84	5518	1.57
Lochan Patel	Pendimethalin 750 g/ha	67	32.6	1.89	18033	3.25
	Farmers' practice- no weeding	164	127.0	1.14	14518	2.13
Sugreev Patel	Pendimethalin 750 g/ha	27	30.3	2.10	41948	3.62
	Farmers' practice- no weeding	106	135.6	1.39	22018	2.03
Atal Patel	Pendimethalin 750 g/ha	32	32.6	1.73	30848	2.98
	Farmers' practice- no weeding	134	173.8	1.07	12418	2.00
Chetu Lal	Pendimethalin 750 g/ha	32	15.6	1.60	26948	2.76
	Farmers' practice -no weeding	106	80.2	1.23	17218	2.30

Weed management technology in soybean at Pola (Majholi)

5.1.2. On-farm research and demonstration of weed management technologies in direct-seeded rice-based cropping system (Bankhedi locality)

Wheat (*Rabi* 2012-13)

On-farm trials were conducted in wheat in village Dhanwahi of Bankhedi locality. Application of mesosulfuron + iodosulfuron at 18 g/ha in wheat cv. 'C 306' and 2,4-D at 725 g/ha in wheat 'GW 273' as post-emergence was done to control weeds and sedges. The fields were infested with *Lathyrus sativus*, *Vicia sativa*, *Chenopodium album* and *Medicago hispida*. Farmers' fields with application of herbicides recorded lower weed infestations and higher grain yields as compared to farmers practice. Enhanced benefit cost (B:C) ratios of 1.80 and 2.20 for the herbicides used (mesosulfuron + iodosulfuron and 2,4-D, respectively) were obtained over farmers practice that recorded the ratio of 1.64 and 1.44 (Table 2).

Table 2: Weed incidence, grain yield and benefit cost ratio in wheat under DWSR recommendations and farmers practice at Dhanwahi village in *Rabi* 2012-13

Treatment	Weed population (no./m²)	Weed dry weight (g/m²)	Grain yield (t/ha)	B:C ratio
Mesosulfuron + iodosulfuron 18 g/ha, wheat variety 'C306'	37.6±2.08	20.7±2.97	2.51±0.47	1.8±0.33
2,4-D 725 g/ha, wheat variety C306 , 'GW-273'	45.6±14.3	19.2±5.00	3.00±0.5	2.2±0.33
Farmers' practice metsulfuron 4 g/ha	133.9± 33.6	64.9±14.84	2.10±0.34	1.6±0.27
Weedy check	147.3±51.16	75.2±19.4	1.85 ± 0.31	1.4±0.24

Values are means of 15 replications ±SD

Rice (*Kharif* 2013)

On-farm research and demonstration of weed management technologies in rice was undertaken in wheat-direct seeded rice based cropping system at Dhanwahi village in Bandkedi locality. The technology of weed management was demonstrated by using four treatments viz., application of pendimethalin at 750 g as pre-emergence followed by bispyribac-sodium at 25 g/ha, bispyribac-sodium at 35 g/ha (farmers' practice), intercropping of sesbania followed by application of 2,4-D and weedy check. The lowest weed population was recorded in field with application of pre- and post-emergence herbicides. Application of herbicides recorded higher gross returns (₹ 68,120/ha) and benefit cost ratio (2.58) over farmers' practice (₹ 55269/ha, 2.03) (Table 3).

Table 3: Weed growth, seed yield and economics in rice under DWSR recommendations and farmers' practice at Dhanwahi village in Bankhedi locality during *Kharif* 2013

Treatment	Weed population (no./m²)	Panicles (no./m²)	Grain yield (t/ha)	Gross returns (₹/ha)	B:C
Pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha	6.3±3.4	212.5±17.9	5.20±0.28	68120±12	2.5 ± 0.29
Bispyribac-sodium 25 g/ha, sesbania *fb* 2,4-D	22.1±9.8	187.6±11.8	4.45±0.57	58295±1647	2.2 ± 0.11
Bispyribac-sodium 35 g/ha (farmers' practice)	22.1±9.8	191.0±17.0	3.99±0.26	52269±3700	2.0 ± 0.47
Weedy check	79.1±4.4	138.2±11.0	2.33±72	33408±8195	1.4 ± 0.64

Values are means of 15 replications ±SD

5.1.3. On-farm research and demonstration of weed management technologies in rice-based cropping system (Panagar locality)

Wheat (*Rabi* 2012-13)

On-farm research and demonstration of weed management technology were carried out at eleven locations in wheat crop at farmers field in Mahagawa and Kariwah villages, Panagar during *Rabi* 2012-13. The seed, fertilizers and herbicides were applied in the fields. Nine farmers from Mahagawa, one each from Kariwah and Bamhnoda village were selected. In three farmer's fields, the sowing of wheat crop was done by happy seeder machine without removal of previous crop residues (rice stubbles and straw) to demonstrate the conservation agriculture technology. Eight farmers carried out sowing of wheat crop with normal seed drill available with them. The herbicides used in these OFR trials were 2,4-D, mesosulfuron + iodosulfuron, clodinofop + metsulfuron and mesosulfuron alone. Wheat crop had good emergence and stand establishment. Weed population in three conservation agriculture OFR trials were less compared to other field trials in which land was prepared by conventional cultivator and harrow. Major weeds were *Lathyrus sativus, Vicia sativa, Chenopodium album, Medicago hispida* and *Melilotus alba* among broad leaved and *Avena* sp. (wild oat) and *Phalaris minor* among grasses. The herbicide controlled the weed flora effectively and increased yield of wheat as compared to the fields cultivated by conventional practice with no weed control measures. The post-emergence application of herbicides controlled *Rabi* weeds effectively and gave higher benefit: cost ratio. In farmers field, mesosulfuron + iodosulfuron and 2,4-D controlled 50 - 68% and 51 - 62% weeds, respectively in wheat crop (Table 4). The herbicide clodinafop + metsulfuron controlled 69% weeds whereas metsulfuron alone controlled 60% weeds in wheat (Table 5).

Table 4: Weed growth, yield and economics of wheat crop in farmers field in Panagar locality using tractor drawn seed drill for sowing (*Rabi* 2012-13)

Herbicide treatment	Weed count (no/m²)	Dry weight (g/m²)	Grain yield (t/ha)	Total income (₹/ha)	Cost of production (₹/ha)	B:C ratio
2,4-D	29.75	13.56	2.81	40056	18800	2.13
Mesosulfuron + iodosulfuron	26	13.6	2.92	41869	19875	2.11
Unweeded	69.9	54.8	1.80	26294	18000	1.46

Table 5: Weed growth, yield and economics ratio of wheat crop in farmers field in Panagar locality using tractor drawn happy seeder and conservation agriculture (*Rabi* 2012-13)

Herbicide treatment	Weed count (no/m²)	Dry weight (g/m²)	Grain yield (t/ha)	Total income (₹/ha)	Cost of production (₹/ha)	B:C ratio
Mesosulfuron + iodosulfuron	24	12.07	3.31	47367	17375	2.73
2,4-D	45	28.8	3.04	43500	16300	2.67
Clodinafop + metsulfuron	20	8.5	3.32	47850	17575	2.72
Metsulfuron	44	31.2	3.01	43500	16375	2.66
Unweeded	70	57.8	2.00	29000	15500	1.87

Happy Seeder in Operation (Conservation Agriculture in wheat)

Rice

In *Kharif* season 2013, eight OFR trials were undertaken in direct seeded and transplanted rice in Mahagawa and Kariwah villages of Panagar locality. The results are shown in Table 6 and 7. The herbicide bispyribac-sodium controlled 55 - 80% weed flora in direct seeded rice and 75% in transplanted rice in farmers' fields in *Kharif* 2013. The herbicide chlorimuron + metsulfuron controlled 65 - 80% weeds in direct seeded rice in *Kharif* 2013 in farmers' field.

Table 6: Weed growth, seed yield and economics of transplanted rice crop in farmer's field in Panagar locality in *Kharif* 2013

Treatment	Weed count (no./m²)	Dry weight (g/m²)	Grain yield (t/ha)	Total income (₹/ha)	Cost of production (₹/ha)	B:C ratio
Bispyribac	42	20.5	3.41	37400	25125	1.48
Bispyribac + 2,4-D	30	16.7	3.60	39600	25425	1.55
Fenoxaprop	38	18.2	3.22	35200	24800	1.42
Unweeded	162	82.5	2.60	27029	23000	1.17

Table 7: Weed growth, seed yield and economics of direct seeded rice (DSR) crop in farmers' field in Panagar locality using tractor-drawn seed-drill in *Kharif* 2013

Treatment	Weed count (no./m²)	Dry weight (g/m²)	Grain yield (t/ha)	Total income (₹/ha)	Cost of production (₹/ha)	B:C ratio
Bispyribac	44	21.8	3.40	36986	22125	1.67
Bispyribac + 2,4-D	38	20.7	3.41	37871	22425	1.69
Fenoxaprop	45	26.1	3.21	34729	21800	1.59
Metsulfuron + chlorimuron	57	38.1	3.12	33629	20875	1.61
Brown manuring + bispyribac + 2,4-D	34	16.7	3.51	38814	22825	1.70
Un-weeded	140	81.3	2.60	27029	20000	1.35

5.1.4. On-farm research and demonstration of weed management technologies in direct-seeded rice-based cropping system (Shahpura locality)

Wheat (*Rabi* 2012-13)

On-farm trials were conducted in village Magarmuha of Shahpura block. Atlantis (mesosulfuron + iodosulfuron) 400 ml/ha and 2,4-D 500 g/ha were applied at 25 days after sowing depending upon nature of weed flora in farmers field to control grassy as well as broad leaved weeds. Among six farmers, the fields of four farmers were infested with only broad leaved weeds viz., *Medicago denticulata, Chenopodium album* and *Cichorium intybus,* where only 2, 4-D was applied, rest of the two farmers' fields were infested with grassy as well as broad leaved weeds (*Phalaris minor, Avena ludoviciana, Medicago denticulata, Chenopodium album* and *Cichorium intybus*), where mesosulfuron + iodosulfuron was used to control these weeds. The application of mesosulfuron + iodosulfuron and 2,4-D recorded lower weed infestation as compared to farmers' practice. Yield increased to the tune of 20-35% and varied with farmers by improved weed management over farmers' practice. Grain yield and benefit: cost ratios were also higher in improved practices as compared to farmers' practice (Table 8).

Chickpea (*Rabi* 2012-13)

During *Rabi* 2012-13, five on-farm trials were conducted in chickpea at Magarmuha village of Shahpura block. Application of pendimethalin (stomp xtra) 700 g/ha as pre-emergence just after sowing + one hand weeding was demonstrated in chickpea. Farmers' fields were mainly infested with broad leaved weeds viz., *Medicago denticulata, Chenopodium album, Cichorium intybus and Parthenium hysterophorus* and grassy weed viz., *Avena ludoviciana.* Application of pendimethalin *fb* one hand weeding significantly reduced the weed infestation as compared to weedy plots. Yield increase as a result of use of improved weed management technologies by the farmers was 20-30% and varied with farmers'. Grain yield and benefit: cost ratios were also higher in improved practices as compared to weedy situation (Table 9).

Rice (*Kharif* 2013)

On-farm research trials on rice were conducted in villages Magarmuha, Tipra and Noni of Shahpura block, about 45 km from DWSR. Bispyribac-sodium was applied at 25 g/ha at 25 days after sowing to control grassy, broad leaved and sedge weeds. The farmers' fields were mainly infested with *Echinochloa colona, Cyperus iria, Alternanthera sessilis, Commelina communis* and *Caesulia auxillaris.* The application of bispyribac-sodium recorded lower weed infestation as compared to farmers' practice. Yield increase was 11-15%, which varied with farmers. Grain yield and B:C ratio were also higher in improved practices (Table 10).

Table 8: Weed growth, grain yield and economics in improved and farmer's practice (Shahpura locality)

Name of farmer	Improved practice		Farmer's practice		Weed control efficiency (%)	Grain yield (t/ha)		B:C ratio	
	Weed count (no./m²)	Dry weight (g/m²)	Weed count (no./m²)	Dry weight (g/m²)		Improved practice	Farmer's practice	Improved practice	Farmer's practice
Amar Singh	40	26.1	134	86.4	69.8	4.15	3.15	2.89	2.32
Shrikant Patel	42	31.1	158	111.0	72.0	3.88	2.98	2.67	2.13
Ramesh Sahu	32	22.3	140	79.4	72.0	3.77	2.95	2.64	2.13
Manoj Namdev	38	23.5	136	82.0	71.3	2.03	1.56	1.40	1.12
Shyam Patel	37	17.6	114	70.6	75.1	4.49	3.37	2.97	2.40
Jitendra Patel	32	19.2	132	86.8	77.8	2.23	1.44	1.55	1.05

Improved and farmer's practice at village Magarmuha

Table 9: Evaluation of on-farm improved weed management technologies in chickpea at Magarmuha village in Shahpura during *Rabi* 2012-13

Name of farmer	Improved practice		Farmer's Practice		Weed control efficiency (%)	Grain yield (t/ha)		B : C ratio	
	Weed count (no./m²)	Dry weight (g/m²)	Weed count (no./m²)	Dry weight (g/m²)		Improved practice	Farmer's practice	Improved practice	Farmer's practice
Vijay Patel	49	30	90	54.3	44.75	1.68	1.17	2.79	1.73
Gajendra Patel	29	26.7	92	78.6	66.03	1.97	1.28	2.89	1.82
Bharat Patel	74	44.7	152	77.4	42.25	1.55	1.13	2.60	1.79
Shyam Patel	56	44.5	172	105.6	57.86	1.53	1.05	2.53	1.58
Madhava Patel	61	36.4	108	63.7	42.86	1.54	1.28	2.62	1.87

Table 10: Weed growth, grain yield and economics of improved weed management technology in Shahpura locality during *Kharif* 2013

Name of farmer	Improved practice		Farmer's practice (FP)		Weed control efficiency (%)	Grain yield (t/ha)		B : C ratio	
	Weed count (no./m²)	Dry weight (g/m²)	Weed count (no./m²)	Dry weight (g/m²)		IWM	FP	IWM	FP
Village Magarmuha									
Vijay Patel	49	28.7	255	165	82.6	3.24	2.92	1.96	1.67
Dhiraj Patel	25	19.0	186	125	84.7	3.46	2.95	2.05	1.68
Manoj Sahu	26	16.7	195	141	88.1	3.08	2.77	1.84	1.61
Shailendra Patel	16	23.3	157	156	85.1	2.93	2.64	1.79	1.53
Village Tipra									
Tejbal Patel	17	52.7	224	183	71.3	3.27	2.83	1.96	1.53
Village Noni									
Bhurelal Patel	47	17.7	196	148	88.0	3.37	2.82	1.99	1.55
Rameshwar Patel	53	25.8	228	179	85.6	3.37	2.84	1.98	1.58

5.1.5. On-farm research and demonstration of weed management technologies in rice based cropping system (Gosalpur locality)

Wheat (*Rabi* 2012-13)

On-farm research trials were undertaken on wheat variety 'GW 273' during *Rabi* season 2012-13 in the villages Bhadom and Khajuri of Gosalpur area. Different weed management technologies based on various herbicide formulations were applied in this programme. All the treatments were found better to the farmers' practices in terms of yield and B:C ratio (Table 11).

Table 11: Comparison of productivity of wheat in farmers practice with improved weed management techniques in Gosalpur area during *Rabi* 2012-13

Name of farmer	Treatment (IWM technology)	Weed population (no./m²)		Weed dry weight (g/m²)		Grain yield (t/ha)		B:C ratio	
		Treated	Farmer's practice	Treated plot	Farmer's practice	Treated plot	Farmer's practice	Treated plot	Farmer's practice
Uday Tiwari	Sulfosulfuron + metsulfuron-methyl	43	123	16.6	65.3	4.05	3.22	3.43	2.81
Panjilal Barman	Mesosulfuron + iodosulfuron	46	125	30.7	78.2	3.56	2.71	2.65	2.37
Bal Kishan Dahiya	Metsulfuron-methyl	38	103	34.4	71.8	3.60	3.01	2.99	2.63
Rambari Sahu	Clodinafop + metsulfuron-methyl	66	157	20.8	82.3	3.79	2.89	2.92	2.52

Rice (*Kharif* 2013)

On-farm research trials demonstrating improved weed management technologies were carried out on direct seeded rice variety 'Kranti' at the fields of seven farmers in the villages Bhadom and Khajuri of Gosalpur area during *Kharif* 2013. Among the technologies adopted, the treatment of stomp extra 750 g/ha (pre-emergence) followed by bispyribac-sodium 25 g/ha (post-emergence) were found more effective over farmer's practice (bispyribac-sodium 25 g/ha). Green manuring also managed weed in rice rendering high B:C ratio at par with the herbicide treatment (Table 12).

Table 12: Direct seeded rice productivity comparison between farmars' practice and improved weed management techniques in the Gosalpur area during *Kharif* 2013

Treatment	Weed population (no./m²)	Weed dry weight (g/m²)	Yield (t/ha)	B:C ratio
Pendimethalin followed by bispyribac-sodium	19.14±4.18	8.59±8.51	4.39±0.71	3.20
Bispyribac-sodium (Farmer's practice)	28.00±8.69	22.75±15.15	3.91±0.75	3.14
Sesbania	32.57±9.69	15.48±12.93	3.73±0.58	3.02
Weedy	50.42±14.59	61.09±24.11	2.36±0.62	2.18

Values are mean of 7 replications (farmers' fields) ± SD

5.1.6. On-farm research and demonstration of weed management technologies in maize and rice-based cropping system (Kundam locality)

Wheat (*Rabi* 2012-13)

Four OFR-cum-demonstrations were laid out in wheat on farmers' fields at two villages (Kalyanpur and Ranipur) of Kundam locality of Jabalpur. Improved weed management technologies tested consisted of post emergence application of herbicides clodinafop @ 60 g/ha + metsulfuron @ 4 g/ha and sulfosulfuron + metsulfuron @ 32 g/ha in wheat crop. Major weeds were *Lathyrus sativus, Vicia sativa, Chenopodium album, Medicago hispida* and *Melilotus alba* among broadleaved weeds, and *Avena* sp. (wild oat) and *Phalaris minor* among grasses. Herbicides were applied according to weed flora at the location. All the treatments controlled weeds effectively and increased the yield of wheat (21-39%) over farmers' practice (FP). Post-emergence application of clodinafop + metsulfuron gave broad-spectrum weed control in wheat (var. 'C-273') and higher benefit of ₹ 10,700 with B:C ratio 3.22 (Table 13).

Table 13: OFR cum demonstrations of improved weed management technologies in wheat in farmers' field at Kundam locality of Jabalpur during *Rabi* 2012-13

Name of farmers	Treatment	Weed count (no./m²)	Dry weight (g/m²)	Grain yield (t/ha)	Economic benefit over FP (₹/ha)	B:C ratio
Location – Ranipur Wheat var. 'C-306'						
Chetan Patel	Farmer's practice	152	91.3	2.11	-	2.02
	Sulfosulfuron + metsulfuron @ 32 g/ha	50	20.6	2.62	7670	2.35
Jage Patel	Farmer's practice	235	105.7	1.82	-	1.74
	Sulfosulfuron + metsulfuron @ 32 g/ha	59	30.3	2.54	10350	2.29
Location - Kalyanpur, Wheat var. 'GW-273'						
Hari Prasad	Farmer's practice	201	92.9	3.12	-	2.48
	Clodinafop + metsulfuron-methyl @ 60 + 4 g/ha	56	33.9	3.86	10700	2.92
Promod Kumar	Farmer's practice	222	114.8	3.51	-	2.79
	Clodinafop + metsulfuron-methyl @ 60 + 4 g/ha	68	36.6	4.25	10705	3.22

FP- Farmer's practice

Pea (*Rabi* 2012-13)

Three OFR cum demonstrations were conducted in the Khukham village of Kundam, Jabalpur. The treatments consisted of pre-emergence application of pendimethalin @ 800 g/ha *fb* one hand weeding at 30-35 DAS. Fields were infested mainly with *Avena* sp., *Chenopodium album, Medicago hispida* and *Lathyrus sativus*. Results revealed that pendimethalin *fb* one hand weeding effectively controlled the weeds (WCE, 60%) with higher benefit and B:C ratio over farmers' practice (Table 14).

Table 14: OFR-cum-demonstration of improved weed management technologies in pea at Khukham locality of Jabalpur

Name of farmer	Treatment	Weed count (no./m²)	Dry weight (g/m²)	Grain yield (t/ha)	Economic benefit over FP (₹/ha)	B:C ratio
Patiram Bhavedi	Farmer's practice	57	40.1	1.41	-	2.70
	Pendimethalin @ 800 g/ha PE *fb* HW	29	16.2	1.71	4789	2.84
Bhagchand	Farmer's practice	75	54.6	1.18	-	2.27
	Pendimethalin @ 800 g/ha PE *fb* HW	41	25.9	1.50	5449	2.51
Shiva Charan	Farmer's practice	88	48.9	1.30	-	2.45
	Pendimethalin @ 800 g/ha PE *fb* HW	29	17.6	1.70	5809	2.70

Farmers' practice had no weeding operation and involved deep summer ploughing

Maize (*Kharif* 2013)

Villages of Kundam locality (Khukham, Padaria and Ranipur) are populated largely by tribes. Farming is predominantly rainfed as there is no source of irrigation. The farmers grow maize and direct-seeded rice only during rainy season. Six on-farm research trial-cum-demonstrations were conducted on maize in these villages. The crop was infested with mixed weed flora viz., *Echinochloa colona, Dinebra retroflexa, Cyperus* spp., *Commelina communis, Ageratum conizoides* and *Euphorbia geniculata*. Pre-emergence application of atrazine @ 1.0 kg/ha with mulching was most effective, and gave additional benefit of ₹ 13,122/ha and B:C ration of 1.83 as compared to farmers practice (Table 15).

OFR trail at Khukham

Table 15: Effect of farmers practice and improved weed management technologies on weed growth, maize productivity and income in Khukham village during *Kharif* 2013

Name of farmer	Treatment	Weed count (no./m²)	Dry weight (g/m²)		Grain yield (t/ha)	Economic benefit over FP (₹/ha)	B:C ratio
Patiram Bhavedi	Atrazine	72	50.5	43	1.83	7652	1.56
	Atrazine + 1 HW	40	28.3	68	2.32	12346	1.77
	Atrazine + mulching	34	23.5	73	2.41	13122	1.83
	Farmers practice	130	88.2	-	1.24	1600	1.13
Shivcharan	Atrazine	77	46.6	51	1.72	7112	1.52
	Atrazine + 1 HW	45	37.1	61	2.21	9970	1.62
	Farmers practice	141	95.4	-	1.13	1024	1.08
Makku Singh	Atrazine	58	37.7	53	1.91	9704	1.71
	Atrazine + 1 HW	38	30.4	60	2.24	10234	1.64
	Farmers practice	111	79.5	-	1.23	2488	1.20
Bhagchandrs	Atrazine	60	33.3	52	2.04	10304	1.76
	Atrazine + 1 HW	47	31.5	55	2.23	9706	1.61
	Farmers practice	118	69.3	-	1.31	3964	1.32
Chunnulal	Atrazine	68	35.4	59	2.04	9908	1.73
	Atrazine + 1 HW	38	32.5	62	2.11	9106	1.57
	Farmers practice	132	86.3	-	1.23	2536	1.21
Raghuveer Singh	Atrazine	61	39.1	54	1.91	9320	1.68
	Atrazine + 1 HW	35	28.2	67	2.30	11890	1.74
	Farmers practice	132	85.2	-	1.10	1912	1.16

5.2. Impact assessment of weed management technologies on social upliftment and livelihood security

A study was conducted at Bankhedi, Shahpura, Panagar and Kalyanpur locations in 2012-13 using the stratified random sampling techniques. The results revealed that most of the farmers followed rice-wheat cropping system. Weed control in rice was a highly cumbersome operation as it involved more labourers, which were mostly not available at the time of need and was capital intensive. The cost of improved weed management practices was only ₹ 2000/ha, while the conventional practices (manual weeding) required around ₹ 5000/ha. The difference in income realization between the adopters and non-adopters of IWM was also studied. The results showed an additional income of ₹ 11000-13000/ha due to adoption of the techniques as compared to non-adopters.

It was also noticed that due to intervention of the DWSR, large numbers of farmers in the 'on-farm research' areas have started using IWM technologies especially in rice, soybean and wheat. It may be concluded that the OFR cum demonstration programme of DWSR was successful in convincing farmers and other stakeholders that utilization of IWM technologies in scientific manner was essential to increase yield and economic benefit.

OFR activities at different localities

7 EXTERNALLY-FUNDED PROJECTS

The Directorate has externally funded projects undertaking investigations on frontier areas of weed science.

	Projects	Principal investigator	Funding agency	Collaborating institutions	Period	Budget (₹ lakhs)
7.1.	Precision farming technologies based on microprocessor and decision support systems for enhancing input application efficiency in production agriculture	V.P. Singh	NAIP, ICAR	CIAE, Bhopal, IIT, Kharagpur and PDCSR, Modipuram	2009-14	65.41
7.2.	Development and formulation of microbial metabolites for the management of root parasite weed *Orobanche* in mustard	C. Kannan	MPBT Council, Bhopal	None	2012-15	15.05
7.3.	Study of domestication traits of two weed species	Bhumesh Kumar	NFBSFARA, ICAR	AAU, Jorhat, UAS, Bengaluru and GBPUAT, Pantnagar	2013-16	119.50
7.4.	Bioremediation of contaminants in polluted sites, use of weedy plants	P.J. Khankhane	NFBSFARA, ICAR	IARI, New Delhi DU, New Delhi	2013-17	206.31

7.1. Precision farming technologies based on microprocessor and decision support systems for enhancing input application efficiency in production agriculture

The project was part of a mega project expected to develop spectral signatures of major weeds in rice, soybean and wheat and to provide the required data for development of an automated decision based application system for herbicide application.

7.1.1. Normalized difference vegetation index (NDVI) of crops and major weeds of wheat, soybean and rice

The spectral signatures of the crops and their respective major weeds were developed by collecting their spectral reflectance data using spectro-radiometer. The data were analyzed and submitted to the lead centre for the purpose of developing decision support software for herbicide spray in rice, wheat and soybean. The NDVI, which is a derived value (signature) of the spectral reflectance at various wavelengths, did not show significant differences between crops and their mimic weeds e.g., *Phalaris minor* and *Avena ludoviciana* in wheat, where the values for wheat alone at 100 plants/m^2 was higher (0.83) when compared to *P. minor* alone at 150 plants/m^2 (0.71). At critical stages of wheat and *P. minor* competition, the NDVI of wheat and wheat together with the weed were similar (0.83). The trend was similar in all stages of growth of the crop and weed. The values estimated were similar for the measurements made for two years. The NDVI values of broad leaved weed *Chenopodium album* alone with 80 plants/m^2 (NDVI 0.43) showed significant difference with wheat alone 100 plants/m^2 (NDVI 0.83). However, at the critical competitive proportion of *C. album* at 15 plants/m^2 and wheat, 100 plants/m^2, the NDVI was found to be similar to wheat alone

(0.84). This showed that wheat is dominating over *C. album* in its NDVI pattern. The trend was similar with other broad leaved weeds and in both the years and at all stages of the crop and weed competition. Similar were the observations with rice and soybean. Thus, the trends in NDVI values of wheat did not show any regular pattern for use.

This suggests potential problems for the identification of individual weed species with an automated system without frequent calibration. However, it may be possible to distinguish weeds as a group, from the crop. Analysis of simple vegetation indices has suggested that, even when crops and weeds are all green and reflectance signatures are apparently similar, there may be significant differences at specific wavelengths. Further, development of these techniques and analyses of the data may allow development of a system which can distinguish weed patches at high densities much earlier in the year.

7.1.2. Precision nitrogen management in rice-wheat cropping system

In addition to developing spectral signatures, the Directorate was also entrusted with conducting field experiment as part of multi-location trials to study precise nitrogen management in rice and wheat using the parameter soil plant analysis development (SPAD) at different threshold levels. The experiment was two-factor experiment. The first factor was SPAD employing three threshold levels nitrogen for rice SPAD-1 = 34, SPAD-2 = 36 and SPAD-3 = 38 and for wheat SPAD-1 = 38, SPAD-2 = 40 and SPAD-3 = 42 and second factor was nitrogen levels (3 levels), (kg/ha) N_1 = 15, N_2 = 25 and N_3 = 35. Treatment combination of SPAD and N levels was 3X3= 9 and 10^{th} treatment with no fertilizer application (control).

Results from the experiment on rice (Table 1) showed that among different SPAD values, maximum yield and yield attributing characters was recorded with SPAD-3 and amongst nitrogen treatments, the maximum values for yield and yield attributing characters were observed with N_3 (128 kg N/ha). But reverse trend was recorded for nitrogen, agronomic and physiological use efficiency. The maximum nitrogen and agronomic- and physiological-use efficiency was observed with SAPD-1 and N_1.

Similarly, results from the experiment on wheat (Table 2) showed that among different SPAD values, maximum yield and yield attributing characters were recorded with SPAD-3 and amongst nitrogen treatments the maximum values for yield and yield attributing characters were observed with N_3 (155 kg N/ha). But reverse trend was recorded for nitrogen, and agronomic- and physiological-use efficiency. The maximum nitrogen and agronomic- and physiological-use efficiency was recorded with SAPD-1 and N.

Table 1: Effect of SPAD values and nitrogen on yield and yield attributes of rice

Treatment	Grain weight (g/panicle)	Grain yield (t/ha)	Straw yield (t/ha)
SPAD value			
SPAD-1 (34)	3.38	3.43	4.24
SPAD-2 (36)	3.87	3.69	4.59
SPAD-3 (38)	4.11	3.86	4.74
SEd±	**0.51**	**1.51**	**4.05**
LSD (P=0.05)	**NS**	**NS**	**NS**
N level			
N_1 (92 Kg/ha)	3.70	3.67	4.21
N_2 (121 kg/ha)	3.71	3.60	4.72
N_3 (128 kg/ha)	3.96	3.71	4.65
SEd±	**0.24**	**0.57**	**0.39**
LSD (P=0.05)	**NS**	**NS**	**NS**
Overall Control	1.85	1.94	2.45

Table 2: Effect of SPAD values and nitrogen on yield and yield attributes of wheat

Treatment	Grain weight (g/spike)	Grain yield (t/ha)	Straw yield (t/ha)
SPAD value			
SPAD-1 (38)	2.02	4.79	5.25
SPAD-2 (40)	2.03	5.09	5.50
SPAD-3 (42)	2.12	5.28	5.67
SEd±	**0.14**	**2.03**	**2.32**
LSD (P=0.05)	**NS**	**NS**	**NS**
N level			
N_1 (121 Kg/ha)	2.02	4.68	5.05
N_2 (135 kg/ha)	2.07	5.13	5.52
N_3 (155 kg/ha)	2.07	5.35	5.85
SEd±	**0.09**	**36.1**	**1.87**
LSD (P=0.05)	**NS**	**0.12**	**0.66**
Overall Control	1.33	2.57	2.78

7.2. Development and formulation of microbial metabolites for the management of *Orobanche* in mustard

The project is aimed at (i) extraction of crude fractions of secondary metabolites from the commonly occurring soil fungi antagonistic on *Orobanche* spp., (ii) bioassay screening of the fungi and their crude fractions on *Orobanche* and to study the interactions of the host plant, parasitic weed and the microbial metabolite for better understanding of the resistance process of the host, and (iii) partial purification and formulation of the potential crude fraction for their sustained and safe release in the farmer's field. Progress made in the project is detailed below:

7.2.1. Extraction of secondary metabolite and screening for inhibition by bioassay

Microbial cultures were grown in pure cultures for 21 days and extracted using dichloromethane. Presence of the metabolites was confirmed on TLC. Bioassay tests were performed using a simple and rapid technique of germinating *Orobanche* under laboratory conditions as per standard procedure developed in the Directorate. Host seeds were treated with microbial metabolites and the seedlings were transplanted to the beakers containing preconditioned *Orobanche* seeds.

Results showed that the microbial metabolites were able to suppress germination of *Orobanche* under controlled conditions (Table 3). Among different microbes, *Fusarium* sp. DWSR 1 was the most effective in suppressing the germination at 50% concentration.

Table 3: Effect of microbial metabolites in the germination of *Orobanche crenata* under laboratory conditions

Treatment	% germination of *Orobanche*			
	Concentration of metabolites			
	5%	10%	20%	50%
Fusarium sp. DWSR1	19.67	17.33	13.33	11.67
Fusarium sp. DWSR2	21.33	19.33	17.33	15.67
Penicillium	23.33	20.33	16.67	14.67
Gliocladium virens	32.67	30.67	29.67	28.67
Trichoderma viride	27.67	25.67	24.67	23.67
Control	46.67	51.67	53.67	54.67
LSD (P=0.05)	**3.72**	**2.91**	**4.04**	**4.10**

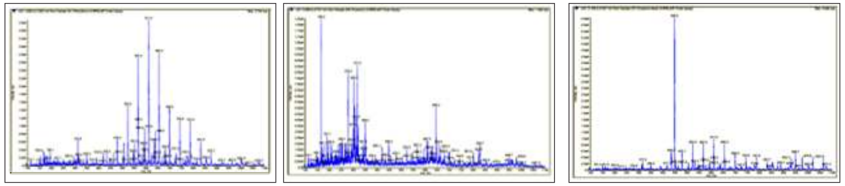
Results also showed that the Ridomil MZ (T_2) followed by *S. rolfsii* and glyphosate were effective in suppressing the development of *O. cernua* in mustard (Table 4).

Table 4: Effect of microbes and herbicides on the emergence of *Orobanche cernua* in mustard

Treatment	Emergence of *O. cernua* days after sowing					
	55	65	75	85	95	105
T_1 (Positive control (*Orobanche* + mustard)	1.3	8.0	9.0	11.3	14.3	17.3
T_2 (Ridomil MZ 0.2%)	1.0	4.6	6.0	6.6	9.0	8.3
T_3 (Foliar spray of *Gliocladium* spore suspension on 30 and 60m DAS @ 20 ml/pot)	2.0	5.3	8.6	9.3	12.0	12.0
T_4 (Post emergence herbicide Glyphosate)	2.3	9.0	9.3	8.3	9.0	10.0
T_5 (Foliar spray of *Fusarium* sp. DWSR 1 on spore suspension on 30 and 60 DAS @ 20 ml/pot)	1.3	4.0	4.3	6.0	7.6	8.3
T_6 (Post emergence spray of Quizalofop)	1.3	5.3	6.3	9.0	9.3	11.0
T_7 (Foliar spray of *Trichoderma viride* spore suspension on 30 and 60 DAS @ 20 ml/pot)	0.3	2.6	4.3	6.3	8.0	11.0
T_8 (Foliar spray of *Sclerotium rolfsii* spore suspension on 30 and 60 DAS)	1.0	3.3	5.6	7.0	10.3	10.0
T_9 (Mustard alone - negative control)	0.0	0.0	0.0	0.0	0.0	0.0
LSD (P=0.05)	**0.90**	**1.75**	**1.42**	**1.20**	**1.67**	**1.48**

7.2.2. Total ion chromatogram of different microbial extracts

Pure lines of *Fusarium* collected from mustard fields of different places were grown on potato dextrose broth for 30 days. The broth was then extracted in ethyl acetate and concentrated under vacuum. The concentrated *Fusarium* extract was analysed by LC-MS/MS. Similarly, the media of *Penicillium* culture was also extracted, cleaned up and analysed by LC-MS/MS. From the total ion chromatography, tentative molecular weight of the major metabolites were assigned (Figure 1). The tentative molecular weight of major secondary metabolite extracted from *Fusarium* spp. DWSR 2 was 447. The molecular weights of the fractions extracted from *Fusarium* spp. DWSR 1 were 165, 278, 317 and 645. The molecular weights of fractions extracted form *Penicillium* sp. were 566, 610 and 654.



Penicillium oxalicum | *Fusarium* spp. isolate DWSR1 | *Fusarium* spp. isolate DWSR2

Figure 1: Total ion chromatogram of crude fractions of microbial extracts

7.3. Study of domestication traits of two weed species

7.3.1. Survey for collection of germplasm of *Echinochloa* and *Physalis* species

Extensive surveys were conducted for collection of seeds of *Echinochloa* and *Physalis* species. Samples were collected from different locations across the agro-climatic zones. Germplasm of a total of 150 accessions of *Echinochloa* and 30 accessions of *Physalis* species have been collected, so far. Locations of germplasm collected have listed in Table 5.

Table 5 : Germplasm collected from different places

State	District	Locations/ (GPS locations)
Echinochloa		
Himachal Pradesh	Palampur	Palampur and surrounding areas
Kerala	Thrissur, Alleppey and locations alongwith highway from Thrissur to Coimbatore	N10 06.700 E76 20.897, N9 57.925E76 19.107, N9 37.543 E76 25.836, N9 37.534 E76 25.840, N12 11.845 E76 10.866, N9 26.211 E76 25.716, N9 24.158 E76 27.031, N9 23.742 E76 26.820, N12 29.996 E76 49.700, N10 32.184 E76 16.157, N10 32.186 E76 16.163, N10 35.503 E76 28.746, N10 41.682 E76 35.020, N10 41.658 E76 34.959
Tamil Nadu	Coimbatore	N11 00.133 E76 55.462, N11 00.146 E76 55.456, N11 00.224 E76 55.474
Karnataka	Bengaluru, Tumkur Kathalagere (Davangere)	N14 16.015 E75 49.399, N14 16.015 E75 49.340, N12 47.806 E77 23.007, N12 32.145 E76 52.776, N12 34.398 E76 49.592, N12 32.146 E76 52.775, N12 23.925 E76 40.131
Chhattisgarh	Raipur, Mahasamand	Area adjoining Raipur and Mahasamand, National Highway leading to Odhisa
Madhya Pradesh	Jabalpur and Kundam area	Local surveys made in and around Jabalpur and Kundam area
Andhra Pradesh	Hyderabad	ICRISAT, Patancheru
Uttrakhand	Mussoorie	Mussoorie
Physalis peruviana and *Physalis minima*		
Kolkata (W.B.), Bengaluru (Karnataka), Mumbai, Pune, Nasik, Nagpur (M.H.), Agra, Modinagar, Lucknow, Varanasi (U.P.), Jaipur, Jodhpur (RAJ.), Suarjpur (CG.), Jabalpur (MP), Delhi, Goa.		

7.3.2. Study of variations in different traits among different accessions of *Echinochloa*

A total of 112 entries were raised in nursery in trays. Eight days after sowing, seedlings were transplanted in six meter rows (plant to plant distance 10 cm). A portion of field layout is shown.

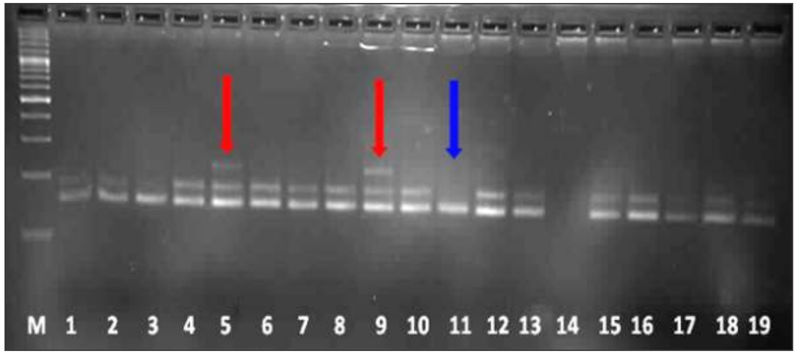
Growth and morphological observations, gas exchange, yield and attributes like shattering behavior, dormancy of freshly harvested grains and molecular diversity were also studied. Summary of important results is given Table 6.

Echinochloa accessions (50 days after sowing) in the field

Table 6: Characteristics of different accessions of *Echinochloa* species

	Plant height (cm)	Tillers/ plant	Leaf area (cm^2)/ plant	Root length (cm)	Panicles/ plant	Panicle length (cm)	Photosynthesis (µmoles CO_2/ m^2/s)	Seed yield (g/plant)
	38 DAS	38 DAS	38DAS	38 DAS	52 DAS	52 DAS	38 DAS	Maturity
Minimum	54.6	2.20	57.6	9.6	2.6	11.9	12.8	1.06
Maximum	125.0	22.7	1735.7	34.3	25.8	22.4	36.3	9.60
Mean	99.6	5.58	430.0	20.5	3.7	15.1	25.1	5.00
SEm±	**2.2**	**0.61**	**26.7**	**1.3**	**0.4**	**0.7**	**0.33**	**0.451**
LSD (P=0.05)	**4.4**	**1.2**	**53.02**	**2.64**	**0.89**	**1.38**	**0.668**	**0.893**

Accessions collected during survey from different locations showed vast variation in morphological traits as well as yield attributes and degree of shattering. On the basis of preliminary results, so far, there is ample scope for improvement in the available germplasm of both the species by selection approach. A short stature accessions with considerable good yield, no shattering and dormancy was indentified. The unique feature of this accession lies in its maturity duration (55-56 days). Such accession may be useful due to their shorter duration and may gain importance for their potential to fit into contingent plan to fill the gap between *Rabi* and *Kharif* crops or in case of failure of main *Kharif* crop (rice) due to less/delayed/excess rainfall. In addition, a dual purpose accession has also been selected which can be utilized first as fodder (first cut) and then for grains (final harvest), however, performance of these two germplasms is yet to be tested. Observation on molecular diversity using SSR markers also indicated the good variations among different accessions.



Molecular vaiabailty among *Echinochloa* accessions

Rice Markers were used for identification of molecular variability among *Echinochloa* accessions collected from different locations. As shown in Figure 8, RM26 amplified specific bands (240bp) with two accessions (5 and 9). These specific amplicons may be associated with valuable traits present in these accessions. One amplicon (190 bp) was absent in accession number 11, which was present in others.

7.4. Bioremediation of contaminants in polluted sites: use of weedy plants

The major activities undertaken in the project during the year involved survey of heavy metal contaminating sites around Jabalpur, dominant weed species in drains, and testing of metal / heavy metal removal efficiency of selected plants grown in mesocosm at varying spiking levels.

7.4.1. Survey of heavy metal contaminated sites in Jabalpur

In a survey of the contaminated sites in Jabalpur and adjoining areas water and plant samples were collected for assessing the extent of water pollution. Various water parameters viz., pH, EC, chloride, total solids, biological oxygen demand, chemical oxygen demand, oil and grease and sodium adsorbtion ratio (SAR) were alaysed. It was observed that among contaminated sites higher EC, BOD, COD, oil and grease were observed at Bhedaghat followed by Richai sites (Table 7). The results showed that more than permissible concentrations of Cd, Ni, Cr and Cu at the Bhedaghat and Richai drain sites. Detailed water quality parameters of drain site are given in Table 8. The weed species at these sites (Table 9) were *Typha latifolia* (bulrush), *Rumex crispus* (yellow dock), *Ageratum conyzoides* (billygoat-weed), *Rumex crispus* (yellow dock), *Chenopodium album* (lamb's quarters), *Eichhornia crassipes* (water hycanth), *Ammannia auriculata* (monarch redstem), *Eryngium foetidum* (wild coriander), *Sida acuta* (baraira) and *Cyperus* sp (nut grass).

Table 7 : Water quality of contaminated sites in Jabalpur and adjoining area

Water parameters	Values at the contaminated sites					
	Panagar	Uldena	Ukhari	Richhai	Bhedaghat	Pariyat
pH	7.1	7.5	7.8	8.1	7.7	7.5
EC (µS/cm)	1607	512	726	714	3270	492
Chloride (mg/l)	47.0	91.0	234.0	102.0	167.0	47.0
Total Solids (mg/l)	511.0	673.0	771.0	677.0	743.0	563.0
BOD (3 days, mg/l)	3.2	18.0	58.0	54.0	48.0	46.0
COD (mg/l)	24.0	148.0	264.0	212.0	228.0	212.0
Oil and grease (mg/l)	4.0	4.0	4.0	4.0	18.0	N. D.
S.A.R. (ppm)	0.82	0.96	0.98	0.98	0.90	0.910
Turbidity	12.0	18.0	38.0	24.0	22.0	28.0

Table 8 : Heavy metals in waste water collected from drains of Jabalpur

Water parameters	Panagar	Uldena	Ukhari	Richhai	Bhedaghat	Pariyat
Total Hardness (mg / l)	126.0	192.0	455.0	360.0	490.0	365.0
Ammoniacal-N (mg/L)	38.0	1.6	2.8	1.6	1.1	1.6
Nitrate-N (mg/L)	20.7	4.4	11.2	3.3	14.0	5.6
Phosphate (mg/L)	6.0	1.9	4.9	1.1	2.3	0.8
Cu (mg/L)	0.0047	0.0021	0.0049	0.46	0.0027	0.0036
Fe (mg/L)	0.099	0.007	0.007	0.007	0.006	0.003
Mn (mg/L)	0.090	0.01	-	1.70	0.030	-
Cr (mg/L)	0.03	0.042	0.053	0.048	0.158	0.06
Ni (mg/L)	0.068	0.063	0.063	0.27	0.088	0.085
Cd (mg/L)	0.046	0.032	0.031	0.029	0.034	0.031
Pb (mg/L)	0.33	0.15	0.18	0.15	0.25	0.13

Table 9 : Dominant weed species in drains of Jabalpur

Weed species	Sampling site
Typha latifolia (bulrush)	Bhedaghat (Gelatin factory)
Rumex crispus (yellow dock)	Bhedaghat (Gelatin factory)
Ageratum conyzoides (billygoat-weed)	Richai industrial area (drainage)
Rumex crispus (yellow dock)	Panagar (drainage)
Chenopodium album (lamb's quarters)	Ukri (drainage)
Eichhornia crassipes (water hycanth)	Ukri (drainage)
Ammannia auriculata (monarch redstem)	Pariyat river
Eryngium foetidum (wild coriander)	Pariyat river
Sida acuta (baraira)	Uldena (drainage)
Cyperus sp. (nut grass)	Panagar (drainage)

7.4.2. Testing metal / heavy metal removal efficiency of selected plants grown in mesocosm at varying spiking levels

This was undertaken on five wetland plants viz., *Phragmites karka, Typha latifolia, Acorus calamus, Vetiveria zizanioides, Arundo donax* and unvegetated control which are exposed to different concentration of 0.5, 3 and 5 mg/L each for Fe, Mn, Cd. The water samples at different spiking are collected from the outlet of the mesocosm, facility developed for the workd at the Directorate. Treated water samples from the outlet were collected from each treatment tanks in acid washed plastic bottles. Collected samples are digested with di-acid (9:4 nitric acid: perchloric acid). Digested samples are analysed for Mn, Fe and Cd concentrations using atomic absoption spectro-photometer (Thermo Solar- S4).

The comparative heavy metal removal efficiency, with particular emphasis on Mn, Fe and Cd of the weedy plants was tested under small-scale field mesocosm system. Preliminary observations on spiked heavy metal concentrations under mesocosm studies indicated that *Typha* followed by *Arundo* and *Vetiveria* were associated with higher Fe and Mn removal efficiencies. The percent removal of manganese and iron in treated water after 1st spiking is depicted in Figure 2 and 3.

Phytoremediation experimental site

Collection of sample from mesocosm facility

Among weed species, higher quantity of manganes was removed by *Typha latifolia* followed by *Vetiveria zizanioides* when treated with 3 ppm concentration. *Typha latifolia* and *Arundo donax* had higher iron removal efficiency at 3 ppm concentration, whereas *Phragmites karka* showed higher iron removal efficiency at 0.5 ppm concentration in the treated water.

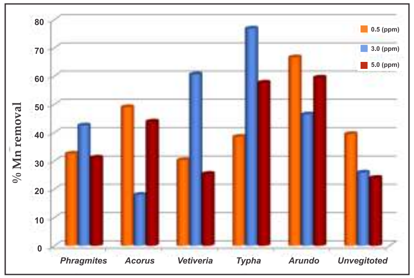


Figure 2 : Manganese removal efficiency of different weeds

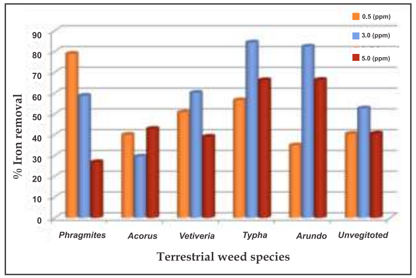


Figure 3 : Iron removal efficiency of terrestrial weeds species

8 SERVICE PROJECTS

Details of service-oriented projects undertaken during 2013-14 are given below:

Service projects	Principal Investigator
8.1. Analysis of herbicide residue in soil and plant samples of farmers' field	Shobha Sondhia
8.2. Supply of Mexican beetles and monitoring at the sites of their release	Sushil Kumar
8.3 Vermicompost from weed and agro-waste biomass	Sushil Kumar

8.1. Analysis of herbicide residues in soil and plant samples of farmer's field

Studies were conducted in the farmers field at five different locations to evaluate terminal residues of imazethapyr in soil and soybean plant samples on application at 100 g a.i/ha, as post emergence herbicide in soybean field. Mature soybean plant and soil were collected at harvest and processed for extraction of terminal residues of imazethapyr using standard protocols and analyzed by HPLC. Imazethapyr residues were found in the range of 0.006 to 0.018 µg/g in the grain samples in all five fields. However in soil, residues were found to be below 0.001µg/g in four locations and in one location residues were 0.0015 µg/g. The overall amount of residue was less in soil as compared to the plant samples. Terminal residues of imazethapyr in soybean plant and soil were found below maximum residue level (MRL) limits. Based on this study, a pre-harvest interval of 90-102 days for soybean crop after imazethapyr application is suggested at farmer's field.

8.2. Supply of Mexican beetles and monitoring at sites of their release

Mexican beetles were mass reared in net houses of the Directorate during 2013. About 80000 beetles were supplied by postal services and personal delivery to different AICRP-WC centres, KVKs, farmers, municipalities, NGOs, colony residents, etc. throughout the country. In West Bengal, beetles were sent in the month of April, 2012 coinciding with the early rains in the area and were also delivered personally. About 10,000 beetles were released in three different sites of Mohanpur area in collaboration with Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur. On request of Punjab State Council of Science and Technology, about 12,000 and 5000 Mexican beetle bioagents *Zygogramma bicolorata* were distributed to farmers free of cost during 1 August, 2013 and 27 March 2014 in Tora village of Patiyala (Punjab) and in Mohali (Punjab), respectively. Monitoring and feedback from different centers confirmed establishment of the bioagents in different parts of the country, viz. in eastern and western Uttar Pradesh, lower Uttrakhand and many parts of Madhya Pradesh, Andhra Pradesh, Punjab, Delhi, Haryana, Maharashtra, Orissa, Bihar, and Jharkhand. Beetles were also found to survive in Kota district of Rajasthan. Positive feedback of establishment of the beetle was received this year from Gwalior region, where beetles were not reported to establish a couple of years back.

8.3. Vermicompost from weed and agro-waste biomass

Vermi composting was undertaken at the experimental farm of the Directorate in big way. It was decided to use all the uprooted weed biomass for vermin composting. In the past, agro-waste residue left during mechanical harvesting in the field was burnt before taking next crop. This practice was totally banned and all such left-over residue was also used for vermin composting besides agro-waste of crops like soybean, rice, wheat, maize, mustard, chickpea and pigeon pea, etc. To reduce the labour cost, vermicompost unit is being mechanized. The turning of huge biomass is being done by hired JCB machine instead of labourers. A dung slurry spray device has been developed to replace the labourers in order to make this technology more cost effective. This year 66 tonnes of vermicompost was prepared, which was twice more than last years' production. Chemical analysis revealed good level of nutrient content in the vermicompost prepared from biomass of weed like *Parthenium*, *Medicago hispida* and water hyacinth.

9 STUDENTS RESEARCH PROGRAMME

The Directorate has collaboration and MoU with Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur for research, teaching and extension. It is also recognized by other universities like Bundelkhand University, Jhansi as a post-graduate research centre. The following students from these universities completed their thesis research work at the Directorate.

Name of student	Degree/ subject	Title of thesis	College/ university	Chairman/ Co-chairman
Rohit Kumar Pandey	M.Sc. (Soil Science and Agricultural Chemistry)	Fungal transformation of orthosulfamuron in rice-rhizospheric soil	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	P.P. Choudhary
Manoj Kumar	M. Sc. (Agronomy)	Effect of crop establishment and weed management practices on growth and yield of wheat	Institute of Agricultural Sciences, Bundelkhand University Jhansi	Raghwendra Singh
Anil Nagvanshi	M.Sc. (Soil Science and Agricultural Chemistry)	Evaluation of pretilachlor, penoxsulam, pyrazosulfuron persistence and yield of paddy grown on a vertisol	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	Shobha Sondhia
Ajay Verma	M.Sc. (Soil Science and Agricultural Chemistry)	Impact of weed management practices on soil health indicators in a citrus orchard with and without intercropping	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	K.K. Barman
Rajesh Patel	M.Sc. (Soil Science and Agricultural Chemistry)	Remediation of agro - contaminants in soil under different plant species	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	P.J. Khankhane
Vinod Jatav	M.Sc. (Soil Science and Agricultural Chemistry)	Effect of industrial waste water on heavy metal accumulation in tomato grown on vertisol	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	P.J. Khankhane
Neeraj Singh Yadav	M.Sc. (Agronomy)	Evaluation of post emergence herbicides under diverse weed flora in wheat (*Triticum aestivum* L.)	Institute of Agricultural Sciences, Bundelkhand University, Jhansi	Anil Dixit

9.1. Fungal transformation of orthosulfamuron in rice-rhizospheric soil

Different fungi were isolated from the rice rhizospheric soil biota. Of these, ten fungi that degraded orthosulfamuron, a sulfomyl urea herbicide in minimal potato dextrose broth were characterized as *Aspergillus niger, A. flavus, A. fumigatus, A. terreus, Curvularia pallescene, Cladosporium herbarum, Penicillium chrysogenum, Trichoderma viride, Trichoderma* sp. and *Penicillium* sp.

The rates of degradation of orthosulfamuron at different concentrations were examined in sterilized black soil incubated with *Aspergillus niger*. Half-life of the herbicide was in between 15 to 20 days depending on application rate. Metabolites isolated from media and soil were characterised by LC-MS/MS as *o*-amino-*N*,*N*-dimethylbenzamide (I), *N*-(4,6-dimethoxypyrimidin-2-yl)urea (II) and 2-amino-4,6-dimethoxypyrim--idine (III), 2-(*N*,*N*-dimethyl carbamoyl) phenyl sulfamoyl urea (IV), and *N*-[2-(*N*,*N*-dimethyl carbamoyl) phenyl] sulfamic acid (V). On the basis of the formation of metabolites two pathways viz., cleavage of sulfonylurea bridge and cleavage of N-C bond were proposed (Figure 1).

9.2. Effect of crop establishment and weed management practices on growth and yield of wheat

An experiment was undertaken to assess different crop establishment practices and efficacy of different herbicides under standing stubble, partial burning, zero tillage and bed planting techniques. Field experiment was conducted at experimental farm in wheat during *Rabi* season of 2012-13. The soil of experimental field was clay loam in texture, neutral in reaction, medium in organic carbon (0.79%), available nitrogen (312 kg N/ha) and phosphorus (18 kg P_2O_5

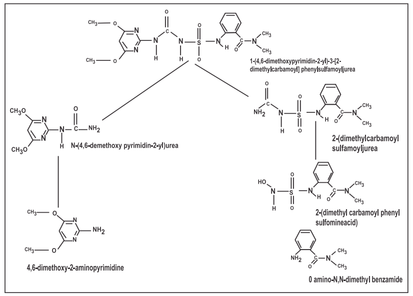


Figure 1: Proposed pathways of orthosulfamuron degradation by *Aspergillus niger in soil*

/ha) but high in available potassium (291 kg K_2O /ha). The experiment included four crop establishment methods viz. zero tillage (ZT), zero tillage + residue (ZT+R), conventional tillage (CT), zero tillage + residue burning (ZT+RB) in main plots and four weed management practices, weedy check, mesosulfuron + iodosulfuron (12+2.4g/ha), sulfosulfuron + metsulfuron (25+4g/ha) and metribuzin (200 g/ha) in sub plots was laid out in split-plot design with three replications. The ZT plots were kept undisturbed after harvesting of rice crop. The CT plots were prepared by using cultivator once and harrowing twice. The rice residue was applied @ 7 ton/ha. Wheat variety 'GW-273' was sown with recommended package of practices. Fertilizers were applied through urea, di-ammonium phosphate and muriate of potash @ 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. Sowing under ZT and CT was done using 'Happy seeder' at seed rate of 100 kg/ha. Data on weed growth and yield performance were recorded.

The most dominant weeds among grassy and broad leave weeds were *Phalaris minor* and *Medicago denticulata,* respectively. The crop establishment techniques did not show significant variation in weed density, weed dry weight and grain and straw yield. However, the weed management practices differed significantly. The minimum weed population (2.84 /m^2) and weed dry weight (2.15 g/m^2) was observed with the application of sulfosulfuron + metsulfuron (25 + 4 g/ha). The maximum grain yield (3.27 t/ha) of wheat was observed with the treatment sulfosulfuron + metsulfuron, however, it was at par with the application of mesosulfuron + iodosulfuron and metribuzin. All the three herbicides controlled the weeds effectively. Repeated use of same herbicide for weed control, may lead to development of herbicide resistance in weed, therefore these three herbicides can be used in rotation to avoid the herbicide resistant problem in wheat crop.

9.3. Evaluation of pretilachlor, penoxsulam and pyrazosulfuron persistence and yield of paddy grown on a vertisol

Agriculture is one of the major contributors of non-point-source pollution to surface waters in intensively managed landscapes. Herbicides transported/leached from treated fields to surface water bodies can cause concern for diversity of aquatic life in waters receiving agricultural drainage. An experiment was conducted during *Kharif* to study the persistence of pretilachlor 750 g /ha, penoxsulam 25 g/ha and pyrazosulfuron 25 g/ha in vertisol cropped with paddy in randomized block design.

Soil samples were drawn from 0-20 cm depth with an interval of 0, 5, 10, 30, 60, 90 and 120 days (at harvest and analyzed for soil physicochemical parameters and residues. The result showed that after application of herbicides on transplanted rice, there was no significant change in soil pH and EC. Pretilachlor, penoxsulam and pyrazosulfuron in soil followed first order rate kinetics and had an average half life of 15-24 days. All three herbicides persisted up to 90 days in soil of paddy field.

9.4. Impact of weed management practices on soil health indicators in a citrus orchard with and without intercropping

An investigation was undertaken for studying the impact of cultural, chemical and mechanical weed management practices on different soil health indicators in a newly planted citrus orchard. Observations on soil physical, chemical and biological parameters of a citrus orchard planted in *Kharif* 2008 at DWSR research farm were recorded during winter season 2012-13 by following standard procedures. The results indicated that managing weeds in the newly established citrus orchard by using cultural, chemical and mechanical means favoured the trees to achieve better growth. The practice of no weed management and consequent growth of grasses, increased the penetration resistance of the surface soil.

The mechanical (repeated rotavator operation) and sole chemical measures (application of metribuzin and glyphosate) hampered the development of soil physical quality in terms of infiltration rate. Besides, the chemical treatments also hampered the development of soil biological health in terms of soil microbial biomass carbon. Growing legume intercrops (greengram-pea-greengram), with recommended doses of N and P, in the orchard improved soil physical health in terms of infiltration rate and penetration resistance. These treatments also maintained good soil biological health in terms of soil microbial biomass carbon, and improved soil available P status, hence, these were considered as better than the sole tillage and sole chemical measures for management of newly planted citrus orchard floor.

9.5. Remediation of agro-contaminants in soil under different plant species

A pot experiment was carried out in net house to evaluate effect of herbicide and fertilizer on three weeds. The plant species viz., *Vetiveria zizinoides, Typha latifolia* and *Acorus calamus* were exposed to three doses of pretilachlor herbicide (0, 750 and 1500 g/ha) and two doses of NPK levels (0 and 120-60-60 kg/ha). Experimental results revealed all three weeds tolerated the optimum pretilachlor dose (750 g/ha) though variations in degree of tolerance existed. At higher doses of pretilachlor, growth of *Acorus* and *Typha* were affected. The difference embodied with the plant height, number of tillers, leaf area, dry weight and chlorophyll. *Vetiveria zizinoides* showed tolerance to pretilachlor. Also, *Vetiveria zizinoides* followed by *Typha latifolia* removed higher N than *Acorus calamus*.

9.6. Effect of industrial waste water on heavy metal accumulation in tomato grown on vertisol

A field experiment was undertaken with eight treatment combinations including four main (drain water, filtered water-I (*Typha* based) and filtered water-II (*Vetiveria* based) and tube well water (control) as irrigation treatment and two sub-treatments - with and without EDTA. The results indicated that among irrigation water treatments, higher concentration of DTPA extractable heavy metals (cadmium, lead, copper, manganese, nickel) were observed in plots irrigated with untreated drain water as compared to tube well water. The sequence of heavy metal accumulation in soil was Cu > Pb >Zn >Ni >Cd. Lower concentration of heavy metals were retained in fruits of tomato than its shoot and root parts. EDTA application enhanced the translocation of heavy metals in tomato. Significantly higher tomato yield was observed under plots irrigated with drain water.

9.7. Evaluation of post-emergence herbicides under diverse weed flora in wheat (*Triticum aestivum* L.)

An experiment was undertaken during *Rabi* 2012-13 to evaluate bioefficacy and phytotoxicity of the post-emergence herbicide against mixed weed flora in wheat. The field experiment was laid out in randomized block design comprising of following 14 treatments - clodinafop-p-propargyl @ 60 g/ha, clodinafop-p-propargyl + 2,4-D @ 60 + 500 g/ha, pinoxaden @ 60 g/ha, sulfosulfuron @ 25 g/ha, metsulfuron-methyl + carfentrazone @ 25 g/ha, metsulfuron-methy + @ 4 g/ha, carfentrazone + sulfosulfuron @ 45 g/ha, sulfosulfuron + metsulfuron-methyl @ 32 g/ha, mesosulfuron-methyl + iodosulfuron–methyl sodium @ 16 g/ha, penoxsulam + cyhalofop-butyl @ 105 g/ha, cyhalofop-butyl @ 150 g/ha, carfentrazone @ 20 g/ha, two hand weedings and weedy check.

The most dominant weeds were *Avena ludoviciana, Phalaris minor, Cichorium intybus* and *Euphorbia geniculata*. All treatments including hand weeding significantly reduced weed population. Post-emergence application of mesosulfuron-methyl + iodosulfuron–methyl sodium had significantly superior effect over all other treatments in terms of reduction in weed population dry matter production and checking the loss of N by weeds. Pinoxaden @ 60 g/ha and clodinafop @ 60 /ha reduced grassy weeds, clodinafop-p-propargyl 60 g/ha better against *Avena* and *Phalaris* but poor against broad leaved weeds. The ready-mix combination of mesosulfuron + iodosulfuron and combined applicat application of clodinafoop-p-propargyl + 2,4-D fetched higher benefit-cost ratio as compared to other treatments including hand weeding.

10 TRANSFER OF TECHNOLOGY

10.1. Knowledge management service

Directorate efficiently utilized its facility of Kisan Mobile Advisory Service (KMAS), a Knowledge Management Service (KMS) through SMS, for disseminating weed management technologies to the farmers of the country. The messages, termed as *kisan mobile sandesh*, containing real time agricultural information and customized knowledge on weed management approaches/ technologies were routinely delivered during the initial period of cropping seasons and thereby enabling the farmers' to make a strategy to manage weeds to increase their production and productivity. Total 10 *kisan mobile sandesh* were delivered to each of the 500 registered farmers and other stake holders during the reported period (Table 1). Registration is free for all interested stakeholders of the country and can be done by sending an e-mail to dirdwsr@icar.org.in.

Table 1: Details of the *Kisan Mobile Sandesh* delivered during 2013

Kisan mobile sandesh	Delivery date
1. धान में सकरी व चौड़ी पत्ती के खरपतवारों के नियंत्रण के लिये विसपायरीबेक सोडियम (नामिनी गोल्ड) 250 ग्रा./हे. का प्रयोग 20-25 दिन पर करें।	01/08/2013
2. धान में चौड़ी पत्ती एवं मोथा कुल के खरपतवारों के नियंत्रण के लिए क्लोरीम्यूरान + (आलमिक्स) 20 ग्रा./हे. का प्रयोग 20-25 दिन पर करें।	02/08/2013
3. सोयाबीन एवं मूंगफली में इमेजेथापायर (परस्यूट) 1 ली./हे. 20-25 दिन पर करने से सभी प्रकार के खरपतवार नियंत्रित होते हैं।	03/08/2013
4. सोयाबीन में इमेजेथापायर + इमाजामॉक्स (ओडिसी) 100 ग्रा./हे. 20-25 दिन पर करने से अधिकांश खरपतवार नियंत्रित होते हैं।	05/08/2013
5. ज्वार, बाजरा एवं मक्का में 2,4-डी 800 मि.ली./हे. 25-30 दिन पर करने से चौड़ी पत्ती वाले खरपतवारों का नियंत्रण होता है। खरपतवार निदेशालय जबलपुर।	06/08/2013
6. **सावधानियां** शाकनाशी रसायनों की सस्तुंत मात्रा, समय एवं विधि का प्रयोग करने से खरपतवार नियंत्रण में पूर्ण सफलता मिलती है। पावर स्प्रेयर पम्प का प्रयोग शाकनाशी रसायनों के छिड़काव हेतु न करें। खरपतवार निदेशालय जबलपुर।	06/08/2013
7. **सावधानियां** फ्लैट फैन नोजल का ही प्रयोग शाकनाशी रसायनों के छिड़काव हेतु करें। शांत वातावरण (जब तेज धूप व हवा न हो) में ही शाकनाशी का छिड़काव करें। खरपतवार निदेशालय जबलपुर।	07/08/2013
8. **सावधानियां** शाकनाशी रसायनों के छिड़काव हेतु करें। शांत वातावरण (जब तेज धूप व हवा न हो) में ही शाकनाशी का छिड़काव करें। खरपतवार निदेशालय जबलपुर।	07/08/2013
9. **सावधानियां** शाकनाशी रसायन का छिड़काव करते समय शरीर को ढक कर रखे विशेषकर नांक एवं मुंह को। छिड़काव के पश्चात स्वच्छ पानी एवं साबुन से शरीर को धोये। खरपतवार निदेशालय जबलपुर।	08/08/2013
10. गेहूं में सकरी व चौड़ी पत्ती के खरपतवारों के नियंत्रण के लिये सल्फोसलफ्युरान + मेटसल्फ्युरान (टोटल) 40 ग्राम/हे. का प्रयोग 30 दिन पर करे।	22/11/2013

10.2. Farmers' visits

A large number of farmers (including farm women) and agricultural officers from different parts of the country visited this Directorate during the year to get familiarized with latest weed management technologies (Table 2). While visiting the experimental / demonstration fields, they interacted with scientists to solve their on-spot queries with regard to weed problems. At the end of the visits, interactive meetings with scientific staff were organized in the Directorate's conference hall, where lectures were delivered on the theme of their interest. Suitable recommendations were given to the concerned farmers for managing their weed problems in response to the questions from various farmers on location-specific weed problems.

10.3. On-farm research programme

DWSR has successfully demonstrated the performance of improved weed management technologies in a participatory mode in the 6 adopted localities (Table 3), situated within 100 km from Jabalpur under On-Farm Research (OFR) programme.

Table 2: Details of agricultural officials (AO) and farmers visiting the Directorate during 2013-14

States/ districts	Number of farmers/AOs	Date
Katni (M.P.)	12	02.04.2013
Umariya (M.P.)	20	02.08.2013
Umariya (M.P.)	20	14.09.2013
Sagar (M.P.)	21	18.09.2013
Narsinghpur (M.P.)	21	25.09.2013
Seoni (M.P.)	33	28.09.2013
Balaghat (M.P.)	25	30.09.2013
Narsinghpur (M.P.)	24	02.10.2013
Balaghat (M.P.)	50	03.10.2013
Chindwara (M.P.)	150	05.10.2013
Chattarpur (M.P.)	150	01.01.2014
Khargaon (M.P.)	150	10.01.2014
Hoshangabad (M.P.)	16	10.01.2014
Narsinghpur (M.P.)	30	23.01.2014
Panna (M.P.)	122	29.01.2014
Sidhi (M.P.)	10	31.01.2014
Chindwara (M.P.)	150	03.02.2014
Dindori (M.P.)	25	03.02.2014
Jhansi, Jonpur, Urai (U.P.)	34	11.02.2014
Damoh (M.P.)	10	12.02.2014
Hoshangabad (M.P.)	18	17.02.2014
Chindwara (M.P.)	100	18.02.2014
Anooppur (M.P.)	40	21.02.2014
Rewa (M.P.)	27	26.02.2014
Umariya (M.P.)	23	26.02.2014
Raigarh (M.P.)	100	01.03.2014
Hoshangabad (M.P.)	18	07.03.2014
Tikamgarh (M.P.)	36	20.03.2014

Table 3: Farmers' participation in OFR programme

Localities	Villages	Major cropping system	Name of the farmers involved
Locality 1 (Majholi)	Pola	Soybean-based cropping system	Atal Bihari Patel, Yogesh Patel, Sugreev Patel, Lochan Patel, Latori Patel, Subhash Patel, Kamlesh Patel, Indu Patel, Virendra Patel, Mithilesh Patel, Marru Patel and Jamman Patel
Locality 2 (Bankhedi)	Dhanwahi	DSR-based cropping system	Suresh Kumar Dubey, Shiv Singh, Smt. Kera Bai, Prakash Singh, Bahadur Singh, Radhelal and Deepa Singh
Locality 3 (Panagar)	Mahagwa	Rice-based cropping system	Satish Dubey, Mukesh Dubey, Harishankar Dubey, Mahesh Tiwari, Vishnu Tiwari, Yogendra Kumar and M.K. Tiwari.
Locality 4 (Shahpura)	Magarmuha, Tipra, Noni	DSR-based cropping system	Shailendra Patel, Manoj Sahu, Vijay Patel, Manoj Namdev, Dheeraj Patel, Tejbal Patel, Tek Singh, Meghraj Pateland Smt. Asha Patel
Locality 5 (Gosalpur)	Bhadam, Khajri	Rice-based cropping system	Udayram Tiwari, Ramkumar Kewat, Ramvishal Patel, Bal Kishan Dahiya, Panjilal Barman, Chandra Bhan Barman, Ayodhya Prasad and Ramakant Patel
Locality 6 (Kundam)	Khukham, Padariya, Ranipur	Maize- and rice-based cropping system	Patiram Bhavedi, Shivcharan, Makku Singh, Bhagchand, Chunnulal, Raghuveer, Nutan Gautam, Pramod Patel, Jage Patel, Ganesh Ban, Dayaram and Sewaram Yadav

A multi-disciplinary team of 3-4 scientists along with technical staff visited each of these localities on a given day of the week, provided detailed technical knowhow, and involved the farmers to practically impose the techniques/ technologies in their fields to facilitate better adoption of weed management technologies. These teams also identified the specific weed problems and suggested the solutions for managing them. Farmers are highly satisfied with the performances of the improved technologies.

10.4. Awareness campaigns

The Directorate has been celebrating *Parthenium* Awareness Week since 2004 with the objective of creating public awareness about the ill effects and management of this problematic/ invasive weed. Accordingly, *Parthenium* Awareness Week was organized from 16-22 August, 2013 throughout the country. The DWSR coordinated this programme and provided published material in the form of charts, posters, leaflets, banners and display boards, etc. to all 22 centres of AICRP-Weed Control, ICAR institutes, SAUs, KVKs, and NGOs. At Jabalpur, the awareness campaigns were organized in Pola, Bankhedi, Mahagwa, Noni, Khajuri and Khukham villages on different days (Table 4). The school children of the respective localities along with their teachers were also invited to take part in those campaigns. A training-cum-awareness programme was conducted at the Directorate on 19 August 2013, in which about 60 stake holders from the city and adjoining districts participated. The Directorate also collaborated with sate agriculture department to successfully organize Parthenium awareness week at Rewa, Dindori and Jhansi.

Table 4: Programmes organized by the Directorate during the *Parthenium* Awareness Week

Date	Village	Activities
16.08.2013	Pola	*Kisan Gosthi*, students rally, uprooting of *Parthenium* and release of Mexican beetles
17.08.2013	Bankhedi	-do-
18.08.2013	Mahagwa	-do-
19.08.2013	DWSR	One-day training for farmers and colony residents' and film show on *Parthenium*
20.08.2013	Noni	Exhibition and quiz competition for school children
23.08.2013	Khajuri	Training, exhibition, release of bioagents and uprooting of *Parthenium*
13.09.2013	Khukham	Lecture on ill-effects of *Parthenium* and its management, uprooting of *Parthenium* and students' rally

10.5. Television and radio talks

Talks on various aspects of weed management were delivered by the scientists of the Directorate. Dr. P.K. Singh delivered two radio talks from Jabalpur station of AIR: (i) *kharif phasalo me kharpatwar niyantran* (21st July, 2013), (ii) *Gehu me needa prabandhan* (8 November, 2013). A television programme by Dr. A.R. Sharma, Director on Parthenium Management was recorded on 1st August 2013 and Telecasted.

11 EDUCATION AND TRAINING

11.1. International exposure

Dr. A.R. Sharma, Director participated in the 24th APWSS Conference, Bandung, Indonesia from 22-25 October, 2013 and presented an invited plenary lecture on "Weed management in conservation agriculture systems – problems and prospects".

Dr. C. Kannan, Senior Scientist (Plant Pathology) attended NAIP-funded training on Biomolecules with Dr. Binne Zwanenburg, Emeritus Professor, Synthetic Organic Chemistry, Institute of molecules and materials, Radboud University, Nijmegen, The Netherlands from 02.09.13 to 30.11.2013. During this period, Dr. Kannan contributed towards development of a new concept for controlling the parasitic weeds by decomposing germination stimulants using simple compounds, prior to their contact with seeds of the parasitic weeds.

Dr. A.R. Sharma, Director attended Leadership Development Programme at Cornell University, Ithaca, USA from 23 February to 8 March, 2014.

11.2. Participation in training programmes

Scientists of the Directorate participated in training programmes to enrich their knowledge and acquire expertise in the discipline. Details of such exposure visits are given in Table 1.

11.3. Organization of training programmes

Four major training programmes were organized during the year (Table 2).

11.4. Lectures delivered by scientists in other institutions

Scientists of the Directorate were invited by many organizations to deliver lectures in different programmes. The details are given in Table 3.

Table 1: Participation in training programmes

Name of scientist	Training attended	Institution	Dates
1. Dr. Sushil Kumar	391 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	20-24 May, 2013
2. Dr. Anil Dixit	391 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	20-24 May, 2013
3. Dr. Partha P. Choudhury	392 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	03-07 June, 2013
4. Dr. Bhumesh Kumar	392 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	03-07 June, 2013
5. Mr. G.R. Dongre	393 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	17-21 June, 2013
6. Mr. S.K. Parey	393 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	17-21 June, 2013
7. Mr. G. Vishwakarma	396 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	17-21 June, 2013
8. Mr. Dibakar Ghosh	393 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	17-21 June, 2013
9. Mr. S.K. Bose	394 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	01-05 July, 2013
10. Dr. K.K. Barman	396 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	02–06 September 2013
11. Dr. Raghwendra Singh	Advances in experimental designs for development of technologies in agriculture	IASRI, New Delhi	23 October-12 November, 2013
12. Mr. Dibakar Ghosh	Advances in experimental designs for development of technologies in agriculture	IASRI, New Delhi	23 October-12 November, 2013
13. Dr. P.J. Khankhane	399 वाँ गहन हिन्दी कार्यशाला	CHTI, New Delhi	18-22 November, 2013
14. Dr. Yogita Gharde	Data analysis using SAS	IISS, Bhopal	9-13 December, 2013
15. Dr. P.J. Khankhane	Management of intellectual property rights in public research	IISS, Bhopal	7 February 2014

Table 2: Training programmes organized at the Directorate

Training programme	Sponsored by	Dates	No. of participants	Course Director	Coordinators
1. Weed management techniques	Project Directorate ATMA, Parbhani, Maharashtra	13-15 June, 2013	30	Dr. P.K. Singh	-
2. Microbes and their biotechnological interventions for sustainable agriculture with special reference to biological weed management	MPBT, Bhopal	22 July-5 August, 2013	30	Dr. C. Kannan	Yogita Gharde
3. 2nd National Training Course on "Advances in weed management"	ICAR, New Delhi	14-23 January, 2014	31	Dr. P.K. Singh	Dr. V.P. Singh, Dr. K.K. Barman
4. Advancement in weed management technology	SIMA, Govt. of U.P.	11-15 March, 2014	25	Dr. P.K. Singh	Dr. Raghwendra Singh

SIMA sponsored training

ICAR sponsored training

MPBT sponsored training

Table 3: Lectures delivered by scientists in other institutions

Speaker	Topic	Institute / meeting	Date
Dr. A.R. Sharma	Weed management scenario - An overview	BCIL, NASC, New Delhi	2 May, 2013
	Weed management in Indian agriculture - An overview	CAFT, JNKVV, Jabalpur	15 October, 2013
	Weed management in conservation agriculture systems	Padjadjaran University, Bandung, Indonesia	22 October, 2013
	Conservation agriculture and weed management - An overview	OUAT, Bhubaneswar	5 December, 2013
	Weed management in conservation agriculture systems	IARI, New Delhi	27 December, 2013
	Weed management in Indian agriculture - achievements and future prospects	GBPUAT, Pantnager	17 January, 2014
	Weed management in conservation agriculture systems	GBPUAT, Pantnager	17 January, 2014
	Weed management in conservation agriculture systems	ISWS Conference, DWSR, Jabalpur	15 February, 2014
Dr. P.K. Singh	खरपतवार प्रबंधन क्यों जरूरी	MKU, Parbhani, Maharashtra	18 May, 2013
	Importance of weed management	XX Zonal Workshop of KVKs, Zone VII, DRI, Chitrakoot	22 June, 2013
	खरपतवार (गाजरघास) प्रबंधन तकनीक	State Agriculture Department, Rewa (M.P.)	12 September, 2013
	Introduction to weed science and challenges	CAFT, JNKVV, Jabalpur	18 October, 2013
	Weed management in non-cropped situation	FTC, Jabalpur	14 December, 2013
	कृषि में खरपतवार प्रबंधन की उपयोगिता	Krishi Workshop, State Agriculture Department. (M.P.), JNKVV, Jabalpur	23 December, 2013
	Important weeds and their management	Agribusiness school for rural youth, JNKVV, Jabalpur	24 January, 2014
Dr. Sushilkumar	Water hyacinth management	Collectorate Office of Banswara, Rajasthan	1 June, 2014
	Weed problems in protected areas and prospects of their management	Workshop on 'Grassland management in protected areas in India: prospect and retrospect', Bandhavgarh Tiger Reserve, M.P.	5 July, 2013
	Biological control-based integrated management of *Parthenium*	Workshop-cum-Demonstration on *Parthenium* Management, PAU, Ludhiana	2 August, 2013
	Integrated *Parthenium* management	NRC Agroforestry, Jhansi U.P.	17 August, 2013
	Biological Control of *Parthenium*	Kisan Mela, Deputy Director of Agriculture, Rewa	12 September, 2013
	Aquatic weed management	Bruhat Bengaluru Mahanagara	28 February, 2014

	Biological control of weeds	NIBSM, Raipur	3 March, 2014
	Biological control based integrated management of *Parthenium*	Brain Storming session, PSCST, Chandigarh	27 March, 2014
Dr. V.P. Singh	Weed management in *Kharif* crops	Agriculture Extension and Training Centre, Jabalpur	25 October, 2013
	Achievements and challenges in weed management in *Rabi* crops	Agriculture extension and training centre, Jabalpur	14 December, 2013
	Weed management in *Rabi* crops	CIFE, Mumbai	31 January, 2014
	Weed management in cropped and non-cropped areas	Project Directorate ATMA, Burhanpur MP	21 February, 2014
Dr. K.K. Barman	Effect of herbicides on symbiotic nitrogen fixation	CAFT, JNKVV, Jabalpur	17 October, 2013
Dr. R.P. Dubey	Weed management in horticulture citrus orchards	National Citrus Meet, NRCC, Nagpur	12-13 August, 2013
Dr. Shobha Sondhia	Use of herbicides for enhanced agricultural production, risk of persistence and mitigation measure	CAFT, JNKVV, Jabalpur	18 October, 2013
Dr. Bhumesh Kumar	Impact of climate change on weed management: challenges and strategies	CAFT, JNKVV, Jabalpur	18 October, 2013

11.5. Technical seminars

The Directorate regularly arranged technical seminars to keep the scientific and technical manpower abreast of the latest developments in weed science. Following technical seminars were delivered by the scientists during the year (Table 4).

Table 4: Technical seminars delivered by scientists during 2013-14

Date	Scientist	Topic
31.4.2013	Dr. Anil Dixit	Herbicide tolerant crops : opportunities and challenges
31.5.2013	Dr. R. Singh	Green house technology for future agriculture
29.6.2013	Dr. R.P. Dubey	ITK in weed management
31.7.2013	Dr. A.R. Sharma	Integrated weed and nutrient management
27.8.2013	Mr. Dibakar Ghosh	Herbicide resistant weeds
30.9.2013	Dr. K.K. Barman	Multi-locational on-farm trials on integrated weed and nutrient management
30.10.2013	Dr. Meenal Rathore	Weedy rice: Problem and its management
28.3.2014	Dr. D.K. Pandey	Future weed problem scenario

11.6. DWSR recognised by ISO 9001 : 2008 Certification

It is an honour and moment of recognition for DWSR obtaining the certification by implementing the Quality Management System in the organization as per the ISO 9001 : 2008 standards. Acquiring ISO 9001:2008 certification is one of the performance monitoring indicators to be complied with by all Government Departments in the country as per the Result Framework Document (RFD) requirement by Performance Management Division, Cabinet Secretariat. A training-cum-awareness programme for the office staffs was organized on 10 December, 2013 at the Directorate's conference hall wherein the officials of the certification agency elaborated the official norms and procedures to be adhered to maintain the ISO 9001:2008 standards.


Registration Certificate

Directorate of Weed Science Research

ISO 9001 : 2008

Quality Management System

12 LINKAGES AND COLLABORATION

Directorate is the nodal agency for research and training in the field of weed management, and also acts as a repository of information in weed science in the country. It offers research and training to research scholars, shares expertise and provides consultancy to the staff and students of SAUs, ICAR Institutes, NGOs, herbicide industries, and other stakeholders etc.

12.1 Collaboration with SAUs

Besides coordinating research and extension programmes with 22 centres of All India Coordinated Research Project on Weed Control, there are a large number of volunteer centres located in different state agricultural universities. Six nodal officers have been identified from the headquarter for effective collaboration and monitoring of the research and extension programmes of these centres.

Visits by the Director and Nodal Officers to different AICRP–WC centres

Date	Visits by Director	Visits by Nodal Officers
17 April, 2013	-	SKUAST, Srinagar
24-27 April, 2013	CSKHPKV, Palampur	CSKHPKV, Palampur
1-3 May, 2013,	-	AAU, Jorhat
1-2 June, 2013	ANGRAU, Hyderabad	-
4-5 September, 2013	-	KAU, Thrissur
6 September, 2013	-	TNAU, Coimbatore
7-8 September, 2013	-	UAS, Bengaluru
29-30 November, 2013	BCKVV, Kalyani	-
4 December, 2013	OUAT, Bhubaneswar	-
6-7 December, 2013	IIT, Kharagpur	-
17 January, 2014	GBPUAT, Pantanagar	-
19-20 Febrary, 2014	CSKHPKV, Palampur	-

12.2. Crop and horticultural institutes

The Directorate has initiated collaboration programmes with ICAR institutes, especially those dealing with field and horticultural crops. Nodal scientists were also identified for providing necessary guidance for refining the weed management research and extension programmes in these institutes. Scientists from this Directorate participated in annual group meetings of DRR Hyderabad, DSR Indore, DRMR Bharatpur, IIPR Kanpur, and took role in finalization of technical programme in respect to weed management.

AMoU was signed on 20-12-2013 in between DWSR and PDFSR, Modipuram to facilitate sharing of expertise in weed management among the staff of AICRP-Weed Control and AICRP-IFS. Eleven common centres of both the AICRPs were identified for collaborative research in weed management in the farming systems and models being developed by them. Emphasis was given at on-station. Emphasis will be given on on-farm utilization of weed biomass and need based capacity building of the AICRP staff.

12.3. Collaboration with KVKs

Two scientists of the Directorate participated in the XX Zonal Workshop of KVKs of Zone-VII involving the states of Madhya Pradesh, Odisha and Chhattisgarh organized at DRI, Chitrakoot from 21-23 June, 2013. Dr Anil Dixit Pr. Scientist of this Directorate made a presentation focusing losses caused due to weeds in different crops and their management practices. In addition to this, a team of scientists along with Director attended DWSR-KVK-State Agril. and ATMA Officials interface meeting at Dindori (MP) and discussed about the weed problems especially in minor millets.

12.4. Education and training programmes

The Directorate collaborates with several other educational and research institutions. MoUs have been signed with Jawaharlal Nehru Krishi Vishva Vidyalaya, Jabalpur and Indira Gandhi Krishi Vishva Vidyalaya, Raipur for better collaboration in the area of research, teaching and extension. This Directorate has also been recognized by Rani Durgavati Vishva Vidyalaya, Jabalpur, AKS University, Satna, and APS University, Rewa, as a post-graduate research centre for their students. Many post-graduate students and research scholars of these institutions are doing their research work at the Directorate.

Training programmes on advanced techniques in weed management have been organized for the scientists, subject matter specialists, extension personnel, state government officials, progressive farmers, and NGOs. Overwhelming responses have been received from various states and institutions for such collaboration. This has encouraged institute scientists to jointly undertake weed management programmes to tackle the location-specific problems as well as proposals for funding have been proposed, by different agencies.

13 हिन्दी राजभाषा कार्यान्वयन

संस्थान में राजभाषा हिन्दी के कार्यान्वयन, इसकी प्रगति एवं समय–समय पर इसके प्रयोग एवं प्रगति की समीक्षा करने हेतु राजभाषा कार्यान्वयन समिति का गठन किया गया है। समिति के प्रयासों के परिणामस्वरूप संस्थान के विभागों/अनुभागों में हिन्दी में कार्य करने के लिए जो उत्साह पैदा हुआ है, वह निःसंदेह राष्ट्रीय गौरव एवं स्वाभिमान का विषय है ।

वर्ष 2013–14 में खरपतवार विज्ञान अनुसंधान निदेशालय की राजभाषा कार्यान्वयन समिति के माध्यम से निदेशालय द्वारा हिन्दी में की गई प्रगति का विवरण इस प्रकार है –

13.1. त्रैमासिक बैठकों का आयोजन

निदेशालय की राजभाषा कार्यान्वयन समिति की त्रैमासिक बैठकों का नियमित आयोजन किया गया। हिन्दी राजभाषा कार्यान्वयन समिति की अप्रैल से जून 2013 तिमाही की बैठक दिनांक 29/06/2013 को निदेशालय के सभागार में आयोजित की गई। जुलाई से सितम्बर 2013 की तिमाही बैठक का आयोजन दिनांक 27/08/2013 को किया गया। अक्टूबर से दिसम्बर 2013 तिमाही की बैठक दिनांक 30/12/2013 को आयोजित की गई। जनवरी से मार्च 2014 को समाप्त तिमाही की बैठक 28/03/2014 को आयोजित की गई।

उक्त बैठकों में निदेशालय के समस्त अनुभाग प्रभारियों, अधिकारियों एवं समिति के पदाधिकारियों ने भाग लिया। बैठक में कार्यान्वयन से संबंधित बिंदुओं पर विचार किया गया एवं पिछली बैठक के कार्यवृत्त को पारित किया गया। राजभाषा कार्यान्वयन समिति के सचिव श्री एम. पी. तिवारी द्वारा पिछली तिमाहियों का विस्तृत ब्यौरा प्रस्तुत किया गया जिसमें राजभाषा अधिनियम 1963 की धारा 3(3) के अनुपालन की स्थिति के संदर्भ में बताया गया, तत्पश्चात् पिछली तिमाहियों के अंतर्गत जारी त्रैमासिक प्रतिवेदनों, कागजातों, मांगपत्रों एवं जांच बिन्दुओं इत्यादि से संबंधित चर्चायें की गई, साथ ही माननीय संसदीय राजभाषा समिति को दिये गये आश्वासनों के संबंध में संबंधित अनुभागों को उचित कार्यवाही करने हेतु पत्र भी जारी किये।

बैठकों में राजभाषा वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने तथा राजभाषा विभाग एवं भारतीय कृषि अनुसंधान परिषद से प्राप्त निर्देशों/आदेशों/ समीक्षाओं के अनुपालन पर चर्चा की गई और इन बैठकों में लिए गये निर्णयों को लागू करने के लिए कार्यवाही की गई।

13.2. त्रैमासिक हिन्दी प्रतिवेदन का संकलन

भारत सरकार के राजभाषा विभाग, गृह मंत्रालय की रिपोर्ट के प्रोफार्मा में निदेशालय के विभिन्न अनुभागों से उनके द्वारा किये जा रहे हिन्दी कार्यों की प्रगति तथा हिन्दी पत्राचार के आंकड़े तिमाही की समाप्ति पर मंगाये गए और उनको समेकित कर समेकित प्रतिवेदन को भारतीय कृषि अनुसंधान परिषद नई दिल्ली, क्षेत्रीय कार्यान्वयन कार्यालय भोपाल तथा नगर राजभाषा कार्यान्वयन समिति को प्रेषित किये गये। त्रैमासिक प्रतिवेदनों से प्राप्त समीक्षा के अनुसार उठाये गये बिन्दुओं पर कार्यवाही की गई तथा संबंधित अनुभाग को पृष्ठांकित किये गये।

13.3. राजभाषा वार्षिक कार्यक्रम पर कार्यान्वयन

भारत सरकार की राजभाषा नीति के अनुसार संस्थान द्वारा संपादित कार्यों में हिन्दी का कार्यान्वयन सुनिश्चित करने के लिए गृह मंत्रालय, राजभाषा विभाग द्वारा जारी राजभाषा वार्षिक कार्यक्रम वर्ष 2013–14 में दिये गये निर्देशों के अनुसार कार्यवाही के लिए सभी अनुभागों को राजभाषा संबंधी नियमों/निर्देशों से अवगत कराया गया तथा इन नियमों के अनुसार कार्यवाही सुनिश्चत करने का अनुरोध किया गया।

13.4. हिन्दी पखवाड़े का आयोजन

निदेशालय में राजभाषा कार्यान्वयन समिति द्वारा दिनांक 16 सितम्बर 2013 को हिन्दी दिवस तथा दिनांक 16 सितम्बर 2013 से दिनांक 30 सितम्बर 2013 तक हिन्दी पखवाड़े का आयोजन किया गया। कार्यक्रम का उदघाटन कार्यकम के अध्यक्ष डॉ. अजीत राम शर्मा, निदेशक, ख.वि.अनु. निदेशालय एवं मुख्य अतिथि डॉ. अरूण कुमार प्राचार्य, गोविन्दराम सेकसरिया अर्थ–वाणिज्य महाविद्यालय द्वारा सरस्वती पूजन एवं दीप प्रज्जवलित कर किया गया। इस कार्यक्रम में कार्यालय के समस्त अधिकारियों/कर्मचारियों ने बढ़–चढ़कर हिस्सा लिया।

निदेशालय में हिंदी दिवस समारोह के दौरान उपस्थित सभी अधिकारी/कर्मचारी

हिन्दी पखवाड़े के दौरान आयोजित क्विज कांटेस्ट प्रतियोगिता में भाग लेते प्रतिभागी

हिन्दी पखवाड़ा समापन समारोह में आयोजित कवि सम्मेलन में निदेशालय के निदेशक महोदय के साथ उपस्थित सभी कवि गण

हिन्दी पखवाड़े के दौरान निदेशालय में विभिन्न प्रतियोगिताएं संपन्न कराई गई जिनमें विजयी प्रतियोगियों के नामों की सूची नीचे दी गई है –

1.	शुद्ध लेखन प्रतियोगिता	
"अ" 1.	श्री नीरज त्रिपाठी	प्रथम पुरस्कार
2.	कु. अदिती पाठक	द्वितीय पुरस्कार
3.	श्री ओ.एन. तिवारी	तृतीय पुरस्कार
"ब" 1.	श्री मोहन लाल दुबे	प्रथम पुरस्कार
2.	श्री अश्विनी तिवारी	द्वितीय पुरस्कार

2.	पत्र लेखन प्रतियोगिता	
"ब" 1.	श्री अश्विनी तिवारी	प्रथम पुरस्कार
2.	श्री पवन तिवारी	द्वितीय पुरस्कार

3.	आलेखन एवं टिप्पण प्रतियोगिता	
"अ" 1.	श्री जी.आर. डोंगरे	प्रथम पुरस्कार
2.	इंजी. एच.एस. बिसेन	द्वितीय पुरस्कार
3.	श्री ओ.एन. तिवारी	तृतीय पुरस्कार

4. क्विज कांटेस्ट प्रतियोगिता

समूह	नाम	स्थान	समूह	नाम	स्थान
1	डॉ. शोभा सौंधिया	प्रथम	1	इंजी. एच.एस. बिसेन	द्वितीय
2	डॉ. के.के. बर्मन		2	डॉ. आर.पी. दुबे	
3	श्री जी.आर. डोंगरे		3	डॉ. भूमेश कुमार	
4	कु. श्री विद्या		4	श्री ओ.एन. तिवारी	

5. वर्ष 2013 में कृषि से संबंधित लेख लिखने हेतु विशेष पुरस्कार

क्र.	अधिकारी/कर्मचारी का नाम	स्थान
1.	डॉ. पी.के. सिंह	प्रथम पुरस्कार
2.	श्री संदीप धगट	द्वितीय पुरस्कार

6. वाहन आगमन एवं प्रस्थान का विवरण हिन्दी में लिखने हेतु वाहन व ट्रैक्टर चालकों को प्रोत्साहन पुरस्कार
   1. श्री दिलीप साहू
   2. श्री सबस्टीन दास
   3. श्री प्रेमलाल दाहिया
   4. श्री भग्वुन्ते प्रसाद

7. नगद पुरस्कार हेतु चयनित अधिकारी/कर्मचारी

क्र.	अधिकारी/कर्मचारी का नाम	स्थान	राशि (₹)
1.	श्री बी.पी. उरिया	प्रथम पुरस्कार	800
2.	श्री घनश्याम विश्वकर्मा	द्वितीय पुरस्कार	600
3.	श्री अश्विनी तिवारी	तृतीय पुरस्कार	400

6. वर्षभर हिन्दी में सर्वाधिक काम करने वाले अनुभाग को चलित शील्ड
   1. क्रय एवं भण्डार अनुभाग – प्रथम
   2. प्रक्षेत्र अनुभाग – द्वितीय
   3. कृषि अभियांत्रिकी अनुभाग – तृतीय

13.5. हिन्दी कार्यशालाओं का आयोजन

राजभाषा कार्यान्वयन समिति द्वारा वित्तीय वर्ष 2013–14 के दौरान चार विभिन्न कार्यशालाओं का आयोजन किया गया, जिनका विवरण निम्नानुसार है –

हिन्दी कार्यशाला में भाग लेते निदेशालय के कुशल सहायी कर्मचारी

वैज्ञानिक एवं तकनीकी वर्ग के अधि./कर्म. हेतु आयोजित हिन्दी कार्यशाला में व्याख्यान देते डॉ. पी. के. सिंह

क्र.	तिमाही	दिनांक	कार्यशाला का विषय	व्याख्याता
1.	अप्रैल से जून, 2013	27 जून, 2013	पत्र लेखन एवं राजभाषा का व्यवहारिक ज्ञान	श्री जी.आर. डोंगरे
2.	जुलाई से सितम्बर, 2013	23 सितम्बर, 2013	प्रशासनिक एवं वित्त संबंधी जानकारी	श्री आर.के. गिरि
3.	अक्टूबर से दिसम्बर, 2013	13 दिसम्बर, 2013	निदेशालय के विभिन्न डेटाबेस की जानकारी	श्री संदीप धगट
4.	जनवरी से मार्च, 2014	7 मार्च, 2014	फसल अवशेषों को बचायें–संरक्षित कृषि अपनायें	डॉ. पी.के. सिंह

13.6. राजभाषा पत्रिका के नवम् अंक का प्रकाशन

तृण संदेश पत्रिका के नवम् अंक 2013 का प्रकाशन किया गया जिसमें खरपतवार प्रबंधन से संबंधित लेख, सामान्य खेती से संबंधित लेख एवं सामाजिक एवं साहित्यिक गतिविधियों को स्थान दिया गया था। पत्रिका को स्लोगन एवं महापुरूषों के वचन इत्यादि से प्रभावशाली बनाया गया।

निदेशालय द्वारा 2013–14 में प्रकाशित हिन्दी प्रकाशनों की सूची निम्नानुसार है –

क्र.	प्रकाशन	प्रतिरूप	संख्या
1.	तृण संदेश नवम् अंक	पुस्तक	200
2.	तकनीकी कैलेण्डर	कैलेण्डर	500
3.	गाजरघास जागरूकता सप्ताह–2013	पोस्टर	3000
4.	पुरस्कार	पोस्टर	2000
5.	जैवकीय विधि से गाजरघास का नियंत्रण	फोल्डर	2000
6.	गाजरघास का समन्वित प्रबंधन	फोल्डर	2000
7.	गाजरघास से कम्पोस्ट बनाना	फोल्डर	2000
8.	गाजरघास प्रबंधन	पुस्तक	600

13.7. वचनामृत एवं शब्द लेखन

निदेशालय स्वागत कक्ष के पास ''आज का शब्द'' एवं ''वचनामृत'' प्रतिदिन द्विभाषी रूप में लिखा जाता रहा।

14 AWARDS AND RECOGNITIONS

14.1. Awards

Dr. Chandra Bhanu and **Dr. V.S.G.R. Naidu** ICAR Dr. Rajendra Prasad Puraskar 2013 for their Hindi book on "*Oushdhiya Kharpatwar*" on 16 July, 2013.

Dr. Anil Dixit, Principal Scientist (Agronomy) received the ISWS Fellow - 2013 at the Biennial Conference of ISWS held during 15-17 February, 2014 at DWSR, Jabalpur.

Dr. Sushilkumar, Principal Scientist (Entomology) was awarded Dr. Anand Prakash Award 2012 for his outstanding work on biological control of weeds by Applied Zoologists Research Association (AZRA), Cuttack during AZRA International Conference on "Probing Biosciences for Food Security and Environmental Safety" on 16-18 February, 2014 at CRRI, Cuttack.

Dr. P.K. Singh, Dr. Sushilkumar, Dr. R.P. Dubey, Dr. P.J. Khankhane, Dr. Shobha Sondhia, Dr. Bhumesh Kumar, Dr. M.S. Raghuvanshi, Sh. Sandeep Dhagat, Sh. S.K Bose, Sh. Bhagunte Prasad and **Sh. Veer Singh** obtained Awards of Appreciation during Silver Jubilee Foundation Day held on 22 April, 2013 at DWSR, Jabalpur.

Sh. Veer Singh, SSR-GR-III and **Sh. S.K. Bose, T-5** became champions in carom and chess events, respectively at the annual sports meet of ICAR-Central Zone held at CIAE, Bhopal during 24-28 September, 2013. In this sports meet **Dr. Meenal Rathore**, Sr. Scientist (Biotechnology) secured first position in javelin-women and second position in shot put-women events; **Sh. Dibakar Ghosh**, Scientist (Agronomy) secured second positions in shot put-men and Javelin-men events, and third position in high jump-men event and **Sh. Nemi Chand** and **Sh. Mohan Dubey** secured third positions in long jump-men event and 1500 m race, respectively.

Sh. Veer Singh, SSR-GR-III and **Sh. S.K. Bose, T-5** also became runner-up in carom and chess events, respectively at the ICAR Inter-Zonal Sports Meet - 2013 held at NAARM, Hyderabad, from 17-20 December, 2013.

15 PUBLICATIONS

15.1. Research articles

1. Arora, A. and Sondhia, S. 2013. Persistence of imazethapyr residues in soybean and soil. *Indian Journal of Weed Science* **45**(3): 226–227.
2. Arora, A., Tomar S.S. and Sondhia, S. 2013. Efficacy of herbicides on wheat and their terminal residues in soil, grain and straw. *Indian Journal of Weed Science* **45**(2): 109–112.
3. Chandra, N., Jain, N.K., Sondhia, S. and Srivastava, A.B. 2013. Deltamethrin induced toxicity and ameliorative effect of alpha-tocopherol in broilers. *Bulletin of Environmental Contamination and Toxicology* **90**: 673–678.
4. Gharde, Y., Rai, A. and Jaggi, S. 2013. Bayesian prediction in spatial small area models. *Journal of the Indian Society of Agricultural Statistics* **67**(3): 355–362.
5. Kannan, C. and Zwanenburg, B. 2013. A novel concept for the control of parasitic weeds by decomposing germination stimulants prior to action. *Crop Protection* **61**: 11–15.
6. Khankhane, P.J., Varshney, J.G. and Naidu, V.S.G.R. 2012. Presence of heavy metals in medicinal weed species grown at contaminated sites. *Indian Journal of Weed Science* **44**(4): 247–250.
7. Rathore, M., Singh, R. and Kumar, B. 2013. Weedy rice: An emerging threat to rice cultivation in India. *Current Science* **105**(8): 1067–1072.
8. Sarathambal, C. and Ilamurugu, K. 2013. Isolation of elite diazotrophic bacterial isolates from *Cyanodon dactylon* rhizosphere of saline soils. *Research Journal of Chemistry and Environment* **17**(12): 70–77.
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15.5. Other publications (Project Reports/ Retrieved information/e-publications)

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16 MONITORING AND REVIEW OF RESEARCH PROGRAMMES

Research programmes of the Directorate were reviewed during 2013-14 by different committees as per the provisions of the Council. Recommendations made by ORT, RAC and IRC in previous years were implemented for strengthening the research programmes of DWSR. The following meetings of various committees were held during the year:

16.1. Institute Research Council meeting

Meetings of Institute Research Council (IRC) were held under the chairmanship of Dr. A.R. Sharma, Director, DWSR on 6 and 7 May 2013. Dr. K.R. Koundal, Emeritus Scientist, CSIR, New Delhi and Dr. V.N. Saraswat, Former Director, DWSR were invited as resource persons. The research works carried out during 2012-13 was reviewed in the meeting, and the new programmes for 2013-14 were decided.

16.2. Institute Management Committee meeting

A meeting of Institute Management Committee (IMC) was convened on 12 July, 2013 under the chairmanship of the Director, DWSR. The other members who attended the meeting were Sh. B.P. Tripathi, Jt. Director (Representative), DFWAD, Govt. of M.P., Bhopal; Dr. S.S. Tomar, Director Research Services, JNKVV, Jabalpur; Dr. S.D. Upadhyay, Professor, Department of Plant Physiology, JNKVV, Jabalpur; Dr. Prem Kishore, Chief Editor, Crop Care, and Vice President, Cristal Crop Protection Pvt. Ltd., New Delhi and Dr. Dev Raj Arya, Technology Development Head, Monsanto India Ltd., Mumbai. The Chairman IMC welcomed all the members of IMC and special invitees, and briefed about the historical background, mandate, networking and collaboration, farm facilities, discipline-wise staff strength, major research programmes in XII plan, and contract research/ consultancy services in respect of this Directorate. Dr. K.K. Barman, Pr. Scientist (Soil Science) presented the draft of DWSR Vision 2050. Five Programme Leaders, viz., Dr. V.P. Singh, Dr. D.K. Pandey, Dr. Sushilkumar, Dr. P.P. Choudhury and Dr. P.K. Singh presented the salient research achievements of 2012-13 and future research programme for 2013-14. Discussion was also held on the other agenda items, viz., budget, status of works and equipment proposals, salient research findings and audit-paras.

16.3. PMC meeting

Project Monitoring Committee (PMC) meeting was held on 23 November, 2013 under the chairmanship of Dr. A.R. Sharma, Director. The Chairman reviewed the action taken report on the points discussed in the previous PMC Meeting. In the meeting, it was decided to conduct more on-farm trials-cum-demonstrations on zero-tillage/happy seeder at farmer's fields. It was also decided to submit proposals for winter/summer school and short-term training programme to the Council and Department of Agriculture and Cooperation.


Glimpses of IRC meeting 2013


Dr A.R. Sharma addressing the scientists


Institute Management committee

17 EVENTS ORGANISED

17.1. Silver Jubilee Lectures

DWSR has completed 25 years of its establishment on 22 April, 2014 and celebrated Silver Jubilee Year in 2013-14. To commemorate this event the Directorate organized following lectures by outstanding scientists.

Date	Scientist	Topic
10.7.2013	Dr. R.K. Rattan, IARI, New Delhi	Pollutant elements and phytoremediation
21.9.2013	Dr. R. Bhattacharya, IARI, New Delhi	C-sequestration through conservation agriculture systems
14.11.2013	Dr. T.R. Sharma, NRCPB, New Delhi	Plant genomics for gene discovery and genotype development
20.12.2013	Dr. B. Gangwar, PDFSR, Modipuram	Farming systems research
4.1.2014	Dr. R.C. Gautam, IARI, New Delhi	Principles of agronomy and 21^{st} century agriculture in India
6.1.2014	Dr. U.K. Behera, IARI, New Delhi	Farming systems research
25.1.2014	Dr. A.K. Singh, IARI, New Delhi	Innovations in basmati rice breeding

Dr. T.R. Sharma delivering lecture

Dr. B. Gangwar interacting with scientists

Dr. R.C. Gautam and Dr. U.K. Behera interacting with scientists

17.2. Training Organized

Directorate organized the following trainings.

- Training on 'Weed Management Techniques' for the progressive farmers under Project Directorate ATMA, Parbhani, Maharashtra (13-15 June, 2013).
- Training on 'Microbes and their biotechnological interventions for sustainable agriculture with special reference to biological weed management' sponsored by Madhya Pradesh Biotechnology Council, Bhopal was organized at DWSR, Jabalpur, during 22 July to 5 August, 2013. Total 30 students participated from different colleges of Jabalpur.
- National Training on 'Advances in Weed Management' for the scientists of ICAR institutes and SAUs (4-13 January, 2014). Dr. V.S. Tomar, Vice-Chancellor, JNKVV, Jabalpur (MP) was the Chief Guest of the inaugural function. He advocated necessity of advanced knowledge of weed management for making intensive agriculture a more profitable venture.
- Training on 'Advances in Weed Management Technology' for officers of State Department of Uttar Pradesh (11-15 March, 2014). Dr. B.P. Tripathi, Joint Director Agriculture, Jabalpur, M.P. Govt. as chief guest of the inaugural function.He emphasized the need of such trainings and revealed that there has been an increase in agricultural production in M.P. due to such type of trainings.

Training of progressive farmers from Maharashtra

2nd National Training Programme

17.3. Foundation Day

The Directorate celebrated its foundation day on 22 April, 2013. Dr. D.P. Singh, former Vice Chanceller, JNKVV, Jabalpur was the chief guest of the function. Former Director of DWSR Dr. J. G. Varshney, Dr. S.K. Rao, Director Farms of JNKVV and Smt. Rama Bhan, wife of the founder Director of the Directororate Late Dr. V.M. Bhan, were the Guest of Honour for the function. Some of the staff members who brought recognition to the Directorate were honoured on this occasion.

Foundation day celebration on 22 April, 2013

17.4. ISWS Executive Council meeting

A meeting of EC members and councilors of ISWS was held at DWSR on 04.05.2013 to discuss various issues relating to renewal of the Society with the Registrar (Bangaluru), publishing the pending issues of the journal, holding biennial conference etc. The meeting was attended by Dr. N.T. Yaduraju, President; Dr. A.R. Sharma, Secretary; Dr. Shobha Sondhia, Treasurer; and others.

17.5. Independence Day and Republic Day

Directorate celebrated the Independence Day on 15th August, 2013 and Republic Day on 26 January, 2014 with great enthusiasm. Director greeted the members of the staff on these occasions. He highlighted the achievements made and also the initiatives taken during the preceding year to further strengthen the research and extension activities of the Directorate. He appealed to all to work wholeheartedly to raise the image of the Directorate. Sports and cultural activities were also organized on these occasions involving the staff and their children.

17.6. *Parthenium* Awareness Week

Parthenium Awareness Week was organized from 16-22 August, 2013 throughout the country under the guidance and supervision of the Directorate. Technical knowhow and published materials in the form of charts, posters, leaflets, banners, display boards etc. were provided to AICRP-Weed Control centres, ICAR institutes, SAUs, KVKs, and NGOs. During this period, DWSR organized scientists-farmers interface meetings at Pola, Bankhedi, Mahagawa, Noni, Khajuri and Kukham villages. The school children of the respective localities along with their teachers were also invited to take part in those meetings A training-cum-awareness programme was conducted at the Directorate on 19 August, in which about 56 stake holders from the city and adjoining districts participated. The Directorate also collaborated with state agriculture department to successfully organize Parthenium awareness week at Rewa, Dindori and Jhansi.

Parthenium Awareness campaign across the country

17.7. Vigilance Awareness Week

Directorate observed Vigilance Awareness Week from 28 October (Monday) - 2 November (Saturday), 2013. This year the main focus of observing Vigilance Awareness Week has "Promoting Good Governance - Positive Contribution of Vigilance". On the occasion, DWSR displayed posters as well as arranged interactive session to make staff aware of the importance of this week. All staff members took a pledge to eradicate corruption from all spheres of life and bring pride to our organization.

Vigilance awareness week celebration

17.8. Agriculture Education Day

Directorate of Weed Science Research, Jabalpur celebrated the Second Agriculture Education Day on December 10, 2013 to promote the spirit of agricultural science among the school children. Thirty four students along with their teachers from 6 different schools, located in rural areas of Jabalpur took part in the day-long activities viz., inspirational talks, visits to information centre, laboratories and research fields, and quiz competition, organized to mark the day. Wings Convent H.S. School, Maharajpur; Govt. H.S. School, Singod; Govt. High School, Barouda; Govt. Girls' H.S. School, Panagar; Ajay Satya Prakash Public School, Panagar; and Sardar Ballavbhai Patel H.S. School, Singod; participated in the programme. Dr. K.K. Barman, Pr. Scientist and the Programme Convener, in the introductory remarks highlighted importance of agricultural education among the current generation school children for country's socio-economic development. Dr. A.R. Sharma, Director enlightened the participants about the historical perspectives and current status of agricultural research and education in India, and highlighted the opportunities existing for pursuing the carrier in agricultural education. Power Point presentations were arranged to educate the students on the topic `Conservation agriculture: an emerging agricultural system' by Dr. V.P. Singh, Pr. Scientist and on `Role of biotechnology in agriculture' by Dr. Bhumesh Kumar, Sr. Scientist. Dr. Sushil Kumar Pr. Scientist demonstrated the methods of making vermicompost using weed biomass and crop residues. The students enthusiastically interacted with the scientists while visiting laboratories, experimental fields and information centre. In the closing ceremony, the students were given the certificate for participation and prizes for successful participants in the quiz competition.

Agricultural Education Day celebration on 10 December, 2013

17.9. Industry Day

Industry Day was celebrated at the Directorate of Weed Science Research, Jabalpur for the first time on 19 December, 2013 in order to further strengthen the linkages for effective collaboration with the herbicide industry for testing of new molecules/formulations as well as those dealing with farm machinery, spraying equipment and instruments.

DWSR–Industry Meet, 19 December, 2013

17.10. Annual Review Meeting of AICRP-Weed Control

Twenty first Annual Review Meeting of AICRP on Weed Control was organized at the DWSR, Jabalpur during 12-14 February, 2014. This 3-day review meeting was graced by the presence of Chief Guest, Dr. L.S. Brar, former Professor and Head, Department of Agronomy, Punjab Agriculture University, Ludhiana, and Guests of Honour, Dr. J.G. Varshney, former Director, DWSR and Dr. R.K. Gupta, Team Leader, Research Station Development, Borlaug Institute for South Asia, New Delhi. Dr. N.T. Yaduraju, former Director, DWSR also participated on 13-14 February, 2014 and reviewed the research programme. Nearly 100 scientists of 22 coordinating and 4 volunteer centres attended the meeting. CCSHAU, Hisar centre of AICRP on Weed Control was conferred the 'Best Centre Award' for 2013.

Annual Review Meeting of AICRP-WC

17.11. Biennial Conference of Indian Society of Weed Science

Indian Society of Weed Science in collaboration with Directorate of Weed Science Research, Jabalpur organized three days biennial conference on the theme 'Emerging challenges in weed management' at the Directorate on 15-17 February, 2014. About 300 weed scientists including 4 overseas delegates participated in the conference. The inaugural function of the conference, held on 15 February, 2014 was graced by the presence of Dr. V.S. Tomar, Vice Chancellor, JNKVV as the Chief Guest of the function; Dr. N.T. Yaduraju and Dr. T.V. Muniyappa, present and immediate past President of ISWS, respectively, Dr. R.K. Malik, past President of ISWS and Dr. A.R. Sharma, Secretary and Director, DWSR, Jabalpur. Dr. Sharma welcomed the participants, and expressed his thanks to Dr. Nimal Chandrasena, Dr. Megh Singh and Dr. Bhagirath Chauhan representing Australia, USA and The Philippines, respectively. He explained the challenges posed by weeds and the importance of their management. Dr. N.T. Yaduraju, President ISWS

and Former Director DWSR, highlighted the current scenerio of weed problems in the country and the world in his presidential address. During the conference, one keynote lecture, 19 lead papers and 26 oral papers were presented in 12 sessions; along with 203 poster presentations. The General Body Meeting of ISWS was held in the evening of 16 February, 2014 in which the following proposals were unanimously approved by the house: (i) Proposal of Dr. A.N. Rao to sponsor one Ph.D thesis award after his father's name for which he handed over a cheque of Rs. one lakh to the Secretary and wished that from the interest of this money, awardee may be provided logistic support; (ii) Proposal of Dr. T.V. Muniyappa, ex-President to sponsor Young Scientist Award after his name for which he assured the house to send a cheque for Rs. one lakh soon to ISWS office; (iii) Proposal of Dr. Mahesh K. Upadhyaya, life member from Canada to sponsor a lecture on non-chemical control after his name for which he contributed Rs. 50000/- and wished that the expenditures may be incurred from the interests of the amount.

Biennial Conference of ISWS 2014

Biennial Conference of ISWS 2014

17.12. National Science Day

The National Science Day was celebrated at DWSR Jabalpur on 28 February, 2014. To mark the occasion, a competition was arranged for the P G students from different colleges on `Role of scientific research in agriculture development in India'. The I/c Director Er. H.S. Bisen gave inaugural remarks followed by a lecture on `Weeds and their impact on Indian Agriculture' by Dr. V.P. Singh. Dr. U. Prakasham, IFS, Director TFRI, Jabalpur was the chief

National Science Day 2014

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National Science Day 2014

guest of the post lunch session, and delivered the guest lecture on the topic "Science as a way of learning". The students had power point presentation on the allotted topic. Finally prizes (books on great scientists) along with certificates were given to the winner and runner up and other students were given certificates for participation in the celebration.

17.13. Kisan Day - cum - Goshthi

Directorate of Weed Science Research (DWSR), Jabalpur organized Farmers' field day-cum-*sangoshthi* on 26 March, 2014 at Bharda (Padariya) village. Dr. A.R. Sharma, Director, DWSR chaired the programme. He explained the farmers field research trials conducted by DWSR scientists, new techniques coming up in crop cultivation, conservation agriculture technique, sowing by happy seeder machine and improved crop production practices being adopted in other localities in Madhya Pradesh. Dr. Sharma also elaborated the role of DWSR in solving the problems being faced by farmers related to weed management in their farms and other aspects of crop production. The experiences gathered by the scientists during the activities carried out in Mahagava, Baihar, Bahmnoda and Bharda villages of Jabalpur for the last two years was discussed in the *sangoshthi*. The outcome of the IWM technologies both in conventional agriculture and conservation agriculture practices were also discussed. The importance of different aspects of weed management in crop production was briefed to the farming community. The scientists of DWSR addressed the queries related to their problems in weed management and crop production raised by farmers during the *Krishak Sangoshthi* . All the farmers visited the nearby field of Shri Satish Dubey at Bharda, where crop of wheat had been raised by adopting the conservation agriculture technique. The field day was attended by nearly 125 farmers and scientists from DWSR. Female farmers also participated in actively.

Glimpses of Kisan Day and Goshthi

Zero-till wheat at village Bharda

18 PARTICIPATION IN SEMINARS AND WORKSHOPS

A.R. Sharma

- AICRP-WC Annual Group Meeting held at CSKHPKV, Palampur during 26-27 April, 2013
- BCIL Workshop on 'Taking Forward Herbicide Tolerant GM Crops: Opportunities and Challenges' at NASC, New Delhi on 2 May, 2013
- *Ambrasio* eradication meeting at NIPHM, Hyderabad on 1, June, 2013
- AICRP on Chickpea Annual Group Meet at JNKVV, Jabalpur during 24-26 August, 2013
- XXIV Asian-Pacific Weed Science Society (APWSS) Conference held at Bandung, Indonesia during 22-25 October, 2013
- AICRP on forage crops - Annual Group Meeting at JNKVV, Jabalpur on 7-8 September 2013.
- Advisory committee meeting of the 'Rice Fallows' project of BCKVV, Kalyani on 29-30 November, 2013.
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014
- Leadership development programme at Cornell University, Ithaca, USA during 23 February to 8 March, 2014

H.S. Bisen

- NSFI Global Agri-Connect 2013 Conference and exhibition at IARI, New Delhi during 25- 27 October, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

P.K. Singh

- AICRP-WC Annual Group Meeting held at CSKHPKV, Palampur during 26-27 April, 2013
- XX Zonal Workshop of KVK, under Zone-VII, ICAR held at DRI, Chitrakoot during 21-23 June, 2013
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

V.P. Singh

- XLVIII AICRP- Rice Annual Group meeting held at SKUAST, Srinagar during 14-16 April, 2013
- AICRP-WC Annual Group Meeting held at CSKHPKV, Palampur during 26-27 April, 2013
- XIV National Science Workshop at CIFE, Mumbai during 14-16 December, 2013
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Sushil Kumar

- AICRP-WC Annual Group Meeting at CSKHPKV, Palampur during 25-26 April, 2013
- Intensive Hindi Workshop at New Delhi during 20-24 May, 2013
- Workshop on Grassland Management in Protected Areas in India: Prospect and Retrospect, held at Bandhavgarh Tiger Reserve, Madhya Pradesh from 4-6 July, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014
- Workshop-cum-Demonstration and Brain-storming session at Chandigarh on 27 March, 2014
- AZRA Silver Jubilee International conference at CRRI, Cuttack during 16-18 February, 2014

K.K. Barman

- Intensive Hindi Workshop at New Delhi during 2- 6 September, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

R.P. Dubey

- AICRP-WC Annual Group Meeting held at CSKHPKV, Palampur during 26-27 April, 2013
- AICRP- Soybean Annual Group Meeting at AAU, Jorhat during 1-3 May, 2013
- National Citrus Meet at NRCC, Nagpur during 12-13 August, 2013
- Mid-term review meeting of ICAR Regional Committee–II at CIFRI, Barrackpore on 24 January, 2014

- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

D. K. Pandey

- National Conference of Plant Physiology held at JAU, Gujarat during 13-16 December, 2013
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

P.J. Khankhane

- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Shobha Sondhia

- AICRP-WC Annual Group Meeting held at CSKHPKV, Palampur during 26-27 April, 2013
- Sensitization workshop on NFBSFARA held at CIFE, Mumbai during 27-28 September, 2013
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

C. Kannan

- Ph.D Students Workshop held at Palacky University, Olomouc, Czech Republic during 17-18 October, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014
- National Seminar on Innovations in Science and Technology for Inclusive Development, held at Bhopal from 26-27 March, 2014

P.P. Choudhury

- Intensive Hindi Workshop at New Delhi during 3-7 June, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Bhumesh Kumar

- Intensive Hindi Workshop at New Delhi during 3-7 June, 2013
- Annual Review Workshop of NFBSFARA projects at New Delhi during 22-23 July, 2013
- National Conference of Plant Physiology held at JAU, Gujarat during 13-16 December, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014
- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- National Seminar on GM Crops: Prospects and Issues held at KAU, Kerala during 17-18 March, 2014

Raghwendra Singh

- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Meenal Rathore

- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

C. Sarathambal

- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Yogita Gharde

- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Dibakar Ghosh

- Intensive Hindi Workshop at New Delhi during 17-21 June, 2013
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

Sandeep Dhagat

- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014
- Biennial Conference of ISWS at DWSR, Jabalpur during 15-17 February, 2014

G.R. Dongre

- Intensive Hindi Workshop at New Delhi during 17-21 June, 2013

O.N. Tiwari

- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014

Pankaj Shukla

- AICRP-WC Annual Review Meeting at DWSR, Jabalpur during 12-14 February, 2014

S.K. Parey

- Intensive Hindi Workshop at New Delhi during 17-21 June, 2013

Ghanshyam Vishwakarma

- Intensive Hindi Workshop at New Delhi during 17-21 June, 2013

19 ALL INDIA COORDINATED RESEARCH PROJECT ON WEED CONTROL

AICRP on Weed Control is running at 22 regular centres located at different state agricultural universities and 6 volunteer centres for carrying out network research and generating location specific technologies on weed management in different crops, cropping system and non-cropped situations. Salient research findings of the project during 2013-14 were as follows :

19.1. Weed surveillance

- Increasing density of *Phalaris minor* in wheat field was recorded in Sabarkantha, Mehsana, Patan, Gandhinagar, Ahmedabad, Kheda, Anand, Panchamahal and Dahod districts of Gujarat.
- Spread of new weeds like *Mikania micrantha, Ambrosia artemisiifolia, Abutilon hirtum, Verbesia encelioides, Solanum elaegnifolium, Pistia stratiotes* and *Ambrosia psilostachya* in South Karnataka has been noticed.
- Sporadic incidences of *Orobanche aegyptiaca* were observed in brinjal and tomato crops at Cuttack and Khurda districts of Odisha.
- *Phalaris minor* and *Convolvulus arvensis* in wheat were spreading in Bikaner district in Rajasthan.
- *Parthenium hysterophorus* was dominant weed in cropped areas of Tamil Nadu.
- Incidence of *Solanum elaegnifolium* infestation in Gadag district (Mundargi taluk) in Karnataka was prominent.
- Due to continuous use of grassy weed killers, infestation of sedges and broadleaf weeds e.g. *Eclipta alba*, *Ammania baccifera*, *Cucumus mello* and *Scirpus tuberosus* etc. was increasing in eastern U.P.
- Tomato crop in several areas of Bhiwani district of Haryana was severely infested with *Orobanche aegyptiaca* causing 15-70% loss in fruit yield.
- Infestation of *Parthenium* was threatening the indigenous vegetation in Assam.
- In maize, there was a shift in weed flora from broadleaf and sedges towards grasses due to continuous use of atrazine in Kapurthala, Jalandhar, Bathinda, Hoshiarpur districts of Punjab. *Ipomoea* sp. in cotton was also causing economic losses.
- *Alternanthra triandra* had heavily infested direct seeded rice and was rampant along road side, bunds etc. in Bilaspur district of Chhattisgarh.

19.2. Weed biology and physiology

- As many as 14 taxa of *Echinochloa* species and intra-specific ranks under altogether 11 species have so far been identified by the Jorhat centre.
- Morphological parameters of *E. colona* and *E. crus-galli* were studied.

Morphological parameters of *Echinochloa* species

Morphological characters	*E. colona*	*E. crus-galli*
Germination (%)	72	64
Emergence (days)	4-5	3-4
Dry weight at 25 days after emergence (g/plant)	0.27	0.32
Flowering (days)	28	31
No. of seeds/plant	568	641
No. of seeds/m^2	5800	6250
1000 seed weight (g)	0.031	0.039

- Weedy rice possessing affinity to *Oryza rufipogon* and *Oryza nivara,* are extremely scarce in transplanted *Kharif* and autumn rice of medium land situation of Assam.
- Results from farmer's fields at Karnal indicated that clodinafop 75 g, sulfosulfuron 30 g and meso + iodosulfuron 14.4 g/ha did not provide effective control of *P. minor* in wheat. Tank mix of metribuzin 105 g with clodinafop 60 g/ha or sulfosulfuron 25 g/ha or pinoxaden 50 g/ha provided effective control of *P. minor*. In Punjab, metribuzin + fenoxaprop-p-ethyl was most effective against *P. minor*.
- Addition of jaggery to glyphosate application for control of *C. rotundus* did not show added advantage at Jorhat, Anand, Ludhiana, Bengaluru however, it was beneficial at Pantnagar and Coimbatore.

19.3. Weed management in crops and cropping systems

- Herbicide combinations for control of complex weed flora in transplanted rice were evaluated.

Post-emergence application of tank mix bispyribac + ethoxysulfuron/Almix was found most effective at Ludhiana, Hisar, Bhubaneswer, Pantnagar and Raipur.

- In direct seeded rice, application of pendimethalin *fb* bispyribac + 1 mannual weeding was most effective for weed control at Bhubaneswer, Hyderabad, Ranchi, Raipur, Coimbatore, Bengaluru, Palampur, Faizabad and Pusa.
- Weed management in turmeric by application of metribuzin 0.7 kg/ha *fb* mulching + 1 hand weeding was found best at Hisar, Ludhiana, Ranchi, Parbhani and Faizabad.
- Application of imazethapyr + pendimethalin 800-000 g/ha was most effective and economical for weed control in blackgram/greengram at Gwalior, Hisar, Ludhiana, Bikaner, Palampur, Pantnagar, Sriniketan and Meerut.
- Experiments conducted in rice-wheat system under conservation agriculture system revealed that higher weed densities in DSR were observed with ZT compared to CT at Ludhiana, Pusa, Kanpur and Faizabad, while CT recorded higher weed density at Pantnagar. In wheat, CT-CT method recorded reduced density of weeds at Ludhiana and Pusa, while it favored higher weed growth at Pantnagar and Kanpur. Integrated weed management was most effective for weed control at all the places.
- In rice-mustard system, at Sriniketan and Jorhat, conventional tillage in transplanted rice was found most effective in controlling weeds.

Treatment	Total weed density (no./m²)	Total weed dry weight (g/m²)	Yield (t/ha)
Crop establishment technique			
CT- CT-	1.7 (60.8)	1.3 (31.2)	1.51
CT – ZT- ZT	1.7 (60.0)	1.3 (29.2)	1.52
CT – CT- ZT	1.7 (60.1)	1.3 (30.1)	1.50
ZT – ZT-ZT	1.8 (73.3)	1.4 (38.3)	1.33
ZT + R- ZT + R- ZT	1.7 (70.9)	1.4 (37.8)	1.36
LSD (P=0.05)	**NS**	**NS**	**NS**
Weed control			
Recommended herbicide	1.7 (56.0)	1.3 (21.4)	1.65
IWM (herbicide + mechanical weeding + intercrop)	1.3 (19.7)	0.8 (3.9)	1.91
Unweeded	2.1(119.3)	1.9(74.7)	0.77
LSD (P=0.05)	**0.11**	**0.11**	**0.16**

In mustard also, lowest weed density was recorded under CT-CT method.

- The weed density was not significantly influenced due to tillage and residue management practices in rice –chickpea system at Bengaluru.
- Effect of tillage and weed management practices on weed and chickpea under conservation agriculture (Bengaluru) have been summarized as under:
- In rice-mustard system, conventional tillage in transplanted rice was found most effective in controlling weeds. In mustard, lowest weed density was recorded under CT-CT method at Sriniketan and Jorhat.

19.4. Long-term herbicide trials

- Sequential application of pre-and post-emergence herbicides (clodinafop *fb* metsulfuron) against grasses and broadleaf weeds in wheat, and butachlor *fb* metsulfuron in rice were most effective for weed control on long-term basis at Ludhiana.
- In long-term herbicide trial, in rice-groundnut at Bhubaneswar, application of butachlor + 2,4-DEE, without organic matter to rice and alachlor to groundnut was found to be the best practice for weed management with high B:C ratio.
- In rice-chickpea system at Raipur, application of oxadiargyl 80 g/ha *fb* post-emergence bispyribac 25 g/ha in rice and pendimethalin 1.0 kg/ha in chickpea was the most effective for weed management and higher crop yields.

19.5. Managementof problematic weeds

- Application of glyphosate @ 25 g/ha on 55 DAS alone or with 1% $(NH_4)_2SO_4$ provided about 80-90% control of *Orobanche* in mustard in Haryana. Whereas, at Gwalior, lowest *Orobanche* shoot population was recorded with glyphosate @ 50 g/ha after emergence of *Orobanche* in mustard.
- In tobacco crop in Tamil Nadu, it was reported that plant hole application of neem cake at 200 kg/ha on 30 DAT or imazethapyr at 30 g/ha on 55 DAT recorded *Orobanche* shoot with higher tobacco leaf yield.
- Pre-emergence application of atrazine at 1.0 kg/ha on 3 DAP + HW on 45 DAP + earthing up on 60 DAP + POE 2,4-D Na salt 5 g/l + urea 20 g/l on 90 DAP *fb* trash mulching at 5 t/ha on 120 DAP **was found most effective to control *Striga* in sugarcane at Coimbatore.**
- The germination of *Cuscuta* was less in stale seedbed *fb* pre-emergence application of pendimethalin 1.0 kg/ha which resulted in the highest seed yield of niger at Bhubaneswar.
- In Bengaluru, for management of *Dendrophthoe* in sapota, padding of cotton with the paste made of 4 g copper sulphate + 0.5 g 2,4-D sodium salt 80 WP on the wounds of the weed shoots caused 100% defoliation after 2 months, without regeneration up to 6 months.

19.6. Biological weed management

- Use of bioagent *Zygogramma bicolorata* resulted in significant control of *Parthenium* at Anand, Hisar, Palampur, Pantnagar, Ludhiana, Parbhani, Bhubaneswar, Kanpur, Faizabad, Pusa, Gwalior, Bikaner and Sriniketan centres with its effect ranging from 7-75%. Larval population, eggs and adults of *Zygogramma* beetles were highest during August to September at Sriniketan, Palampur, Faizabad and Bikaner.
- Broadcasting of seeds of *Cassia tora* was done during February-May in the pre-marked *Parthenium* infested sites. *Cassia tora* successfully replaced *Parthenium* by September-October at Anand, Jorhat, Ranchi, Hisar, Kanpur, Faizabad, Palampur, Pantnagar, Ludhiana, Raipur, Bhubaneswar, Muzaffarpur (Bihar), Gwalior and Sriniketan. At Coimbatore, *C. tora* did not germinate well due to scanty rainfall.
- *Neochetina* spp. weevils multiplied and caused excellent control of water hyacinth at Hyderabad, Thrissur, Hisar and Faizabad centre. Alligator weed replaced the niche vacated by water hyacinth.

19.7. Herbicide residues and environmental quality

- In long-term herbicide trial in rice-wheat cropping system, the residues of butachlor, pretilachlor and anilophos at Hisar and Ludhiana and butachlor and isoproturon at Palampur and Pantnagar were found below detectable level (0.01 ppm) in soil, grain and straw.
- In maize-pea cropping system at Palampur, pendimethalin residues were below detectable limits (0.001 µg/g) in post-harvest soil, grain and straw samples. Soil samples from chickpea, peas and mustard crops also showed residues of pendimethalin below detectable level. However, 0.095 µg/g residue was detected in mustard at the time of harvest of crop.
- At Hyderabad, in no-till maize soils, atrazine residues in soil could be detected upto 60 days after application at recommended dose either in combination with the paraquat or sole application. In post-emergence application, residues could be detected up to 45 days. No residues of butachlor could be detected in the rice grain or straw samples collected at harvest.
- At Hisar, the water samples from the tube-wells from farmers' fields were collected after 45 days of application of herbicide. Results revealed that 5 out of 21 sites were having pretilachlor residues ranging between 0.21–1.30 µg/g.
- At Hisar, soil, wheat grain and straw samples were collected from farmers' field at harvest from different rice-wheat growing regions of Haryana. The samples were taken from the sites where farmers were continuously using the pretilachlor for many years. At harvest, four samples were found to contain sulfosulfuron within range of 0.011-0.028 µg/g. Five soil samples were having either sulfosulfuron or meso + iodosulfuron. No other herbicide residues were detected in wheat grain and straw in the framer's fields.

19.8. Transfer of technology

- During 2013, AICRP-WC centres conducted 843 frontline demonstrations on location-specific weed management technologies, and broadcast 29 radio and 27 TV talk-shows. In addition to this, 80 training programmes were conducted and 20 handouts, folders, pamphlets, bulletins/booklet in various languages were published and distributed to the farmers and other end-users.
- At Hisar, ready mix combination of pretilachlor + bensulfuron was tested against complex weed flora in transplanted rice at 17 locations in various parts of Haryana and compared with existing herbicide pretilachlor. Results showed that 94.2% control of complex weed flora by the

new herbicide tested and 84.7% with pretilachlor and also yield increase of 157 kg/ha.

- At Bhubaneswar, 6 on farm trails were conducted in transplanted rice, results revealed that maximum yield of 4.21 t/ha was recorded with application of oxadiargyl 0.065 kg/ha *fb* pyrazosulfuron-ethyl 0.02 kg/ha (4.02 t/ha) and net saving of Rs 2150 - 2654/ ha was recorded.

19.9. Tribal sub-plan

- Tribal sub plan was implemented at Anand, Jorhat, Ranchi, Palampur, Raipur, Bhubaneswar, Bikaner, Coimbatore, Bengaluru, Dharwad and Dapoli centres during 2013-14.
- Anand centre distributed herbicide spray equipments, hand hoes etc. to 50 tribal farmers of Dahod districts. OFTs were also conducted to demonstrate weed management technologies.
- FLDs, field day and training on weed management in *boro* rice were conducted by Jorhat Centre at Karbi Anglong, Kokrajhar districts. Inputs related to weed management were distributed to 80 tribal farmers
- Palampur center conducted 5 training programmes for 500 tribal farmers. Knapsack sprayers were distributed to the farmers.
- Frontline demonstrations on weed management in maize, rice and wheat were conducted in 26 tribal districts at 318 farmer's fields by Raipur centre in Chhattisgarh state.
- Ranchi centre conducted several training programmes for tribal farmers of Ranchi, West Singhbhum, Lohardaga and Gumla districts. Implements like cono weeder, grubber and dutch-hoe were also distributed to tribal farmers.

Training and distribution of inputs to tribal farmers by Ranchi centre

- Bhubaneswar centre distributed implements and other inputs to tribal farmers in Keonjhar, Deogarh, Sundergarh and Mayurbhanja districts.
- Bikaner center organized 3 training programmes at Dungarpur and Banswara districts. Sprayers and herbicides were distributed to 90 tribal farmers.
- Training on weed management and distribution of implements were carried out by Bengaluru, Dharwad and Dapoli centres for the benefit of tribal farmers.

20 DISTINGUISHED VISITORS

Dr. D.P. Singh, Chairman, Kisan Kalyan Board, Haryana and Former Vice Chancellor, JNKVV, Jabalpur	23 April, 2013
Dr. S.K Rao, Dean Faculty (Agricultural Science), JNKVV, Jabalpur	23 April, 2013 15 February, 2014
Dr. Jay G. Varshney, former Director, DWSR, Jabalpur	23 April, 2013
Dr. K.R. Koundal, Emeritus Scientist-CSIR and former Director, NRC on Plant Biotechnology and Joint Director (Research), IARI, New Delhi	6 May, 2013
Dr. V.N. Saraswat, former Director, DWSR, Jabalpur	7 May, 2013
Dr. R.K. Rattan, IARI, New Delhi	10 July, 2013
Dr. T.K Vaid, Agronomist, Department of Animal Husbandry, Dairying and Fisheries, GOI, New Delhi	8 September, 2013
Dr. P.K. Ghosh, Director, IGFRI, Jhansi	8 September, 2013
Dr. Ranjan Bhattacharya, Sr. Scientist, Incharge Division of Environmental Science, New Delhi	21 September, 2013
Dr. B. Mohan Kumar, Assistant Director General (Agronomy), ICAR, New Delhi	29 September, 2013
Dr. Thomas Tan, Agricultural Chemicals, Malaysia	8 October, 2013
Dr. Vishwanath Gade, GM, PI Industries Ltd.	8 October, 2013
Dr. Poh Leong Tat, Agricultural Chemicals, Malaysia	8 October, 2013
Dr. T.R. Sharma, Principal Scientist, NRCPB, New Delhi	14 November, 2013
Dr. B. Gangwar, Director, PDFSR, Modipuram, Meerut	20 December, 2013
Dr. R.C. Gautam, Former Head, Agronomy and Dean IARI, New Delhi	4 January, 2014
Dr. U.K. Behera, Principal Scientist, IARI, New Delhi	6 January, 2014
Dr. M.S. Basu, Former Director, National Research Centre for Groundnut (ICAR), Junagarh	20 January, 2014
Dr. C.B. Singh, Ex-Dean and Director Extension, JNKVV, Jabalpur	20 January, 2014
Dr. A.K. Singh, Professor (Genetics), IARI, New Delhi	25 January, 2014
Dr. L.S. Brar, Ex-Professor and Head (Agronomy), PAU, Ludhiana	12-17 February, 2014
Dr. N.T. Yaduraju, Former Director, DWSR, Jabalpur	13-17 February, 2014
Dr. V.S. Tomar, Vice Chancellor, JNKVV, Jabalpur	15 February, 2014
Dr. R.K. Malik, Coordinator, CIMMYT-India, New Delhi	14-17 February, 2014
Dr. R.K. Gupta, South Asia Coordinator, CIMMYT-India, New Delhi	14-17 February, 2014
Dr. N.N. Angiras, Ex-Professor and Head, CSKHPV, Palampur	15-17 February, 2014
Dr. Nimal Chandrasena, Principal Ecologist, GHD Water Sciences, Australlia	15-17 February, 2014
Dr. Megh Singh, Weed Scientist, University of Florida, US A	15-17 February, 2014
Dr. A.N. Rao, Visiting Scientist , ICRISAT, Hyderabad	15-17 February, 2014
Dr. (Mrs.) Gita Kulshrestha, Ex-Professor, IARI, New Delhi	15-17 February, 2014
Dr. B.S. Chouhan, Weed Scientist, IRRI, Phillipines	15-17 February, 2014
Dr. T.K. Das, Principal Scientist, IARI, New Delhi	15-17 February, 2014
Dr. U. Prakasham, IFS, Director, TFRI, Jabalpur	28 February, 2014
Dr. B.P. Tripathi, Joint Director (Agriculture), Govt. of M.P., Jabalpur	11 March, 2014



21 PERSONALIA

21.1. Scientific Staff

	Names	Specialization
	**Dr. A.R. Sharma** Director Email: sharma.ar@rediffmail.com Mobile: 09425807290	Weed management, conservation agriculture and nutrient management
	**Er. H.S. Bisen** Pr. Scientist (Agril. Engg.) Email: erhsbien@gmail.com Mobile: 09425388101	Mechanical weed management, weeding tools and implements, spray application techniques, spraying machinery and gadgets.
	**Dr. P.K. Singh** Pr. Scientist (Agril. Extension) Email: drsinghpk@gmail.com Mobile: 09425388721	Technology transfer, demonstration, adoption and impact assessment
	**Dr. V.P. Singh** Pr. Scientist (Agronomy) Email : vpsinghnrcws@gmail.com Mobile: 09424306051	Weed management in cropping systems, orchards, and conservation agriculture
	**Dr. Sushilkumar** Pr. Scientist (Entomology) Email: sknrcws@gmail.com Mobile: 09425186747	Biological control of weeds, aquatic weed management and herbicide tolerant crops
	**Dr. Anil Dixit** Pr. Scientist (Agronomy) Email: dranildixit@in.com Mobile: 09424371588 (Transferred on 17.7.2013)	Integrated weed management in crop and cropping systems, herbicide tolerant crops
	**Dr. K.K. Barman** Pr. Scientist (Soil Science) Email: barmankk@gmail.com Mobile: 09826811536	Integrated weed management and environmental quality
	**Dr. R.P. Dubey** Pr. Scientist (Agronomy) Email: dubeyrp@gmail.com Mobile: 09425412041	Integrated weed management and organic agriculture
	**Dr. D.K. Pandey** Pr. Scientist (Plant Physiology) Email: dayapandey@hotmail.com Mobile: 09893659994	Allelopathy, natural herbicidal molecule isolation, seed biology and aquatic weeds
	**Dr. P.J. Khankhane** Sr. Scientist (Soil Science) pjkhankhane@yahoo.com.ph Mobile: 09926715757	Bioremediation, soil and water quality, weed utilization, plant biomass management and wetland management
	**Dr. Shobha Sondhia** Sr. Scientist (Organic Chemistry) Email: shobhasondia@yahoo.com Phone No: 0761-2353934, Ext. 340	Environmental impact of herbicide, mode of degradation, bio-molecules, herbicide residues and herbicide mitigation measures
	**Dr. C. Kannan** Sr. Scientist (Plant Pathology) Email: agrikannan@gmail.com Mobile: 09425865057	Biological management of water hyacinth and parasitic weeds, systemic induced resistance in host, microbial composting and bio-ethanol
	**Dr. Partha Pratim Choudhury** Sr. Scientist (Organic Chemistry) Email: parthatinku@yahoo.com Mobile: 09179457045	Fate of herbicides in the environment, decontamination techniques, impact of solar UV-fraction on small organic molecules
	**Dr. Bhumesh Kumar** Sr. Scientist (Plant Physiology) Email: kumarbhumesh@yahoo.com Mobile: 09806622307	Weed dynamics and management under the regime of climate change, herbicide resistance and bio-prospection of weed species
	**Dr. Raghwendra Singh** Sr. Scientist (Agronomy) Email: singhraghu75@gmail.com Mobile: 09806637031	Weed ecology, integrated weed management and conservation agriculture
	**Dr. Meenal Rathore** Sr. Scientist (Biotechnology) Email: mr10@rediffmail.com Mobile: 08989755865	Molecular tools to assess diversity, biology of weeds and characterization of weedy rice bio-similars
	**Dr. Yogita Gharde** Scientist (Agril. Statistics) Email: yogita_iasri@rediffmail.com Mobile: 09425412748	Agricultural statistics, modeling on crop-weed associations
	**Dr. C. Sarathambal** Scientist (Microbiology) Email: csaratha@yahoo.co.in Phone No: 0761-2353934, Ext. 327 (Joined after study leave on 26 November, 2013)	Soil microbiology
	**Mr. Dibakar Ghosh** Scientist (Agronomy) Email: dghoshagro@gmail.com Mobile: 08989190213	Weed ecology and management in conservation agriculture

21.2. Technical staff

Dr. M.S. Raghuwanshi (Transferred on 20.7.2013)	T-7&8, Assistant Chief Tech Officer	Sh. J.N. Sen	T-5, Technical Officer
Sh. R.S. Upadhyay	T-7&8, Assistant Chief Tech Officer (Farm Manager)	Sh. S.K. Parey	T-5, Technical Officer
Sh. Sandeep Dhagat	T-7&8, Assistant Chief Tech Officer	Sh. S.K. Bose	T-5, Technical Officer
Sh. Mukesh Kumar Bhatt	T-6, Sr. Tech Officer (Artist Cum Photographer)	Sh. G. Vishwakarma	T-5, Technical Officer
Sh. V.K.S. Meshram	T-6, Sr. Tech Officer (Artist)	Sh. S.K. Tiwari	T-5, Technical Officer
Sh. G.R. Dongre	T-6, Sr. Technical Officer	Sh. K.K. Tiwari	T-5, Technical Officer
Sh. M.P. Tiwari	T-6, Sr. Technical Officer	Sh. Mukesh K. Meena	T-4, Sr. Technical Assistant
Sh. Basant Mishra	T-5, Technical Officer	Sh. Ajay Pal Singh	T-4, Sr. Technical Assistant
Sh. O.N. Tiwari	T-5, Technical Officer	Sh. Bhagunte Prasad	T-3, Technician (Tractor Driver)
Sh. Pankaj Shukla	T-5, Technical Officer	Sh. Prem Lal	T-3, Technician (Driver)
Sh. R.N. Bharti (Transferred on 07.09.2013)	T-5, Technical Officer (Librarian)	Sh. Dilip Sahu	T-3, Technician (Driver)
		Sh. Sebestene Das	T-3, Technician (Driver)

22.3. Administrative staff

Sh. R.K. Giri	Administrative Officer	Sh. T. Lakhera	Assistant
Sh. R Hadge	Assistant Administrative Officer	Sh. Beni Prasad Uriya	Assistant
Smt. Nidhi Sharma	PS to Director	Kum. Sri Vidya	Assistant
Sh. Manoj Gupta	PA	Sh. Francis Xavier	Sr. Clerk

22.4. Skilled support staff

Sh. Veer Singh	Skilled Support Staff	Sh. Jethuram Viswakarma	Skilled Support Staff
Sh. Raju Prasad	Skilled Support Staff	Sh. Shiv Kumar Patel	Skilled Support Staff
Sh. Jagoli Prasad	Skilled Support Staff	Sh. Ashwani Tiwari	Skilled Support Staff
Sh. Jagat Singh	Skilled Support Staff	Sh. Suresh Chand Rajak	Skilled Support Staff
Sh. Chhoteylal Yadav	Skilled Support Staff	Sh. Gajjulal	Skilled Support Staff
Sh. Anil Sharma	Skilled Support Staff	Sh. Gangaram	Skilled Support Staff
Sh. Ram Kumar (Left for his heavenly abode)	Skilled Support Staff on 27 January, 2014	Sh. Sant Lal	Skilled Support Staff
Sh. Naresh Singh	Skilled Support Staff	Sh. Mahendra Patel	Skilled Support Staff
Sh. Shankar Lal Koshta	Skilled Support Staff	Sh. Santosh Kumar	Skilled Support Staff
Sh. J.P. Dahiya	Skilled Support Staff	Sh. Nemichand Kurmi	Skilled Support Staff
Sh. Madan Sharma	Skilled Support Staff	Sh. Mohan Lal Dubey	Skilled Support Staff

22.5. Promotions

- Sh. K.K. Tiwari was promoted from T-4 Sr. Technical Assistant to T-5 Technical Officer w.e.f. 14 January, 2012
- Sh. Ghanshyam Vishwakarma was promoted from T-4 Sr. Technical Assistant to T-5 Technical Officer w.e.f. 28 March, 2012
- Sh. Ajay Pal Singh was promoted from T-3 Technical Assistant to T-4 Sr. Technical Assistant w.e.f. 28 March, 2012
- Sh. Sabesteen Das was promoted from T-2 Technical Assistant (Driver) to T-3 Sr. Technican (Driver) w.e.f. 21 May, 2012
- Sh. S.K. Tiwari was promoted from T-4 Sr. Technical Assistant to T-5 Technical Officer w.e.f. 14 January, 2013
- Sh. S.K. Bose was promoted from T-4 Sr. Technical Assistant to T-5 Technical Officer w.e.f. 14 January, 2013
- Sh. Rajendra Hadge was promoted from Office Assistant to Assistant Administrative Officer w.e.f. 9 December, 2013

22.6. Farewell to staff members

Dr. Anil Dixit, Principal Scientist (Agronomy) was transferred on 17 July, 2013 from DWSR, Jabalpur to National Institute of Biotic Stress Management, Raipur.

Dr. M.S. Raghuwanshi, Assistant Chief Technical Officer was transferred on 20 July, 2013 from DWSR, Jabalpur to CAZRI Regional Research Station, Leh (Jammu and Kashmir) on his selection as Sr. Scientist (Agronomy)

Sh. R.N. Bharti, Librarian was transferred on 7 September 2013 from DWSR, Jabalpur to Indian Institute of Sugarcane Research, Lucknow.

22.7. Obituary

Sh. Ram Kumar, Skilled Support Staff (SSS) passed away untimely on 27 January, 2014. The staff of the Directorate condole his death and beg the Almighty for solace to the departed soul.

22 ON-GOING RESEARCH PROGRAMMES

22.1. List of research programmes and sub-programmes during 2013-14

Research programmes and sub-programmes	Co-Principal Investigator	Associates
1. Development of sustainable weed management practices in diversified cropping systems **Programme Leader: Dr. V.P. Singh**		
Sub-programmes		
1.1. Weed management under long-term conservation agriculture systems	Dr. V.P. Singh	Dr. Raghwendra Singh Mr. Dibakar Ghosh Dr. K.K. Barman Dr. R.P. Dubey Dr. Yogita Gharde Dr. P.P. Choudhary Dr A.R. Sharma
1.2. Systems approach to weed management	Dr. R.P. Dubey	Dr. V.P. Singh Dr. K.K. Barman Dr. P.P. Choudhury Dr. Raghwendra Singh Dr. Yogita Gharde Mr. Dibakar Ghosh
1.3. Improving input-use efficiency through weed management	Dr. Raghwendra Singh	Dr R.P. Dubey Dr. V.P. Singh Dr. K.K. Barman Dr. P.P. Choudhury Dr. Yogita Gharde
1.4. Standardization of spraying techniques and mechanical tools for weed management	Er. H.S. Bisen	Dr V.P. Singh Mr. Dibakar Ghosh
2. Crop-weed dynamics and management under the regime of climate change and herbicide resistance **Programme Leader: Dr. D.K. Pandey**		
2.1. Effect of climate change on crop-weed interactions, herbicide activity and bioagents	Dr. Bhumesh Kumar	Dr. D.K. Pandey Dr. P.P. Choudhury Dr. Raghwendra Singh Dr. Sushil Kumar Dr. Meenal Rathore
2.2. Physiological and molecular basis of herbicide resistance development in weeds and evaluation of herbicide tolerant crops	Dr. D.K. Pandey	Dr. Bhumesh Kumar Dr. Meenal Rahore
2.3: Development of weed seed identification tools and weed risk analysis	Dr. D.K. Pandey	Dr. Bhumesh Kumar Dr. Raghwendra Singh Dr. Meenal rathore
3. Biology and management of problematic weeds in cropped and non-cropped areas **Programme Leader: Dr. Sushil Kumar**		
3.1. Biology and management of problematic weeds in cropped areas	Dr. C. Kannan	Dr. Meenal Rathore Dr. Sushil Kumar Mr. Dibakar Ghosh Dr. P.J. Khankhane Dr. A.R. Sharma
3.2. Biology and management of problematic weeds in non-cropped areas	Dr. Sushil Kumar	Dr. Sushil Kumar Dr. Yogita Gharde
3.3. Biology and management of aquatic weeds	Dr. Sushil Kumar	Dr. C. Kannan Dr. Shobha Sondhia
4. Monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment **Programme Leader: Dr. Shobha Sondhia**		
4.1. Impact of herbicides in soil, water and non targeted organisms and herbicide mitigation measures	Dr. Shobha Sondhia	Dr. P.J. Khankhane Dr. K.K. Barman Dr. Sushil Kumar
4.2. Degradation of herbicides in the environment	Dr. P.P. Choudhury	Dr. Meenal Rathore Dr. K.K. Barman Dr. Shobha Sondhia
4.3. Bio-remediation of pollutants using terrestrial / aquatic weeds	Dr. P.J. Khankhane	Er. H.S. Bisen Dr. Shobha Sondhia
5. On-farm research and demonstration of weed management technologies, and impact assessment **Programme Leader: Dr. P.K. Singh**		
5.1. On-farm research and demonstration of weed management technologies for enhanced productivity and income	Dr. P.K. Singh Dr. V.P. Singh Er. H.S. Bisen Dr. Sushil Kumar Dr. D.K. Pandey Dr. R.P. Dubey	Dr. P.J. Khankhane Dr. Shobha Sondhia Dr. C. Kannan Dr. Bhumesh Kumar Dr. Meenal Rathore Mr. Dibakar Ghosh Dr. Raghwendra Singh Dr. Yogita Gharde Dr. P.P. Choudhury Dr. K.K. Barman Dr. A.R. Sharma
5.2. Impact assessment of adoption of weed management technologies on socio-economic upliftment and livelihood security	Dr. P.K. Singh	Dr. Yogita Gharde

23 WEATHER REPORT

The climate of Jabalpur is broadly classified as sub-tropical, characterized by very hot summers and cold winters. Maximum temperature ranges from 39-45°C during April to June, while the coldest months are December-January. The average annual rainfall is 1379 mm, most (90%) of which is received during June-September. In the year 2013, total annual rainfall was 2543 mm, while the total annual evaporation was 1520 mm. Heavy north-eastern monsoon showers (107.3 mm) with hail storm were received during January - February - March 2014 and damage to the *Rabi* crops. The rainfall of 2013 was 85% higher than the average of last 46 years and distribution was erratic. More than 85% of total annual rainfall received within three months i.e. June to August, 2013. Due to heavy and continuous rain during June, direct-seeding of rice was delayed by 1-2 week. The high rainfall during July-August even caused flooding of upland crops and resulted in total failure of soybean. Although rainfall of September was lower and of October was higher than normal. The mean maximum relative humidity during hot months (April-June) ranged from 35-80% and mean minimum relative humidity was 13-59%. The mean maximum daily sunshine of 10.2 hr was in May and mean minimum of 1.9 hr in August. Weather data obtained from adjacent meteorological observatory of JNKVV, Jabalpur are presented in Table 1 and Figure 1.

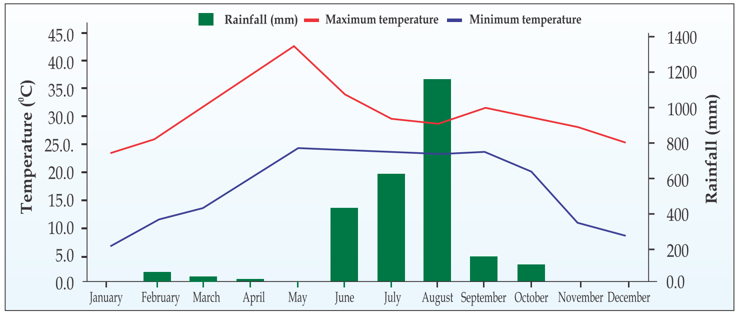

Figure 1:Mean monthly maximum and minimum air temperature, and total monthly rainfall at Jabalpur, during 2013

Table 1: Monthly mean maximum and minimum air temperature, rainfall, sunshine and evaporation at Jabalpur during 2013

Month	Temperature (°C)		Humidity (%)		Rainfall (mm)		Sunshine (hr/day)	Evaporation (mm)
	Maximum	Minimum	Maximum	Minimum	Average (46 years)	2013		
January	23.6	6.6	86.6	35.9	20.1	0.0	7.8	80.9
February	25.8	11.4	90.3	51.1	22.9	60.2	6.8	81.0
March	31.8	13.4	81.1	31.6	15.2	33.3	8.5	136.2
April	37.3	18.9	59.7	19.1	3.6	13.8	8.8	219.7
May	42.7	24.4	34.6	12.5	9.9	0.0	10.2	344.9
June	34.3	24.2	80.4	58.7	177.7	422.3	4.8	171.0
July	29.8	23.7	92.9	79.7	393.4	613.8	2.3	87.4
August	28.8	23.4	94.6	81.5	454.4	1144.9	1.9	69.2
September	31.6	23.7	91.2	64.8	216.0	150.4	6.2	109.5
October	29.7	20.2	90.8	61.9	39.0	103.8	6.4	77.9
November	28.1	10.9	90.2	33.3	12.5	0.0	8.1	77.3
December	25.7	8.6	90.1	34.7	14.5	0.0	7.4	65.3
Total					**1379.3**	**2542.5**		**1520.3**

24 NEW INITIATIVES AND NOTABLE ACHIEVEMENTS DURING 2013-14

1. Five focused research programmes on sustainable weed management, climate change, problem weeds, herbicide residues and on-farm research have been launched in multi-disciplinary mode.
2. Effective collaboration with ICAR Institutes of Crops, Horticulture and NRM Division has been established through the identified Nodal Officers at the Directorate.
3. Effective system of monitoring research and extension work at 22 regular centres and some voluntary centres of AICRP-Weed Control has been developed.
4. A major initiative on 'On-farm research' has been taken. Six teams have worked in 6 localities around Jabalpur for two years (2012-2014).
5. A major programme on weed management in conservation agriculture systems was taken up at the HQ as well as AICRP-WC centres in diversified cropping systems.
6. Research farm was developed as a 'Model' based on the principles of conservation agriculture involving laser land leveling, mechanization of field operations, zero-till sowing, residue management *in situ*, biomass composting, crop diversification, beautification with ornamental plantations, boundary plantations, *Parthenium*-free campus, renovation of roads, ponds for water harvesting and facilitating drainage, layout and organization of blocks etc.
7. Farm mechanization – laser leveller, happy seeder, roto-till drill, multi-crop zero-till drill, multi-crop seed-cum-fertilizer drill, multi-boom tractor operated sprayer, power weeder, reaper, trailed type disc harrow, disc plough, mould board plough, rotavator, disc bund former, dozer blade, tractor-mounted front loader etc. were procured.
8. Quality seed production has been taken up at the research farm in collaboration with National Seeds Corporation. More than 100t seed of rice, wheat and maize was produced during 2012-13; and 70t seed of rice was produced in *Kharif* 2013.
9. Technology Park displaying the weed management technologies in different crops has been developed.
10. Field data books are being maintained and duly verified for proper data management
11. *Parthenium* Awareness Week was organized on a much larger scale during 16-22 August, 2013, which was widely covered by the national and local print and electronic media.
12. All records of RPF and other proceedings were updated and computerized in the PME cell. Articles for publications are duly examined and routed through the PME cell.
13. Most equipments lying idle for several years have been repaired and made functional (ovens, refrigerators, balances, autoclaves, incubators, shakers, microscopes, water bath, heating mantle, mixer, vacuum compressor, pH meter and others).
14. FACE facility which was non-functional for nearly two years, has been repaired and further improved.
15. Two laboratories on Plant Physiology and Environmental Chambers have been renovated.
16. Two new projects were approved under NFBSFARA. Collaboration with JNKVV, RDVV, IGKV and other universities/ colleges for PG students' research and guidance was started.
17. All the days as per instructions of the Council were organized–Agricultural Education Day, Foundation Day, Farm Innovators Day, Industry Day and National Science Day.

18. Seven silver jubilee lectures by eminent scientists of the country were organized during 2013-14, besides 8 technical seminars by the scientists of the Directorate.

19. Biennial Conference of the Indian Society of Weed Science and Annual Review Meeting of AICRP on Weed Control were organized for the first time at this Directorate.

20. Best Worker Awards were instituted for different category of staff and conferred on the Foundation Day of the Directorate.

21. Four training programmes were organized, including the 2nd National Course on Advances in Weed Management, and a first time training programme for the PG students on biological weed management.

22. Certification for ISO 9001 : 2008 has been obtained during December, 2013 for a period for 3 years through the Global Certification Agency.

23. Website of the Directorate has been improved in content and quality. All the available information on weed database including weed seed / seedling identification, Annual Report, Weed News etc. has been uploaded on the website. All circulars/ officer orders, tour reports are also uploaded on the intranet.

24. Initiatives for modernization and reducing file/paper work in the office have been undertaken. Biometric system for marking attendance and Online Leave Management System have been introduced. Computerization of all office records is in progress.

ABBREVIATIONS

AAS : Atomic Absorption Spectrophotometer
AAU : Anand Agricultural University
AAU : Assam Agricultural University
AICRP : All India Coordinated Research Project
AKMU : Agriculture Knowledge Management Unit
ANGRAU : Acharya NG Ranga Agricultural University
B:C ratio : Benefit cost ratio
BAU : Birsa Agricultural University
ICAR : Indian Council of Agricultural Research
BOD : Biological oxygen demand
BPSR : Puddled broadcast sowing with sprouted seeds
BSKV : Baba Saheb Ambedkar Krishi Vidya Peeth
CAs : Conservation agriculture system
CCSHAU : Choudhary Charan Singh Haryana Agricultural University
CeRA : Consortium of for e-Resources in Agriculture
cm : Centimetres
CIAE : Central Institute of Agricultural Engineering
CO_2 : Carbon di-oxide
COD : Chemical oxygen demand
CSAUAT : Chandra Sekhar Azad University of Agriculture and Technology
CTs : Conventional tillage system
DAS : Days after sowing
DAT : Days after transplanting
DBT : Department of Biotechnology
DO : Dissolved oxygen
DSR : Direct-seeded rice
DWSR : Directorate of Weed Science Research
EC : Emulsifiable concentrate, electrical conductivity
FACE : Free Air CO_2 Enrichment
FP : Farmers' practice
fb : Followed by
FYM : Farm yard manure
g/m^2 : Gram per square meter
GBPUAT : Govind Ballabh Pant University of Agriculture and Technology
GC : Gas Chromatograph
GR : Glutathione reductase
HPKV : Himachal Pradesh Krishi Vishwavidyalaya
HPLC : High Performance Liquid Chromatography
HV : High volume
HW : Hand weeding
IGKV : Indira Gandhi Krishi Vishwa Vidyalaya
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 Mission Unit
IWM : Improved weed management
KAU : Kerala Agricultural University
KMAS : Kisan mobile advisory service
KMS : Knowledge management service
KVK : Krishi Vigyan Kendra
L/ha : Litre per hectare
LAI : Leaf area index
LAN : Local Area Network
LC-MS/MS : Liquid Chromatography-Mass Spectroscopy/ Mass Spectroscopy
LSD : Least significant difference
LV : Low volume
MAU : Maharashtra Agricultural University
MHV : Medium high volume
MLV : Medium low volume
NAIP : National Agricultural Innovative Programme
NDUAT : Narendra Dev University of Agriculture and Technology
NDVI : Normalized difference vegetation index
NGO : Non-Governmental Organization
NRM : Natural Resource Management
OC : Organic carbon
OFR : On farm research
OTC : Open top chamber
OUAT : Orissa University of Agriculture and Technology
PAGE : Poly-acryl amide gel electrophoresis
PAU : Punjab Agricultural University
PCT : puddle /conventional tillage
PE : Pre-emergence
PME : Prioritization, Monitoring and Evaluation
PO : Post emergence
POX : Guaiacol peroxidase
PSCST : Punjab State Council of Science and Technology
QRT : Quinquennial Review Team
R : Residue
RAC : Research Advisory Committee
RAU : Rajasthan Agricultural University
RAU : Rajendra Agricultural University
RFD : Results Framework Documents
RGR : Relative growth rate
RVSKVV : Rajmata Vijayaraje Sindhia Krishi Vishwa Vidyalaya
S : *Sesbania* brown manuring
SAU : State Agricultural University
SD : Standard deviation
SEd : Standard error of difference
SE m : Standard error of the mean
SOD : Superoxide dismutase
SOR : Sodium adsorption ratio
SPAD : Soil plant analysis development
t/ha : Ton per hectare
TNAU : Tamil Nadu Agricultural University
TPR : Transplanted rice
UAS : University of Agricultural Sciences
VB : Vishwa Bharati
VLV : Very low volume
WCE : Weed control efficiency
ZT : Zero tillage