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वार्षिक प्रतिवेदन
Annual Report

2012–2013

खरपतवार विज्ञान अनुसंधान निदेशालय
Directorate of Weed Science Research

जबलपुर (मध्य प्रदेश) भारत
Jabalpur (Madhya Pradesh) India

वार्षिक प्रतिवेदन
Annual Report
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खरपतवार विज्ञान अनुसंधान निदेशालय
DIRECTORATE OF WEED SCIENCE RESEARCH
जबलपुर 482 004 (म.प्र.) भारत
JABALPUR 482 004 (M.P.) INDIA

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

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Dr. A.R. Sharma
Director

Editorial Committee
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Dr. V.P. Singh
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Photographs
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Cover page design
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Cover theme

Front : Directorate has launched five major research programmes during 2012-13, focusing on conservation agriculture, climate change, problem weeds, herbicide residues and on-farm research. These are depicted through wheat sowing under no-till residues with happy seeder, chickpea grown in FACE ring with elevated CO_2, *Orobanche* infestation in mustard crop, LC-MS/MS facility for herbicide residues / metabolite analysis, and scientists - farmers interaction on technology transfer (in clockwise manner). A healthy crop of soybean is shown at the centre.

Back : Campus of the Directorate showing the location of different facilities and experimental blocks / fields, which have been categorised and numbered in a systematic manner.

Preface

Weeds are one of the major biotic constraints in agricultural production. As per the available estimates, these cause up to one third of the total losses in yield, besides impairing produce quality and various kinds of health and environmental hazards. Despite development and adoption of weed management technologies, the weed infestations are virtually increasing. This is due to adoption of high-input and intensive cropping systems; neglect and discontinuation of some of the traditional practices like intercropping, mulching and crop rotations involving legumes; shift in weed flora due to adoption of fixed cropping systems and management practices including herbicides; development of herbicide resistance in weeds e.g. *Phalaris minor* in the 1990s; growing menace of wild rice in many states and *Orobanche* in mustard-growing areas; invasion by alien weeds like *Parthenium, Lantana, Ageratum, Chromolaena,* Mikania in many parts of the country; impending climate change favouring more aggressive growth of weed species; and herbicide residue hazards. This indicates that weeds problems are dynamic in nature, requiring continuous monitoring and refinement of management strategies for alleviating their adverse effects on agricultural productivity and environmental health.

In view of the emerging concerns and challenges in agricultural production particularly with respect to weed infestation, the Directorate has reorganized its research and development programmes in the XII Plan starting from 2012-13. Focused and multi-disciplinary research programmes have been formulated to address these challenges and developing location-specific weed management strategies aimed at increasing productivity and input-use efficiency, while reducing costs and environmental hazards. The first research programme on *'Development of sustainable weed management practices in diversified cropping systems'* addresses 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. The second research programme on *'Weed dynamics and management in the context of climate change and herbicide resistance*' focuses on the effect of CO_2 and temperature on crop-weed associations, biochemical and physiological aspects of herbicide resistance development in weeds, and weed risk analysis and development of weed seed standards. Some weed species have assumed serious proportions in different parts of the country, and are causing havoc to agricultural production, biodiversity and environment. It has been proposed to launch the third research programme on *'Biology and management of problem weeds in cropped and non-cropped areas'* such as wild rice, *Ageratum, Cyperus, Phalaris, Echinochloa, Alternanthera,* and parasitic weeds like *Orobanche* in cropped lands; *Lantana, Parthenium, Chromolaena,* and *Mikania* in non-crop lands; and water hyacinth and Pistia in aquatic bodies. 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 effect on environment. Accordingly, the fourth research programme on environmental aspects of herbicides focuses on *'Monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment'*. An important programme in farmer participatory mode has been launched on *'On-farm research and demonstration of weed management technologies, and impact assessment,* in which all the scientists of the Directorate are involved. Each scientist is devoting 60-70% of his time for research work, and 15-20% time each for training / teaching and extension-oriented on-farm research.

The Directorate needs to expand its reach and show visibility and impact all over the country through effective collaborations, networks and partnerships with various agencies including international organizations. Besides strengthening the existing collaboration with 22 centres of AICRP on Weed Control, linkages with other SAUs and ICAR institutes, particularly those dealing with field / cash crops and horticultural crops have been established. Awareness programmes on the serious problem weeds such as the one on *Parthenium* have been organized in association with state department of agriculture and other agencies. The Directorate has also served as a nodal centre for training on weed management to different stakeholders.

All India Coordinated Research Project on Weed Control has focused on location-specific problems to generate technologies for improving productivity and resource-use efficiency. Major weed species of the states have been identified, and their biology and management investigated in greater depth. The areas infested with serious problem weeds like *Orobanche, Ageratum, Lantana, Phalaris,* wild rice, and an emerging invasive weed, *Ambrosia psilostachya* need special attention.

SFC document for XII plan of the Directorate has been prepared considering the emerging issues in Indian agriculture with respect to weed management, developing sound weed management strategies for meeting these challenges, effective collaboration and linkages with other institutions in order to increase the visibility and impact of our technologies, modernizing existing infrastructure of the building, laboratories and research farm.

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. Singh, former Deputy Director General (Natural Resource Management), ICAR and Dr. A.K. Sikka, Deputy Director General (NRM); Dr. J.C. Dagar, former Assistant Director General (Agronomy and Agroforestry) and Dr. B. Mohan Kumar, Assistant Director General (Agronomy and Agroforestry), ICAR for their kind consideration, generous support and critical inputs. I express my sincere gratitude to all the staff members of the Directorate for their help and cooperation.

This report presents the work done and activities organised at the Directorate during the period from April 2012 to March 2013. I shall appreciate comments and suggestions for further improvement and strengthening of our programmes.

Date : 30 May, 2013

(A.R. Sharma)

CONTENTS

विशिष्ट सारांश

o"k 2012&13 d nkjku fun'kky; u vul/kku d vrxr [kjirokj ic/ku gr viukb xb cg&vk;keh vul/kku dk;Øek d ek/;e l fofHkUUk 'kkdukf'k;k d mi;kx] mud yEc le; rd mi;kx dju d iHkko] 'kkdukf'k;k d iHkko c<ku ,o mudk Hkfe e vo'k"k lcf/kr vul/kku] Qlypd l [kjirokjk e cnyko] tyok; ifjoru dk Qly&[kjirokj ifrLi/kk] dhVk ,o to&'kkdukf'k;k }kjk [kjirokjk dk todh; fu;=.k vkfn 'kkkfey gA lkFk gh lkFk [kjirokjk dh of) rFkk fodkl ,o ikfjfLFkfrd&dkf;dh l lcf/kr vul/kku Hkh fd;k x;kA fun'kky; u bl lky Hkh xktj?kkl dk [kku oky efDldu chVy dk ij Hkkjr e iHkkoh rkj ij foLRkkj ,o forj.k tkjh j[kkA bld vykok] fun'kky; u mUur [kjirokj ic/ku rduhdk dk db fdlkuk d i{k=k ij ijh{k.k] in'ku] if'k{k.k ,o fdlku eyk vk;ftr fd, x;A

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- /kku&pu Qly pØ e [kjirokjk dk fu;f=r dju gr fclik;fjcd&lkfM;e dk mi;kx dju l ohMh pd dh ryuk e [kijrokjk d 'k"d inkFk ,o l[;k e Øe'k% 79 ,o 94 ifr'kr dh deh vkdh xb ,o 4-60 Vu@g- dh mit ikIr gbA tcfd fQukDlkiki + 2]4&Mh ekFkk dy d ik/kk dk fu;f=r dju e vi Hkkoh ik;k x;kA pu dh Qly e [kjirokjk d vfrde.k l mit e 86 ifr'kr dh deh vkdh xbA bUg fo'k"k #i l txyh tb dk fu;f=r dju gr Dohtykykjkt dk mi;kx gkFk l funkb d rY; ik;k x;kA ijUr ;g 'kkduk'kh iUMhfeFkkfyu dh vi{kk *Medicago hispida, Chenopodium album* ,o *Cichorium intybus* dk fu;f=r dju e vlQy jgkA
- dkcfud [kjirokj ic/ku d vrxr /kku&xg d Qly pØ dh xg dh Qly e] 50 ifr'kr xkcj dh [kkn + 50 ifr'kr u=tu] QkLQkjl ,o ikVk'k dk DykfMukQki 60 xk@g- + ,d funkb d lkFk nu l 60 fnu ij [kijrokjk d 'k"d inkFk ,o l[;k e vFki.k deh ikb xb vkj 4-84 Vu@g- dh mit ikIr gbA /kku e] u=tu] QkLQkjl ,o ikVk'k d lkFk 'kkduk'kh dk mi;kx dju l mit ohMh pd ¼1-48 Vu@g-½ dh vi{kk 3-26 Vu ifr g- ikIr gbA
- VekVj dh Qly e xkcj dh [kkn d lkFk dkyh ikyhFkhu dk mi;kx dju l [kjirokjk dh l[;k ,o mud 'k"d inkFk e iHkkoh deh nt dh xb rFkk VekVj dh mit ohMh pd ¼2-59 Vu@g-½ dh ryuk e vf/kd ¼23-9 Vu@g-½ ikIr gbA ogh fHk.Mh dh Qly e mDr mipkj d lkFk 2 funkb dju l [kjirokjk dk iHkkoh fu;=.k ikIr gvk rFkk ohMh pd dh vi{kk rhu xuk T;knk mit ikIr gbA
- lk;kchu e] befthFkkik;j dk vdj.k i'pkr 'kkdukf'k;k d lkFk ,o Dykjhejku dk mi;kx dju l ok vkj ekFkk dk 60 fnu ij iHkkoh fu;=.k d lkFk funkb dh vi{kk vf/kd mit ikIr gbA befthFkkik;j vkj bektkekDl d feJ.k dh 60 xk@g- ek=k dk mi;kx dju l Hkh [kjirokjk dk iHkkoh fu;=.k nt gvkA
- /kku dh Qly e iUMhfeFkkfyu dh 1000 xk@g- dh nj l cokb d lk'pkr fdUr vdj.k io rFkk fclik;jhcd 25 xk@g- dh ek=k vFkok ,d funkb cokb d 25 fnu ckn mi;kx dju l [kjirokjk dk l[;k e deh ,o mit e vFki.k c<kRrjh nt dh xbA
- Pku dh Qly e iUMhfeFkkfyu d 38-7 ifr'kr lh- ,l- fu#i.k dh 700 xk@g- dh nj l vdj.k io ,o befthFkkik;j dh 75 xk@g- d mi;kx l mit e vFki.k c<kRrjh nt dh xbA
- ykdh dh Qly e [kjirokj l yxHkx 40 ifr'kr rd dk mit e udlku nt fd;k x;kA bud iHkkoh fu;=.k gr gykslYQ;jku d 120 xk@g- vFkok iUMhfeFkkfyu d 700 xk@g- dh nj l mi;kx l [kjirokjk d lkFk&lkFk ekFkk dk Hkh iHkkoh fu;=.k n[kk x;k vkj mit e vFki.k 40 ifr'kr rd dh c<kRrjh nt dh xbA
- ,d vU; ijh{k.k e ik;k x;k fd /kku e lok d 15 ik/k ifr oxehVj d ?kuRo l /kku dh mit e 40 ifr'kr rd dk mit e udlku nt fd;k x;kA tcfd lk;kchu e ;g udlku mlh [kjirokj d 20 ik/k ifr oxehVj d ?kuRo gku l Hkh 18 ifr'kr udlku nt fd;k x;kA xg e Qyfjl d 75 ik/k ifr oxehVj e ;g udlku 10 ifr'kr jgkA blh Qly e txyh tb ¼15 ik/k@ox ehVj½ l ;g udlku 37 ifr'kr nt fd;k x;kA

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- mPp dkcZu MkbZvkWDlkbM lkanzrk ij mxk;s x;s xktj?kkl dh ifRr;ksa ls izkIr vo'ks"k (allelochemical crude extract) dk iz;ksx 'kkduk'kh ds :i esa tyh; [kjirokjksa (Eichhornia crassipes, Pistia stratiotes, Azolla pinnata, Spirodela pollyrrhiza) ij djus ls irk pyk fd mPp dkcZu MkbZvkWDlkbM ds dkj.k 'kkduk'kh {kerk ij dksbZ vlj ugha iM+rkA
- blds vfrfjDr ;g Hkh irk pyk fd xktj?kkl dh ifRr;ksa esa ik;s tkus okys e[; 'kkduk'kh rRo fQukWfydl ,oa Vjfiuk;MIl dh ek=k lkekU; dh vis{kk mPp dkcZu MkbZvkWDlkbM ij mxk;s x;s ikS/kksa esa vf/kd gSA
- mPp dkcZu MkbZvkWDlkbM lkanzrk ij xktj?kkl dh c<+okj lkekU; dkcZu MkbZvkWDlkbM lkanzrk dh vis{kk vf/kd gksrh gSA
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- yUVkuk dh ifRr;ksa ls izkIr ?kksy (allelochemical crude extract) 0-50 izfr'kr dh lkanzrk esa /kku vkSj 0-25 izfr'kr lkanzrk esa gkbfMyk ds fy, ?kkrd ik;k x;kA
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- ,d ,sls ifjj{kd (preservative) dk fodkl fd;k tk jgk gS tks QQwanh ,oa [kjirokjksa ds chtksa dks lkekU; rkieku ij 20 o"kZ ls Hkh vf/kd le; rd lqjf{kr j[k ldrk gSA

QQwanh; ,oa xSj&QQwanh; {ks=ksa esa TkfVy [kjirokj dk tSofoKku ,oa iz.c/ku

- [kjirokj :ih /kku ds 112 leLrjksa ds fofHkUu y{k.kksa dk v/;;u djus ij mUgsa vkil esa fofHkUurk ikbZ xbZA /kku cksus ds 60 fnu ckn mud ok"iksRltu vkSj iRrh ds rkieku esa mYys[kuh; vUrj ik;k x;kA /kku ds 112 leLrjksa ds rkM+ ¼vkuqokaf'kd fujh{k.k djus ij½ 68 leLrjksa ds jax vkSj yEckbZ esa fofHkUu izdkj ds vrj ik;s x;sA
- Xokfy;j vkSj Hkjriqj esa ^vkjkcdh^ ¼xfM;k] xtk] Bkdj] HkbZQkM½ ls xfBr feVVh ds uewuksa esa VkbZdkMjek] ¶;qlsfj;e] ikbfFk;e] ifufl;e ,oa ,lijftyl uke dh QQwan ikbZ xbZ bu QQwanksa ls dkf'kdk fofgu lRr ds lo/kZu ds fy, vkSj 'kdjk vkSj vEy MDVkl ds 'kkjc esa QQwanh dk vPNk fodkl gqvkA
- vkjkcdh ds ik"kZ ik/k ¼ljlksa½ ds vdqj.k vkSj lØe.k dk v/;;u djus ij Kkr gqvk fd vdqj.k ds fy, 2&3 eghus dh vudqyu vof/k dh vko';drk iM+rh gSA HkbZQkM dk ljlksa ds cksus ds 40&50 fnu ckn vdqj.k gksrk gSA nks ljlksa ds ik/kksa ls vf/kdre HkbZQkM ds uks ik/kksa dk vdqj.k gksrk ik;k x;kA xeyk esa v/;;u ds nkjku ;g Hkh ik;k x;k fd HkbZQkM dk vdqj.k lHkh xeyk esa ,d leku u gksdj fofHkUu izdkj gqvkA
- ljlksa dh ^jkguh^ vkSj ^,u-vkj-lh-Mh-vkj- 2^ uke dh iztkfr;k¡ HkbZQkM ds izfr lonsu'khy ikbZ xbZA
- lo{k.kksa ls Kkr gqvk fd NRrhlx<+ jkT; ds taxyksa ij fty esa Chromolaena odorata uke dk [kjirokj cgqrk;r ls viuk ij iSlkj jgk gSA tcfd ,d n'kd igys ogk¡ bls [kjirokj dk ukekfu'kku rd u FkkA FkkM ls le; esa gh bl [kjirokj dk Qyko ogk¡ ds taxyksa] lM+d ds fdukjs] lkenkf;d vkSj catj Hkwfe esa gks x;k gSA taxyksa ij ls jk;ij tkus okys jk"Vªh; ekxZ ij ;g fiNys o"kksZa esa rsth ls QSyk gSA bl [kjirokj ds tSodh; fu;=.k ds fy; uoEcj 2011 esa yxHkx 3000 xkWB cukus okys dhV dks ogk¡ NksM+ x;s ij vHkh rd bl dhV dh ogk¡ ij of) ugha ns[kh xbZA
- tcyiqj vkSj vkl&ikl rkykcksa ds lo{k.k djus ij xzh"e rkykc esa tyxzkHkh ;k tyh; lykn (Pistia strateotis) dk Hkh"k.k izdksi ik;k x;kA bl tyh; [kjirokj u rkykc dk iwjh rjg ls <d fy;kA tcyiqj esa blh izdkj ds tyh; [kjirokj dk ;g igyk vkØe.k ekuk tk jgk gSA

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- dkjQUVk tku jlk;u dh xg dh Qly dh feVVh e 90 fnuk d i'pkr 0-001 µg/g ek=k nt dh xbA
- [kjhQ d ekl e e ihfVykDykj] ikbj tkl Y¶;jku ,o fiukDl ye 'kkdukf'k;k dh /kku dh Qly e fNMdko d ckn ; jlk;u o"kk ty d lkFk cgdj ikl d ikuh d Vd e py x; ftl l jlk;uk dh fo"kkDrrk d dkj.k db eNfy;k dh eR; gk xbA eNfy;k e ihfVykDykj dh ek=k 0-063 ,o 0-010 µg/g 30 ,o 60 fnuk d lk'pkr ikb xb] ,o 60 fnuk d i'pkr ikbj tkl Y¶;jku vo'k"kk dh ek=k fu/kkj.k ek=k 0-001 µg/g l de ikb xbA
- enk e ikb tku okyh QQnk t l fd ,lijftyl ¶yol ,o ,lijftyl ukbtj] iuhlhfy;e d;ktue ,o vYVjufj;k vYVjuVk dh 'kkduk'kh jlk;uk tl fd ikbj tkl Y¶;jku ,o ihukDlye dh enk e vi?kVu dh {kerk dk v/; ;u fd;k x;kA v/; ;u d nkjku ;g ik;k x;k fd ,lijftyl ¶yol ,o ,lijftyl ukbtj ihukDlye dk /kku dh Qly dh enk e vPN l vi?kfVr dj ldr g, ,o vi?kVu dh ifd;k }kjk bu jlk;uk dk db fo'yf"kr@:ikUrfjr ljy inkFkk e vi?kfVr dj nr gA tcfd iuhlhfy;e Ø;ktue dh ikbj tkl Y¶;jku dk :ikUrfjr ifØ;k }kjk ljy vi?kfVr inkFkk e cnyu dh {kerk Øe'k% ,lijftyl ukbtj] ,o vYVjufj;k vYVjuVk l vf/kd gA ftld dkj.k iuhlhfy;e d;ktue lYQkukby&;fj;k fct dk rkMdj budk mi;kx Åtk d L=kr d :i e djr g ,o vi?kfVr inkFkk dk fQj l vi?kVu djd db :ikUrfjr ,o vi?kfVr inkFk cukr g] ,o bu vi?kfVr inkFkk dk mi;kx iu% Åtk d L=kr d :i e djrk gA
- feVVh ,o lhlk d Åij lYQklY¶;jku dk l; d vYVkok;yV fofdj.k }kjk fo'y"k.k ,o fo'yf"kr fd;k x;k ,o fo'yf"kr inkFk dk dkye dkeVkxkQh vkj Vh-,y-lh- }kjk iFkd djd ,y-lh-,e-,l-@,e-,l- }kjk fu/kkj.k fd;k x;k ,o ik;k x;k fd lYQklY¶;jku dk fo'y"k.k lYQkukby&;fj;k fct foHkktu ,o lYQkukby ,ekbM c/ku foHkktu }kjk gkrk gA
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EXECUTIVE SUMMARY

Directorate has achieved its targets during 2012-13 in research and transfer of technology. The major research areas were 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. The programme on popularization of biocontrol of Parthenium through Mexican beetle was continued throughout the country. In addition, collaboration was made with ICAR institutes and SAUs to contain location-specific weed problems and develop effective linkages. Several on-farm trials and field demonstrations were taken up on weed management technologies, besides awareness campaigns, trainings, and Kisan Mela to educate farmers and end-users.

Major research achievements are summarized below:

Development of sustainable weed management practices in diversified cropping systems

- In rice-wheat cropping system, presence of weeds throughout growing season caused 44% reduction in grain yield in rice. Application of bispyribac-sodium @ 25 g/ha significantly reduced the population of *Echinochloa colona* (90%), *Cyperus iria* (97%), *Commelina communis* (98%) and *Caesulia axillaris* (58%) over weedy check and recorded 28% higher effective tillers/m row length and 44% higher grain yield over weedy check. In wheat, application of clodinafop + 2,4-D caused significant reduction in *Avena sterilis*, *Phalaris minor* and *Physalis minima*, whereas the lowest populations of *Cichorium intybus*, *Medicago hispida* and *Chenopodium album* were recorded with sulfosulfuron.
- In rice-chickpea cropping system, application of bispyribac-sodium in rice caused significant reduction in weed density and weed biomass by 79 and 94% over weedy check, respectively. However, application of fenoxaprop + 2,4-D failed to reduce the population of *Cyperus iria*. Maximum number of effective tillers/m row (51), grain weight/panicle (3.7 g) and grain yield (4.60 t/ha) were recorded with bispyribac-sodium. In chickpea, presence of weeds throughout the growing season caused 86% reduction in seed yield. Application of quizalofop acted similarly as hand weeding, causing significant reduction in density of *Avena sterilis* over weedy check. However, it failed to check emergence of *M. hispida*, *C. album* and *C. intybus* compared to pendimethalin and oxyfluorfen. Significantly lower population of *M. hispida*, *C. album* and *C. intybus* was recorded with pendimethalin and oxyfluorfen.
- Stand establishment techniques in direct-seeded rice did not influence total weed population and weed dry biomass at 60 DAS. However, significantly lower weed dry biomass production was recorded with transplanted rice, which produced higher grain yield.
- In rice–wheat cropping system, application of 50% FYM + 50% NPK along with clodinafop @ 60 g/ha *fb* one manual weeding significantly reduced the weed density and weed dry biomass at 60 DAT in wheat. Wheat grain yield was significantly higher (4.84 t/ha) under NPK + herbicide. In rice, grain yield was the highest under NPK + herbicide (3.26 t/ha), followed by that under FYM @ 10 t/ha + Sesbania incorporation at 30 DAS (2.79 t/ha) and 50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS (2.61 t/ha).
- In okra-tomato cropping system, in tomato, the lowest weed density and biomass were recorded under FYM + black polythene mulch. The highest tomato yield was also recorded under FYM with black polythene mulch (23.9 t/ha) as compared to control (2.59 t/ha). In okra, the lowest weed density and biomass were recorded under FYM + black polythene mulch *fb* FYM + 2 manual weeding. The highest pod yield of okra was

recorded under FYM + black polythene (13.84 t/ha), which was about 3 times more than control (3.84 t/ha).

- In soybean, application of imazethapyr in combination with pre-emergence (PE) herbicides and sole application of chlorimuron-ethyl effectively reduced the biomass of *Echinochloa colona* and *Cyperus rotundus* at 60 DAS and produced maximum seed yield (1.54 t/ha) which was at par to two manual weeding (1.69 t/ha) and metribuzin (PE) @ 500 g/ha *fb* imazethapyr @ 100 g/ha (1.47 t/ha). Combination of imazethapyr + imazamox @ 60 g/ha proved more effective in decreasing weed population and weed biomass than other treatments. The per cent increase in seed yield in weed-free and under the treatment of imazethapyr + imazamox was 518 and 497%, respectively.
- In direct-seeded rice, application of pendimethalin @ 1.0 kg/ha, followed by bispyribac-sodium at 25 g/ha or manual weeding at 25 DAS caused reduction of weed density and dry weight and produced the highest grain yield at par with 3 hand weedings.
- In chickpea, the highest seed yield was recorded in pendimethalin 38.7% CS @ 700 g/ha, followed imazethapyr. Post-emergence application of imazethapyr @ 75 g/ha caused slight injury to chickpea but the crop recovered subsequently.
- In bottle gourd, weeds caused 40% fruit yield reduction. Application of halosulfuron @ 120 g/ha and pendimethalin @ 700 g/ha reduced the overall weed population and population of *Cyperus iria* to a greater extent. The yield obtained with pendimethalin @ 700 g/ha was 40% more than unweeded control.
- In rice, critical density (15 plants/m^2) of *Echinochloa* caused significant reduction in plant growth and its parameters which reduced the grain yield of rice by 40%. In case of soybean, presence of the same weed i.e. *Echinochloa* with critical density of 20 plants/ m^2 caused significant reduction in seed yield (18.4%). In wheat, *Phalaris minor* (75/m^2) caused significant reduction in grain yield by 10%. On the other hand, a critical density of *Avena ludoviciana* even at 15/m^2 caused significant reduction in grain yield by 36.9%.

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

- Research has shown that weed problems would become more intense due to vulnerability to global climate changes. Differential response of plants to changing climatic factors would make weed management a more complex preposition.
- Enrichment of atmospheric CO_2 had a positive effect on overall growth of greengram plants as well as weed species. Promotion in growth at elevated CO_2 could be attributed to higher dry matter accumulation in above-ground parts. Increase in dry matter accumulation at elevated CO_2 was 19.5% in greengram, 90.8% in *Brachiaria reptans* and 75.6% *Eragrostis diarrhena* as compared to that at ambient CO_2. Rate of photosynthesis and instantaneous water-use efficiency increased, while stomatal conductance and rate of transpiration decreased in greengram, *Brachiaria reptans* and *Eragrostis diarrhena* at elevated CO_2 as compared to that at ambient CO_2.
- Fate of phytotoxic secondary metabolites (including allelochemicals) in *Parthenium hysterophorus* leaves was studied under elevated CO_2. *Parthenium* leaves were sampled from its stands grown at ambient and elevated CO_2 (550 ± 50 ppm). Leaf residues were evaluated for herbicidal activity on five floating weeds, viz. *Eichhornia crassipes*, *Pistia stratiotes*, *Azolla pinnata*, *Spirodela polyrrhiza* and *Lemna pausicostata;* and four submerged weeds, viz. *Hydrilla verticillata*, *Ceratophylum demersum*, *Najas graminea* and *Potamogeton crispus*. Results showed almost similar phytotoxicity in the leaf residues obtained from plants grown in both the CO_2 regimes.
- *Parthenium* leaves are known to have phytotoxicity on floating and submerged aquatic weeds, have phenolics (mostly water soluble) and terpenoids (water insoluble) as major phytotoxic constituents. Leaves of plants grown under elevated CO_2 had much higher (5.5% w/w)

phenolics than those grown at ambient CO_2 (3.4% w / w).

- Elevated CO_2 enhanced growth of Parthenium hysterophorus. There was higher defoliation by beetles coupled with reduction in plant height as compared to control after 25 days of exposure.
- *Parthenium* leaf allelochemical crude was lethal to rice as well as to aquatic weeds, viz. floating weed *Pistia stratiotes* and submerged aquatic weeds *Hydrilla verticillata* and *Ceratophylum demersum* at and above 0.1% (w / v).
- *Lantana* leaf allelochemical crude was lethal to rice seedlings at and above 0.5%, whereas Pistia stratiotes, though inhibited, was not killed by it even up to 1%. However, *Hydrilla verticillata* and *Ceratophylum demersum* were killed at and above 0.25%.
- *Solanum viarum* leaf allelochemical was lethal to rice seedlings and submerged aquatic weed *Hydrilla verticillata* at and above 0.1%, to *Ceratophylum demersum* at and above 0.25%, and to *Pistia stratiotes* at and above 0.5%. *Solanum viarum* seed allelochemical crude was lethal to rice and submerged aquatic weeds at and above 0.1%. However, it was lethal to *Pistia stratiotes* at and above 0.25%.
- A preservative has been developed to extend the longevity of crop and weed seeds by more than two decades at ambient temperature.

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

- Characterization of 112 weedy rice accessions revealed significant morphological variation amongst them and with control at both 45 and 60 DAS. Significant variation was observed in transpiration and leaf-air temperature difference at 60 DAS among weedy rice accessions and with control. Sixty-eight of 111 accessions were awned with varying color and length of awn. Awn length was found to vary between 0.8 cm and 7.8 cm.
- *Trichoderma* sp., *Fusarium* sp., *Pythium* sp., *Penicillium* sp. and *Aspergillus* sp. infested with *Orobanche* were identified from the soil samples collected from in and around Gwalior and Bharatpur. For extracting cell-free culture extracts from the microbes, PD and PS broths were found to give more robust growth of the fungi.
- Studies on germination of *Orobanche* and process of infection and estimation of systemic resistance in the host plant (mustard) showed that *Orobanche* required a conditioning period of 2-3 months in the pots kept in the containment chamber. *Orobanche* emergence was recorded after 40-45 DAS of mustard and a maximum number of 9 flowering stalks per pot of two mustard plants were recorded. *Orobanche* germination was very erratic, and there was no emergence in many of the treatments.
- *Chromolaena odorata*, a problematic weed of Western Ghats, Karnataka and Tamil Nadu was not found in Baster area of Chhattisgarh about a decade back. However, in a short span, it has invaded large areas of forest, community and waste lands in and around Jagdalpur. This weed is spreading fast on road sides from Jagdalpur to Raipur. To manage this weed using biological means, about 3000 galls infested with gall fly (*Cecidocharus connexa*) were collected from Bengaluru and released during November 2011. So far, bioagent has not established in the released area.
- During survey in and around Jabalpur, severe infestation of *Pistia stratiotes* was recorded in 'Gulaua pond'. The weed covered the pond completely. This invasion was considered first time in the Jabalpur at such large scale.

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

- Persistence of herbicides in soil and water, and their effect on non-target organisms was evaluated in rice-based cropping system. Penoxsulam, pyrazosulfuron-ethyl and pretilachlor was applied at 25, 25 and 750 g / ha in rice crop. Initially, 0.0595 and 0.714 µg / g residues of pyrazosulfuron-ethyl and pretilachlor were found in rice soil, which dissipated to 0.0103 and 0.017 µg / g at 30 days. At 90 days, the residues of pyrazosulfuron-ethyl and pretilachlor were <0.001 and 0.003 µg/g in soil. Half-life of pyrazosulfuron-ethyl and pretilachlor was found to be 8.02 and 13.08 days. In wheat, carfentrazone residues were dissipated to 0.001 µg/g after 90 days.

- Fish mortality and toxicity symptoms were recorded initially in the pond where herbicides entered through runoff water in rainy season. Residues of pretilachlor, 0.063 and 0.010 µg/g were found in fishes at 30 and 60 days; and 0.0056 µg/g pyrazosulfuron-ethyl residues were found in fishes at 30 days, while residues were below detection limit (<0.001 µg/g) at 60 days.

- *Aspergillus flavus* and *A. niger* were found more effective to degrade penoxsulam, resulting in more number of degradation products. *Penicillium chrysogenum* was found to be more effective to degrade pyrazosulfuron-ethyl in the soil as compared to *A. niger* and *Alternaria alternata* by the cleavage of sulfonylurea bridge, resulting in formation of two major metabolites which further cleaved to several minor products.

- Sulfosulfuron was irradiated on soil and innert glass surface, and the generated photoproducts were isolated by column chromatography and preparative TLC. The structure of the products was elucidated by mass spectrum from LC-MS/MS. A similar experiment was carried out on glass surface. In both cases, the routes of degradation were the cleavage of sulfonyl-urea bridge and the cleavage of sulphonamide linkage.

- *Trichoderma viride* and *Cladosporium herbarum* were identified as sulfosulfuron degrading fungi from soil and the degradation products from media and soil were: 2-amino-4,6-dimethoxypyrimidine, 2-ethylsulfonyl imidazo {1,2-a}pyridine-3-sulfonamide, N-(4,6-dimethoxypyrimidin-2-yl)urea, N-(4,6-dimethoxypyrimidin-2-yl)-N'-hydroxyurea and N, N'-bis(4,6-dimethoxypyrimidin-2-yl)urea.

- *Mucor piriformis* and *Aspergillus flavus* were identified as sulfosulfuron degrading fungi from irrigation water, and the degradation products from media and irrigation water were: 2-amino-4,6-dimethoxypyrimidine, 2-ethylsulfonyl imidazo{1,2-a}pyridine-3-sulfonamide, N-(4,6-dimethoxypyrimidin-2-yl)urea, N-(4,6-dimethoxypyrimidin-2-yl)-N'-hydroxyurea, N, N'-bis(4,6-dimethoxypyrimidin-2-yl)urea and N-(4,6-dimethoxypyrimidin)- N'-(4-hydroxy-6-methoxypyrimidin-2-yl)urea.

- Humic acid imparted quenching effect to protect pretilachlor from sunlight. Pretilachlor itself could absorb UV-fraction of sunlight undergoing phototransformation. But the polymers of humic acid in its vicinity acted as sunscreen for pretilachlor. Presence of humic acid favoured the cleavage of amide linkage of acetanilide group. Products were formed due to deacylation, dechlorination, cleavage of ether linkage, hydroxylation on N-ether chain, and C-C bond cleavage.

- *Arundo*-based wetland system showed its usefulness for removal of heavy metals (Cd and Pb) from industrial drain water prior to irrigation use. Reduction of nitrate in treated water has implications for protection of pond water quality where aquaculture is practiced. There was drastic change in the colour of treated water after its treatment as compared to untreated waste water.

- Higher Pb content was recorded in shoots of *Arundo donax* (104.8 mg/kg), followed by *Vetiveria zizinoides* (56.8 mg/kg), *Typha latifolia* (38.3 mg/kg) and *Acorus colamus* (20.9 mg/kg). Higher Pb transfer factor (from root to shoot) was observed in case of *Vetiveria zizinoides* (2.22). At the higher levels (200-400 ppm), most of Pb accumulation by *Arundo donax* and *Typha latifiolia* and *Acorus calamus* was retained in their roots.

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

- In wheat, 35 demonstrations were laid out on farmers' fields in three locations (Panagar, Sihora and Patan) around Jabalpur on post-emergence application of clodinafop @ 60 g + metsulfuron @ 4 g/ha, mesosulfuron + iodosulfuron @ 18 g/ha, clodinafop @ 60 g/ha, sulfosulfuron + metsulfuron @ 32 g/ha in wheat crop. Application of mesosulfuron + iodosulfuron and clodinafop + metsulfuron gave broad-spectrum weed control and additional benefit of ` 13,500 per ha.

- In chickpea (Mahangwa, Padariya and Bharda villages) and mustard (Tagar, Mahangwa and Umariya villages), 10 demonstrations (5 each) were conducted on pre-emergence application of pendimethalin (stomp-xtra) @ 800 g/ha and mechanical weeding (hoeing) at 30 DAS. Pendimethalin effectively controlled weeds and gave higher weed control efficiency (WCE 59%) with additional benefit of ` 10,530 and ` 11,415 per ha, respectively.

- A programme was initiated from rainy season 2012 to transfer as well as to evaluate the improved weed management technologies at the farmers' field in and around Jabalpur district. The aim of this programme was to enhance adoption level of weed management technologies with simultaneous increase in productivity as well as improvement in the socio-economic conditions of the farmers in a sustainable manner.

- Six localities (Majholi, Bankhedi, Panagar, Shahpura, Gosalpur and Kundam) with no technical knowhow in terms of existing weed management practices were selected and subsequently 7-8 farmers representing all section of farmers were selected randomly in each locality. OFR/demonstration using improved weed management technologies were laid out in rice, soybean and maize during rainy season.

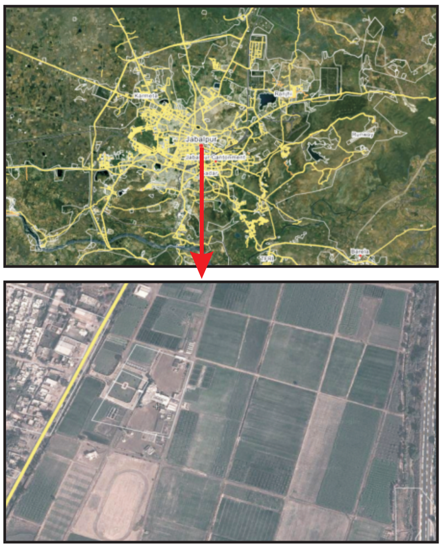
- In rice, 35 demonstrations (Bhamki, Kisrod villages of Shahpura locality, Amna, Bankhedi and Paudi villages of Gosalpur and Mahangwa, Baher of Panagar locality) were carried out in direct-seeded rice on bisbyribac-sodium alone or followed by chlorimuron + metsulfuron / 2,4-D, and bensulfuron + pretilachlor. Results showed that in *Echinochloa colona* dominated areas, bisbyribac-sodium should be used. In areas where there was infestation of broadleaved weeds also along with *Echinochloa colona*, application of chlorimuron + metsulfuron/2,4-D should be applied one week after bisbyribac-sodium.

- In soybean (Pola and Dhora villages of Majholi locality), 12 demonstrations were undertaken. Application of imazethapyr gave broad-spectrum weed control and higher benefit of ` 11,400 per ha.

- In maize (Khukham, Ranipur and Padaria villages of Kundam locality), 8 on-farm evaluation and demonstrations were conducted. Pre-emergence application of atrazine @ 1.0 kg/ha followed by one hand weeding at 30 DAS was most effective, and gave additional benefit of ` 13,126 per ha.

1. INTRODUCTION

Considering the problem of weeds and need for weed science research in India, a Coordinated Weed Control Scheme on wheat, rice and sugarcane was initiated as early as 1952 in 11 states of the country by the ICAR to monitor the weed flora and also to find out the relative feasibility of economic weed control. In 1978 the weed research programmes were strengthened through the All India Coordinated Research Project on Weed Control by the ICAR in collaboration with the United States of Agriculture. This project assisted farming community through the scientific technologies developed, which are effectively utilized for alleviating the yield losses due to weeds in field crops. National Research Centre for Weed Science was established in 1989 at Jabalpur for carrying out basic as well as applied research in weed science. The centre was upgraded to Directorate of Weed Science Research in 2009. The work under the AICRP on Weed Control which is operating at 22 centres all over the country is also coordinated by the DWSR.



DWSR Campus, Jabalpur

Jabalpur is located in the centre of India, and falls under the agroclimatic region of Kymore plateau and Satpura hills zone. The climate of the region is sub-tropical, with average annual rainfall of 1380 mm. The soil are mostly black and the crops grown are rice, soybean, sugarcane, pigeonpea and blackgram during rainy season, and wheat, chickpea, lentil, peas and mustard in the winter season. DWSR is located at 23.13^{0}N latitude, 79.58^{0}E longitude at an altitude of 390 m above mean sea level. It is about 11 km from railway station and 28 km from Dumna airport on the national highway (NH-7) on one side and Jabalpur-New Delhi railway line on the other side. It is an ideal place for weed management research as diversified crops and weed species are encountered throughout the year.

The Directorate is engaged in developing and disseminating improved weed management technologies for enhancing agricultural productivity. The DWSR is unique institution of its own kind where all the aspects of weed management are taken care of in a holistic manner using multi-disciplinary approach. The Directorate has contributed significantly in identifying major weeds in different crops and non-cropped situations; weed competitive crop cultivars and weed smothering intercrops; developing national database on weeds; evaluating new herbicides and making herbicide recommendations; assessing impact of herbicides and their residues in environment; improving non-chemical methods of weed control; and transferring improved weed management technologies to the end-users. The future challenges are to address the issues relating to management of weeds in rainfed and dryland ecosystems, threat posed by alien invasive weeds, parasitic weeds like *Orobanche*, aquatic weeds, weed dynamics due to climate change and conservation agriculture, herbicide residues and their mitigation.

Vision

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

Mission

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

Mandate

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

- To provide leadership and coordinate the network research with state agricultural universities for generating location-specific technologies for weed management in different crops, cropping and farming systems
- To act as a repository of information in weed science
- To act as a centre for training on research methodologies in the area of weed science and weed management
- To collaborate with national and international agencies in achieving the above-mentioned goals
- To provide consultancy on matters related to weed science

Organization and Management

The Directorate is headed by its 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 AICRP on Weed Control centres, 4 administrative sections, and about one dozen other units and cells (Organogram).

Laboratories

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

Free Air CO_2 Enrichment (FACE) facility and three open top chambers are there for studies on crop-weed competition vis-à-vis climate change. The research outcome of these facilities provides information about the possible impact of anticipated global warming on weed menace in crops.

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

AKM Unit and Library

Agriculture Knowledge Management (AKM) unit is well equipped with computers, VSAT and LAN facilities, colour photocopier-cum-printer and A-0

plotter. Specialized softwares for GIS analysis, satellite image analysis and routine data analysis are available. All the scientists are provided with internet facility.

The library is having a total collection of 2942 books pertaining to weed science and related subjects, modern facilities, such as CAB-PEST and CAB-SAC CD-ROMs and Current Contents on Diskette (CCOD) on biological sciences. The library subscribes 70 Indian and 20 foreign journals. The DWSR library is also a member of Consortium for e-Resources in Agriculture (CeRA) under NAIP (ICAR). All the scientists have online access to more than 2000 e-journals in various fields of science. Reprographic and documentation facilities have been created for the preparation of documents and reports.

Networking and Collaboration

Directorate carries out various network programmes through All India Coordinated Research Project on Weed Control (AICRP-WC) which has 22 centres at agricultural universities located in different agro-climatic zones of the country. There are 9 additional centres in other agricultural universities participating voluntarily in the network programme. 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 in the area of dissertation work.

It has active collaboration with several ICAR Institutes and other research organizations. Besides, a healthy interaction exists with 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 the same in the field of weed management and to avoid duplication of research in weed management.

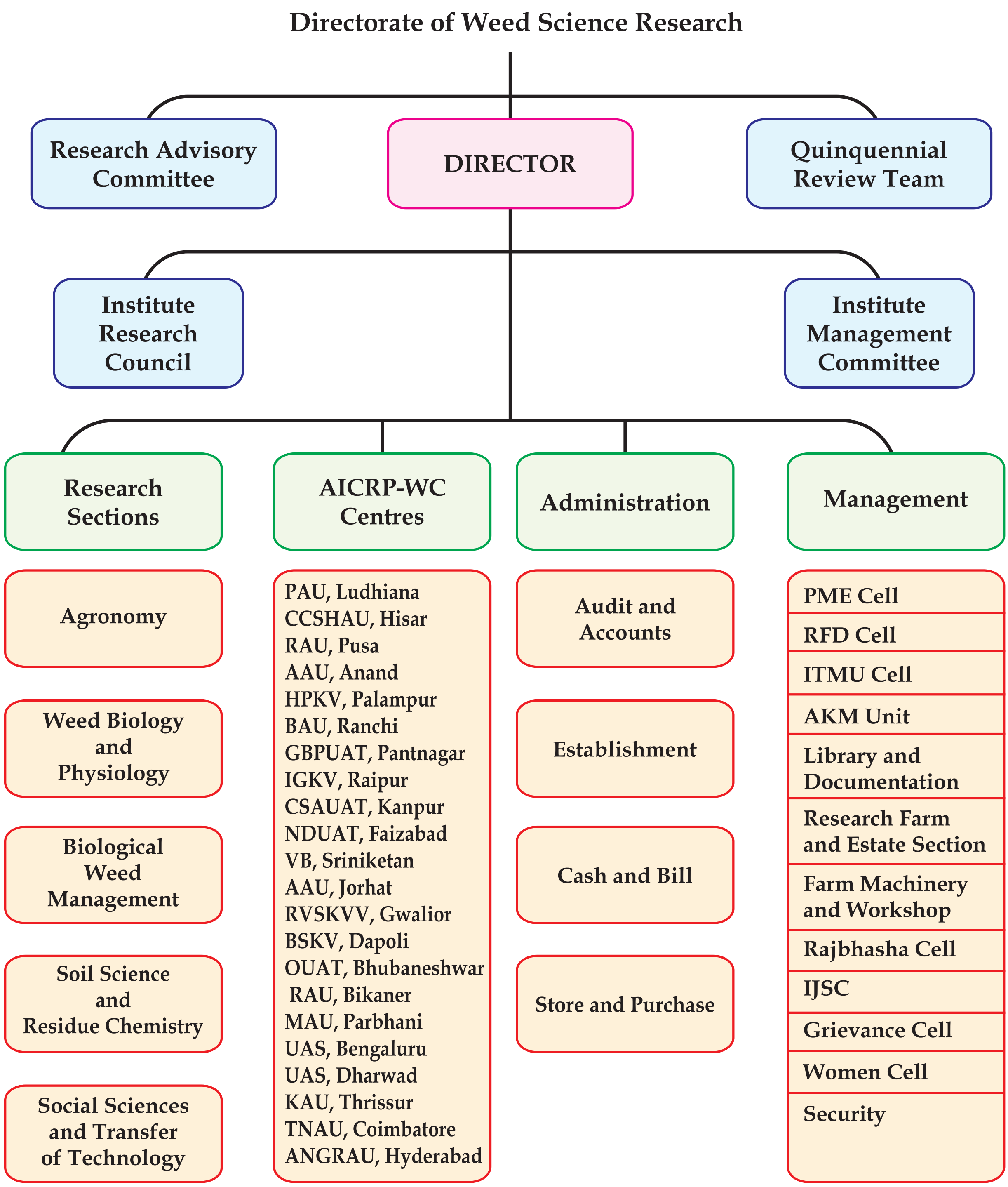
Farm and Glass house/Net house facilities

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

Budget during 2012-13 (₹ in lakhs)

Particulars	Plan		Non-Plan		AICRP - Weed Control	
	Receipt	Expenditure	Receipt	Expenditure	Receipt	Expenditure
(A) Recurring						
Establishment expenses	-	-	476.00	451.51	884.97	884.97
Pension	-	-	13.80	13.80	-	-
P-Loan and advances	-	-	8.00	4.60	-	-
Travelling allowances	4.00	4.00	9.00	7.01	14.18	13.52
HRD/IT	4.00	3.92	-	-	37.97	37.97
Research and operational expenses	46.00	45.98	44.00	44.00	52.88	52.88
Administrative expenses	32.00	31.84	90.30	82.45	-	-
Miscellaneous expenses	10.00	7.59	8.21	6.00	-	-
Tribal Sub-Plan	-	-	-	-	50.00	50.00
Total (A)	**96.00**	**93.33**	**649.31**	**609.37**	**1040.00**	**1039.34**
(B) Non-Recurring						
Equipment	17.15	16.92	2.00	1.64	-	-
Works	6.85	6.06	-	-	-	-
Library	5.00	5.00	-	-	-	-
Land	-	-	-	-	-	-
Vehicle	-	-	-	-	-	-
Livestock	-	-	-	-	-	-
Others	-	-	-	-	-	-
Total (B)	**29.00**	**27.98**	**2.00**	**1.64**	**-**	**-**
Grand total (A+B)	**125.00**	**121.31**	**651.31**	**611.01**	**-**	**-**

ORGANOGRAM



Directorate of Weed Science Research
Research Advisory Committee
DIRECTOR
Quinquennial Review Team
Institute Research Council
Institute Management Committee
Research Sections
AICRP-WC Centres
Administration
Management
Agronomy
Weed Biology and Physiology
Biological Weed Management
Soil Science and Residue Chemistry
Social Sciences and Transfer of Technology
PAU, Ludhiana
CCSHAU, Hisar
RAU, Pusa
AAU, Anand
HPKV, Palampur
BAU, Ranchi
GBPUAT, Pantnagar
IGKV, Raipur
CSAUAT, Kanpur
NDUAT, Faizabad
VB, Sriniketan
AAU, Jorhat
RVSKVV, Gwalior
BSKV, Dapoli
OUAT, Bhubaneshwar
RAU, Bikaner
MAU, Parbhani
UAS, Bengaluru
UAS, Dharwad
KAU, Thrissur
TNAU, Coimbatore
ANGRAU, Hyderabad
Audit and Accounts
Establishment
Cash and Bill
Store and Purchase
PME Cell
RFD Cell
ITMU Cell
AKM Unit
Library and Documentation
Research Farm and Estate Section
Farm Machinery and Workshop
Rajbhasha Cell
IJSC
Grievance Cell
Women Cell
Security

Staff Position (as on 31.3.2013)

Particulars	Sanctioned	Filled	Vacant
Research management position	1	1	-
Scientist	27	18	9
Technical	24	23	1
Administrative	12	08	4
Supporting	23	23	-

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	-	-	-	-
Agricultural Microbiology	-	-	1	-	-	1	-	-	-
Agricultural Statistics	-	-	1	-	-	1	-	-	-
Agronomy	2	1	3	1	1	3	1	-	-
Economic Botany and Plant Genetic Resources	-	1	2	-	-	-	-	1	2
Farm Machinery and Power	-	-	1	-	-	1	-	-	-
Plant Pathology	-	1	-	-	1	-	-	-	-
Plant Physiology	1	1	1	1	1	-	-	-	1
Soil Science	-	1	2	-	1	1	-	-	1
Total	**4**	**9**	**14**	**2**	**8**	**8**	**2**	**1**	**6**

PS - Principal Scientist, SS - Senior Scientist, S - Scientist

Resource Generation (₹ in lakhs)

Particulars	Amount
Contract research	9.63
Consultancy services	27.00
Sale of farm produce	28.30
Others (auction, guest house, transport, tender paper, RTI, interests, license fee, water charges, dissertation fees, etc.)	9.10
Total	**74.03**

2. RESEARCH PROGRAMME - 1

DEVELOPMENT OF SUSTAINABLE WEED MANAGEMENT PRACTICES IN DIVERSIFIED CROPPING SYSTEMS

Weeds are dynamic in nature and keep changing with crops and cropping systems, cultivation practices, environment and other production factors. 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. This necessitates 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 systems. There are increasing instances of herbicide residues hazards on following crops; therefore, their use has to be investigated in a systems perspective. Weed management practices strongly influence use-efficiency of other production factors like water, nutrients, etc. Further, herbicide-use efficiency is also greatly 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. This research programme has been undertaken 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. Continuous use of herbicides on weed dynamics and crop productivity in direct-seeded rice-wheat cropping system	V.P. Singh, K.K. Barman and Shobha Sondhia
	1.1.2. Continuous use of herbicides on weed dynamics and crop productivity in direct-seeded rice-chickpea cropping system	V.P. Singh, K.K. Barman and Shobha Sondhia
	1.1.3. Weed management in rice-based cropping systems under conservation agriculture	V.P. Singh, Raghwendra Singh, Dibakar Ghosh and A.R. Sharma
	1.1.4. Effect of crop establishment methods and weed management practices on growth and yield of rice under rice-wheat cropping system	Raghwendra Singh, V.P. Singh and K.K. Barman
1.2. Systems approach to weed management	1.2.1. Effect of organic weed management practices in rice–wheat cropping system	R.P. Dubey, K.K. Barman, P.P. Choudhury and Yogita Gharde
	1.2.2. Effect of organic weed management practices in soybean–wheat cropping system	
	1.2.3. Effect of organic weed management practices in okra-tomato cropping system	
1.3. Improving input-use efficiency through weed management	1.3.1. Long-term effect of herbicides on nodulation in soybean and blackgram	K.K. Barman
	1.3.2. Weed management studies in soybean	Dibakar Ghosh and V.P. Singh
	1.3.3. Bioefficacy of fluazifop + fomasafen mixture in soybean	Anil Dixit
	1.3.4. Efficacy of post-emergence herbicides with and without surfactant in soybean	Anil Dixit
	1.3.5. Herbicide combinations for control of complex weed flora in direct-seeded rice	Anil Dixit

	1.3.6. Evaluation of post-emergence herbicides in chickpea	Anil Dixit
	1.3.7. Efficacy of post-emergence herbicides in wheat under high weed pressure	Anil Dixit
	1.3.8. Effect of herbicides for weed management in bottle gourd	Anil Dixit
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 and V.P. Singh
Exploratory trials	i. Effect of different weed management practices on performance of greengram	Raghwendra Singh, Dibakar Ghosh and A.R. Sharma
	ii. Impact of weed management practices on performance of zero-till summer legumes after wheat	Raghwendra Singh, Dibakar Ghosh and A.R. Sharma
	iii. Performance of sesame during post-rainy season under different weed management practices	Raghwendra Singh, Dibakar Ghosh and A.R. Sharma
	iv. Influence of crop establishment practices, green manuring and weed control measures on yield of rice	Raghwendra Singh, Dibakar Ghosh and A.R. Sharma
	v. Exploratory trial on weed management in cotton	Raghwendra Singh, Dibakar Ghosh and A.R. Sharma

2.1. Weed management under long-term conservation agriculture systems

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

A field study was initiated from June, 2010 and continued during rainy season of 2012 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 - wheat cropping system. The experiment comprised of treatment combinations consisting 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 + 2,4-D @ 500 g/ha, one HW at 30 DAS and weedy check in wheat as sub-plot treatments. The experiment was laid out in split-plot design with 3 replications.

Dominant weeds in the field were: *Echinochloa colona, Alternanthera sessilis, Commelina communis, Physalis minima, Caesulia axillaris*, and *Cyprus iri*a during rainy season. All the weed control treatments reduced the total weed density and weed dry biomass production significantly over weedy check. Weed dynamics in direct-seeded rice was significantly influenced by weed control treatments. Application of bispyribac-sodium @ 25 g/ha significantly reduced the population of *E. colona* (90%), *C. iria* (97%), *C. communis* (98%) and *Caesulia axillaris* (58%) over weedy check. However, application of cyhalofop-butyl failed to check the growth of *C. iria, A. sessilis*, and *C. communis* but significantly reduced the population of *E. colona* by 96% over weedy check (Table 1). Application of bispyribac-sodium significantly reduced the weed density (96%) and weed biomass (95%) over cyhalofop-butyl (Figure 1).

Growth parameters of rice, viz. plant height and leaf area index were not influenced significantly due to various weed control treatments. However, the highest reduction in leaf area index due to weed infestation was recorded in weedy plots, followed by cyhalofop-butyl treated plots. The least reduction in leaf area index was seen in bispyribac-sodium treated plots. The highest effective tillers / m row length and grain yield of rice were obtained in the bispyribac-sodium treated plots. Application of bispyribac-sodium recorded 28% higher effective tillers / m row length and 44% higher grain yield over weedy check. The lowest grain yield of rice (2.35 t / ha) was obtained under weedy check (Table 2). Presence of weeds throughout growing season caused 44% reduction in grain yield. The preceding treatments applied in wheat did not influence the weed flora distribution and weed biomass production in rice.

Phalaris minor and *Avena ludoviciana* among grassy weeds, and *Chenopodium album, Medicago hispida, Physalis minima* and *Cichorium intybus* among broad-leaved weeds were dominant in wheat during winter season of 2011-12. All the treatments significantly reduced the emergence of all weed species, except *C. intybus*. Application of clodinafop + 2,4-D caused significant reduction in *A. sterilis*, *P. minor* and *P. minima*, whereas the lowest populations of *C. intybus, M. hispida* and *C. album* were recorded with sulfosulfuron. Application of isoproturon failed to check growth of *A. sterilis* and *P. minor*, but was very effective against *C. intybus* and *C. album*. Clodinafop + 2,4-D caused 53 and 64% reduction in total weed population and weed dry biomass, respectively over weedy check. This was followed by application of sulfosulfuron. Both the herbicide treatments, viz. sulphosulfuron and clodinafop + 2,4-D were effective in reducing population of almost all weed species and weed biomass production (Table 3). Presence of weeds throughout the growing season caused 31% reduction in yield. The grain yield recorded with application of sulfosulfuron was 21 and 31% higher than isoproturon and weedy check, respectively. Preceding treatments applied to rice did not influence the weed distribution, crop growth, yield attributes and grain yield of wheat (Table 4).

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

Table 1: Weed density (no./m^2) dynamics in rice as influenced by continuous use of herbicides under direct-seeded rice - wheat system (2012)

Treatment (applied to rice)	*Cyprus iria*	*Echinoch-loa colona*	*Alternan-thera sessilis*	*Commelina communis*	*Physalis minima*	*Caesulia axillaris*	Total
Bispyribac-sodium	1.7 (2.4)*	1.1 (0.7)	0.9 (0.3)	0.8 (0.1)	0.7 (0.0)	1 (0.5)	2.2 (4.3)
Cyhalofop-butyl	9.5 (89.8)	1.5 (1.8)	1.4 (1.46)	2.4 (5.3)	1.1 (0.7)	1.6 (2.1)	10.4 (103.2)
Hand weeding	5.2 (26.5)	3.5 (11.8)	1.1 (0.7)	0.9 (0.3)	0.7 (0.0)	1.4 (1.46)	6.7 (44.4)
Weedy check	9.5 (89.8)	7.1 (49.9)	1.0 (0.5)	2.3 (4.8)	1.2 (0.9)	1.3 (1.2)	12.5 (155.8)
LSD (P=0.05)	2.8	2.8	0.4	0.6	0.1	0.6	3.7

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

Table 2: Growth and yield of rice as influenced by continuous use of herbicides under direct-seeded rice - wheat system (2012)

Treatment (applied to rice)	Plant height (cm)	LAI	Panicles/m row	Grains/ panicle	Grain weight/ panicle (g)	100-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium	57.2	3.4	53.8	159.0	4.0	2.5	4.18
Cyhalofop-butyl	60.0	2.8	48.0	157.6	3.8	2.4	3.59
Hand weeding	56.6	2.3	49.3	154.8	3.9	2.5	3.62
Weedy check	57.1	2.0	39.0	149.1	4.0	2.6	2.25
LSD (P=0.05)	3.6	1.6	5.4	26.0	0.9	0.3	0.32

Table 3: Weed density (no./m^2) in wheat as influenced by continuous use of herbicides under direct-seeded rice - wheat system (2011-12)

Treatment (applied to wheat)	*Avena ludoviciana*	*Phalaris minor*	*Chichorium intybus*	*Medicago hispida*	*Chenopodium album*	*Physalis minima*	Total
Sulfosulfuron	2.34 (4.98)*	0.88 (0.27)	1.19 (0.92)	3.36 (10.79)	1.18 (0.89)	2.25 (4.56)	5.30 (27.60)
Clodinafop fb 2,4-D	5.91 (34.43)	1.82 (2.81)	2.44 (5.46)	2.21 (4.38)	1.60 (2.06)	0.75 (0.06)	7.60 (57.26)
Isoproturon	7.94 (61.91)	2.19 (4.30)	0.82 (0.17)	3.49 (11.68)	0.71 (0.00)	0.71 (0.00)	9.48 (89.37)
Hand weeding	5.92 (34.54)	2.34 (4.98)	1.26 (1.09)	2.84 (7.57)	2.14 (4.08)	1.45 (1.60)	*8.06 (64.46)*
Weedy check	7.24 (51.92)	3.74 (13.48)	1.38 (1.40)	5.65 (31.42)	2.67 (6.62)	0.89 (0.29)	11.35 (128.32)
LSD (P=0.05)	1.50	1.07	0.71	1.46	0.88	0.60	1.60

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

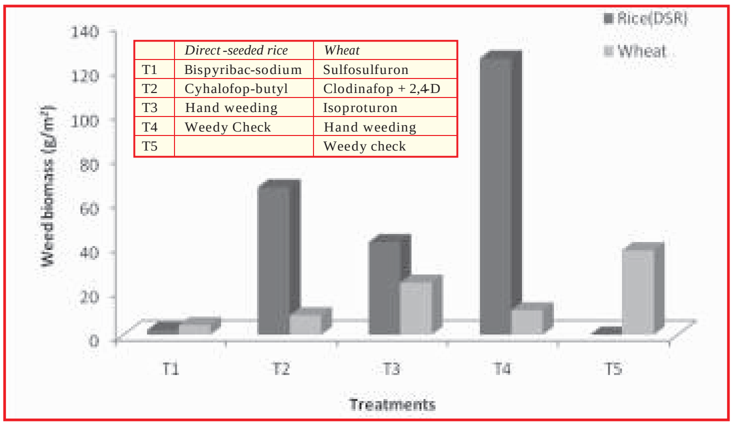


Figure 1: Weed biomass as influenced by continuous use of herbicides under direct-seeded rice - wheat cropping system

Table 4: Yield attributes of wheat as influenced by continuous use of herbicides under direct-seeded rice - wheat system (2011-12)

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	13.8	98.6	51.0	2.3	4.51	5.37
Clodinafop + 2,4-D	14.8	96.9	49.4	2.2	4.40	5.87
Isoproturon	13.7	86.4	49.0	2.2	4.36	4.62
Hand weeding	14.3	86.7	50.5	2.2	4.54	4.91
Weedy check	13.8	77.3	47.0	2.1	4.41	4.05
LSD (P=0.05)	1.0	8.7	2.99	0.2	0.25	0.54

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

A field trial was initiated from June 2010 and continued in 2011-12 to evaluate continuous use of commonly-applied herbicides in direct-seeded rice-chickpea cropping system. Treatment consisted 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. 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.

Dominant weeds in the third cycle of experimentation were: *Echinochloa colona, Ischaemum rugosum, Commelina communis* and *Caesulia axillaris* in rice. All weed control treatments influenced density and distribution of weed flora. Application 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 79 and 94% reduction in total weed density and biomass production, respectively over weedy check (Table 5, Figure 2).

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 (51), grain weight / panicle (3.7 g) and grain yield (4.60 t / ha) were recorded with bispyribac-sodium. Application of fenoxaprop + 2,4-D resulted in less grains / panicle and grain yield by 13 and 20% than bispyribac-sodium. The lowest effective tillers / m row length (43), grains / panicle (125) and grain yield (2.82 t / ha) were recorded under weedy check (Table 6). The preceding treatments applied in wheat did not influence the weed flora distribution and biomass production.

Avena ludoviciana and *Phalaris minor* among grassy weeds, and *Medicago hispida*, *Chenopodium album* and *Cichorium intybus* among broadleaved weeds were dominant in chickpea. Quizalofop being at par with hand weeding caused reduction in density of *Avena sterilis* over rest of the treatments. However, it failed to check emergence of *M. hispida*, *C. album* and *C. intybus* compared to pendimethalin and oxyfluorfen. Significantly lower population of *M. hispida*, *C. album* and *C. intybus* were recorded with pendimethalin and oxyfluorfen. None of the herbicides was found effective against *P. minor* (Table 7). Hand weeding resulted in the lowest total weed population and dry biomass, followed by quizalofop.

Presence of weeds throughout the growing season caused 86% 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 than rest of the treatments. Application of quizalofop resulted in higher yield attributes and seed yield. The lowest yield attributes and seed yield were recorded under weedy check and pendimethalin, respectively (Table 8).

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. Application of oxyfluorfen and quizalofop, however, did not show any adverse effect on chickpea nodulation (Table 9).

Table 5: Weed density (no./m^2) in rice as influenced by continuous use of herbicides under direct - seeded rice - chickpea system (2012)

Treatment (applied to rice)	*Echinochloa colona*	*Cyprus iria*	*Alternanthera sessilis*	*Commelina communis*	*Ischaemum rugosum*	*Caesulia* sp.	*Ammania bacifera*	Total
Bispyribac-sodium	1.5 (1.8)*	2.8 (5.8)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	3.2 (9.7)
Fenoxaprop *fb* 2,4-D	0.8 (0.1)	7.7 (58.8)	0.7 (0.0)	0.7 (0.0)	0.8 (0.1)	0.7 (0.0)	0.7 (0.0)	7.8 (60.3)
Hand weeding	2.1 (3.9)	4.1 (16.3)	1.0 (0.5)	0.7 (0.0)	1.0 (0.5)	0.8 (0.1)	0.8 (0.1)	4.8 (22.5)
Weedy check	7.2 (51.3)	10.1 (101.6)	0.9 (0.3)	2.0 (3.5)	1.7 (2.39)	0.9 (0.3)	0.8 (0.1)	12.8 (163.3)
LSD (P=0.05)	1.1	1.3	0.3	0.3	-0.6	0.2	0.2	1.6

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

Table 6: Growth and yield of rice as influenced by continuous use of herbicides under direct-seeded rice - chickpea system (2012)

Treatment (applied to rice)	Plant height (cm)	LAI	Panicles/m row	Grains/ panicle	Grain weight/ panicle (g)	100-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium	62.0	2.6	51.0	150.1	3.7	2.7	4.60
Fenoxaprop *fb* 2,4-D	60.0	2.4	52.0	129.8	3.3	2.7	3.68
Hand weeding	60.0	2.3	51.0	136.7	3.6	2.6	3.66
Weedy check	62.0	2.1	43.0	125.3	3.3	2.5	2.82
LSD (P=0.05)	5.2	0.3	5.4	37.3	0.8	0.2	0. 57

Table 7: Weed density (no./m^2) in chickpea as influenced by continuous use of herbicides under direct-seeded rice - chickpea system (2011-12)

Treatment (applied to chickpea)	*A. ludoviciana*	*M. hispida*	*P. minor*	*C. album*	*C. intybus*	Total
Pendimethalin	29.0 (840.5)*	4.1 (16.3)	1.8 (2.7)	1.4 (1.5)	2.0 (3.5)	29.6 (875.7)
Oxyfluorfen	27.6 (761.3)	3.0 (8.5)	1. 5 (1.8)	5.9 (34.3)	2.3 (4.8)	28.8 (828.8)
Quizalofop	11.4 (129.5)	8.4 (70.1)	2.6 (6.3)	10.7 (114.0)	4.9 (23.5)	19.3 (372.0)
Hand weeding	11.7 (136.4)	2.3 (4.8)	2.4 (5.2)	4.0 (15.5)	1.8 (2.7)	13.1 (171.1)
Weedy check	29.8 (887.5)	5.2 (26.5)	2.0 (3.5)	5.0 (24.5)	3.0 (8.5)	29. 6 (875.7)
LSD (P=0.05)	2.4	1.7	0.9	1.8	1.1	3.2

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

Table 8: Growth and yield of chickpea as influenced by continuous use of herbicides under direct-seeded rice - chickpea system (2011-12)

Treatment (applied to chickpea)	Branches/ plant	Pods/ plant	Seeds/ pod	Seed weight/ plant (g)	100-seed weight (g)	Seed yield (kg/ha)
Pendimethalin	3.0	14.3	1.7	2.9	15.4	173
Oxyfluorfen	3.1	15.6	1.6	3.5	16.2	265
Quizalofop	3.4	17.7	1.6	3.7	16.2	532
Hand weeding	5.8	32.5	1.7	6.0	15.0	1237
Weedy check	2.9	13.9	1.5	2.6	14.9	167
LSD (P=0.05)	1.00	5.1	0.2	1.5	1.6	120

Table 9: Nodulation in chickpea as influenced by continuous use of herbicides under direct-seeded rice - chickpea system (2011-12)

Treatment (applied to rice) (A)	Treatment (applied to chickpea) (B)					
	Pendimethalin	Oxyfluorfen	Quizalofop	Hand weeding	Weedy check	Mean
	Nodule count (no./plant)					
Hand weeding	30	33	37	41	30	34
Weedy check	26	30	38	31	27	30
Bispyribac-sodium	30	40	46	47	43	41
Fenoxaprop	26	33	33	34	30	31
Mean	28	34	39	38	33	
LSD (P=0.05)	For comparing A means: NS A x B : Within row : 12			For comparing B means: 6 Within column : NS		
	Nodule dry matter (mg/plant)					
Hand weeding	32	58	61	68	52	54
Weedy check	52	53	82	73	46	61
Bispyribac-sodium	50	62	68	70	70	64
Fenoxaprop	50	57	55	58	47	53
Mean	46	57	67	67	54	
LSD (P=0.05)	For comparing A means : NS A x B : Within row : 27			For comparing B means : 13 Within column : NS		

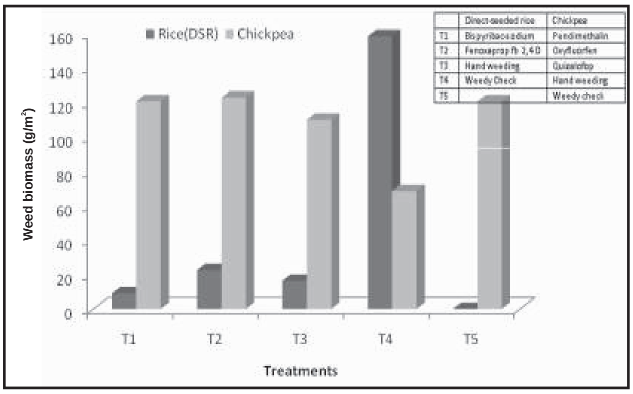


Figure 2: Weed biomass as influenced by continuous use of herbicides under direct-seeded rice - chickpea cropping system

2.1.3. Weed management in rice-based cropping systems 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, 2012 with the objectives to monitor weed dynamics, crop productivity, herbicide residues, C-sequestration, physico-chemical and biological properties of soil under rice-based cropping systems. Treatments consisting of rice crop establishment under direct seeding and transplanting with or without *Sesbania* brown manuring and previous crop residue, followed by wheat, mustard, chickpea and maize during winter season with or without rice residue under zero and conventional tillage, and greengram during summer under zero tillage with and without previous crop residues. Weed control measures involving continuous or rotational use of a crop-specific herbicide and integrated weed management were followed. During first cropping cycle, different crop establishment techniques in DSR did not influence the total weed population and weed dry biomass at 60 DAS. However, significantly lower weed dry biomass production was recorded with transplanted rice, which produced higher grain yield (Table 10 and 11). Being the first crop, rice was sown under conventional tilled condition in treatments, and overall weed infestation was less due to continuous submergence during the season.

Table 10: Weed growth and grain yield of rice as influenced by different tillage systems and weed management measures (2012)

Treatment	Weed population (no./m²)	Weed dry biomass (g/m²)	Grain yield (t/ha)
Tillage and crop establishment			
CT (DSR) + S – CT (wheat) – ZT (greengram)	15.11	18.04	4.40
CT (DSR) + R + S – CT (wheat) + R – ZT (greengram) + R	11.78	15.74	4.22
ZT (DSR) + S – ZT (wheat) – ZT (greengram)	13.33	21.13	4.38
ZT (DSR) + R + S – ZT (wheat) + R – ZT (greengram) + R	11.89	17.66	4.13
TPR – CT (wheat)	18.67	8.76	5.07
LSD (P=0.05)	4.07	6.43	0.52
Weed management			
Weedy check	21.06	23.82	3.96
Continuous bispyribac + pre-sowing non-selective herbicides in ZT	11.60	12.13	4.63
Herbicide rotation	9.80	12.86	4.72
LSD (P=0.05)	4.68	3.82	0.64

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

Table 11: Weed growth and grain yield of rice as influenced by different crop establishment techniques and weed management measures (2012)

Treatment	Weed population (no./m^2)	Weed dry - biomass (g/m^2)	Grain yield (t/ha)
Tillage and crop establishment			
CT (DSR) + S – CT (mustard / chickpea / winter maize) – ZT (greengram)	12.48	17.96	4.20
CT(DSR) + R + S – CT (mustard / chickpea / winter maize) – ZT (greengram) + R	10.81	16.76	4.13
ZT (DSR) + S – ZT (mustard / chickpea / winter maize) – ZT (greengram)	12.22	21.50	4.27
ZT(DSR) + R + S – ZT (mustard / chickpea / winter maize) - ZT (greengram) + R	11.55	24.01	4.15
TPR – CT (mustard / chickpea / winter maize)	22.96	5.89	4.44
LSD (P=0.05)	3.54	5.88	NS
Weed management			
Weedy check	17.95	29.4	3.78
Recommended herbicide + pre-sowing non-selective herbicides in ZT	13.20	12.36	4.44
Recommended herbicide + manual / mechanical weeding	10.87	9.86	4.49
LSD (P=0.05)	4.03	4.77	0.50

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

2.1.4. Effect of crop establishment methods and weed management practices on growth and yield of rice - wheat cropping system

An experiment was conducted to study the effect of crop establishment methods and weed management techniques on weeds and productivity of rice-wheat system. The experiment was initiated from rainy season, 2012 in split-plot design with four main treatments, viz. transplanting (TP), puddled broadcast sowing with sprouted seed (PBSR), direct-seeded rice (DSR) and System of Rice Intensification (SRI); and 4 sub-plot treatments of weed management, viz. weedy check, herbicide alone (bispyribac-sodium @ 25 g / ha), bispyribac-sodium @ 25 g / ha + 1 manual weeding at 20 DAS/ DAT and 2 manual weedings at 20 and 45 DAS / DAT with three replications.

Results showed that grain yield of rice under SRI (4.65 t / ha) was significantly higher than all other treatments (Table 12). Further, maximum yield was recorded with 2 manual weedings (4.37 t / ha), which was at par with bispyribac-sodium + manual weeding (4.14 t / ha). Interaction also revealed maximum yield of 5.17 t / ha with SRI and bispyribac + manual weeding.

Table 12: Grain yield of rice (t/ha) under different crop establishment and weed management practices (2012)

Crop establishment methods	Weed management practices				
	Weedy check	Bispyribac-sodium	Bispyribac + manual weeding	Two manual weedings	Mean
TP	2.78	3.77	4.29	4.42	3.81
PBSR	3.14	3.95	3.93	4.82	3.96
DSR	2.47	2.77	3.17	3.40	2.95
SRI	3.99	4.58	5.17	4.86	4.65
Mean	3.10	3.77	4.14	4.37	3.84

LSD (P=0.05)
Crop establishment : 0.41 Weed management : 0.34 Interaction : 0.68

After harvest of rice, wheat was grown during winter season 2011-12 to study the effect of crop establishment practices of rice under low and high weed pressure. The experiment was designed in spilt-split plot, comprising of main treatments (transplanting (TP), puddled broadcast sowing with sprouted seed (PBSR), direct-seeded rice (DSR) and System of Rice Intensification (SRI) during rainy season), sub-treatments (conventional tillage and zero tillage in wheat), and sub-sub treatments (mesosulfuron + iodosulfuron and weedy check).

Weed infestation in the experimental field was very less, with some species of *Avena ludoviciana* and *Medicago hispida*. Preceding treatments of crop establishment to rice did not have any significant effect on wheat yield and infestation of weeds. There was no significant difference between CT and ZT treatments in wheat on yield and attributing characters (Table 13). The weed infestation was comparatively more in ZT as compared to CT. Since weed infestation was very less, the weed management practices showed no significant difference on yield but mesosulfuron + iodosulfuron recorded less infestation of weeds as compared to weedy check.

Table 13: Effect of crop establishment practices of rice and tillage and weed management practices in wheat on growth and yield of wheat (2011-12)

Treatment	Plant height (cm)	Spike length with awn (cm)	No. of spikes/m²	No. of grains /spike	Total weed dry weight at 60 DAS (g/m²)	Grain yield (t/ha)
Treatments to rice						
Transplanting	92.3	16.8	292	56.8	2.76	6.45
PBSR	93.1	17.8	312	56.3	3.72	6.45
DSR	92.6	16.6	307	55.8	3.96	6.19
SRI	90.5	16.9	300	58.9	3.96	6.14
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Treatments to wheat						
CT	92.7	16.7	317	57.3	1.88	6.35
ZT	91.5	17.3	289	56.6	5.43	6.28
LSD (P=0.05)	NS	0.49	NS	NS	0.27	NS
Treatments to wheat						
Mesosulfuron + iodosulfuron	91.7	16.8	311	56.99	1.20	6.34
Weedy check	92.5	17.1	298	57.0	2.50	6.29
LSD (P=0.05)	NS	NS	NS	NS	0.27	NS

2.2. System-based approach to weed management

Field experiments in fixed plots initiated in 2010 to evaluate organic weed management practices in direct-seeded rice–wheat, soybean–wheat, okra–tomato cropping systems were continued during winter season 2011-12 and rainy season 2012.

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

Wheat

In winter season (2011–12), wheat was grown in sequence with rice. Major weed flora were: *Phalaris minor*, *Medicago denticulata* and *Chenopodium album*, *Cichorium intybus*, *Vicia sativa* and *Physalis minima*. Application of 50% FYM + 50% NPK along with clodinafop @ 60 g / ha *fb* 1 hand weeding significantly reduced the weed density and weed dry biomass at 60 DAT (Table 14). Wheat grain yield was significantly higher (4.84 t / ha) under NPK + herbicide (T_6) than other treatments. Treatments T_5, T_7 and T_3 resulted in grain yield at par with each other but higher than T_1, T_2, T_4 and control. It was interesting to note that application of FYM @ 10 t / ha + berseem intercrop (T_3) recorded yields at par with T_5, T_6 and T_7 treatments due to combined effect of better crop nutrition and weed control.

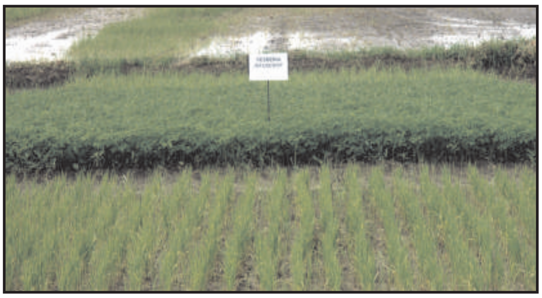
Table 14: Effect of treatments on weed density, weed dry biomass at 60 DAS, yield attributes and yield of wheat (2011-12)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Spikes/m²	Grain yield (t/ha)
T1	FYM @ 10 t/ha + stale seedbed *fb* 1 HW at 25 DAS	6.7 (45)*	3.5 (12)	385	2.03
T2	FYM @ 10 t/ha + stale seedbed *fb* reduced spacing (15 cm)	7.1 (51)	4.6 (21)	769	2.34
T3	FYM @ 10 t/ha + berseem intercropping	4.8 (24)	1.8 (3)	492	4.08
T4	FYM @ 10 t/ha + mechanical weeding 25 and 45 DAS	5.7 (32)	2.8 (8)	440	2.56
T5	FYM @ 10 t/ha + 2 hand weedings at 25 and 45 DAS	3.7 (13)	1.5 (1.7)	451	4.19
T6	Recommended NPK (120-60-40 kg/ha) + herbicide	5.1 (25)	1.9 (3)	475	4.84
T7	50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS	1.4 (3)	0.7 (0)	492	4.09
T8	Unweeded / unfertilized control	7.9 (64)	4.1 (16)	380	1.74
	LSD (P=0.05)	1.6	0.8	104	0.49

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

Rice

During rainy season (2012), direct-seeded rice was grown. Major weed flora were: *Cyperus iria*, *Commelina benghalensis*, *Echinochloa colona*, *Alternanthera sessilis* and *Caesulia axillaris*. Results revealed that treatments, viz. T_5, T_6, T_7, T_3, T_2 and T_1 recorded lower weed densities compared to T_4 and T_8. Weed dry biomass was lowest in T_5, T_6 and T_7. Grain yield was the highest under NPK + herbicide (3.26 t/ha), followed by that under FYM @ 10 t/ha + *Sesbania* incorporation 30 DAS (2.79 t/ha) and 50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS (2.61 t/ha) (Table 15). Unweeded control yielded 1.48 t/ha. The rice grain yield in general was low due to complete submergence at intial stages of growth and moisture stress at grain filling.



A view of experimental crop of rice

Table 15: Effect of treatments on weed density and biomass at 60 DAS, and grain yield of direct-seeded rice (2012)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Panicles/m²	Grain yield (t/ha)
T1	FYM @ 10 t/ha + stale seedbed fb 1 HW at 25 DAS	4.4 (18.7)*	3.2 (9.8)	259	2.40
T2	FYM @ 10 t/ha + stale seedbed *fb* reduced spacing (15 cm)	3.9 (15.2)	4.1 (17.1)	273	1.82
T3	FYM @ 10 t/ha + *Sesbania* incorporation 30 DAS	3.3 (10.7)	3.1 (9.6)	268	2.79
T4	FYM @ 10 t/ha + mechanical weeding 25 and 45 DAS	7.2 (54.0)	3.2 (10.5)	219	2.03
T5	FYM @ 10 t/ha + 2 hand weeding 25 and 45 DAS	3.1 (9.2)	1.8 (2.8)	259	2.57
T6	Recommended NPK (80-40-20) kg/ha + herbicide	3.2 (10.0)	2.6 (6.9)	265	3.26
T7	50% FYM + 50% NPK + herbicide *fb* 1 hand weeding at 25 DAS	3.3 (10.5)	2.8 (7.7)	253	2.61
T8	Unweeded / unfertilized control	9.7 (99.5)	8.7 (75.7)	138	1.48
	LSD (P=0.05)	1.7	1.2	33	0.38

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

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

Wheat

During winter season (2011-12), wheat was grown after soybean. Major weed flora were: *Medicago denticulata*, *Cichorium* sp., *Chenopodium album* ,*Vicia sativa P.minor*, *Rumex* sp. and *Lathyrus sativa*. The lowest weed population was recorded under 50% NPK + 50% FYM and herbicide + 1 hand weeding (35.0 / m^2) *fb* FYM + stale-seedbed and 1 hand weeding (39.0 / m^2) as compared to control (365 / m^2). Wheat grain yield was significantly higher (6.18 t / ha) under NPK + herbicide (T_6) than other treatments. Treatments T_5, T_7 and T_3 resulted in grain yield at par with each other but higher than T_1, T_2, T_4 and control (Table 16).

Table 16: Effect of treatments on weed density and biomass at 60 DAS, and yield of wheat (2011-12)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Plant height at maturity (cm)	Panicles/ m²	Grain yield (t/ha)
T1	FYM @ 10 t / ha + stale seedbed *fb* 1 HW at 25 DAS	6.2 (39)*	1.6 (2)	93.9	553	2.69
T2	FYM @ 10 t / ha + stale seedbed *fb* reduced spacing (15 cm)	7.9 (63)	2.7 (7)	88.5	798	2.83
T3	FYM @ 10 t / ha + berseem intercropping	7.5 (58)	4.8 (25)	93.2	477	5.02
T4	FYM @ 10 t / ha + mechanical weeding 25 and 45 DAS	10.7 (114)	6.7 (48)	89.7	432	3.21
T5	FYM @ 10 t / ha + 2 hand weeding 25 and 45 DAS	8.9 (80)	2.4 (5)	86.8	488	5.32
T6	Recommended NPK (120-60-40) kg / ha + herbicide	8.9 (79)	3.5 (14)	96.7	509	6.18
T7	50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding at 25 DAS	5.8 (35)	2.5 (6)	91.2	505	5.25
T8	Unweeded / unfertilized control	18.5 (365)	10.1 (108)	91.0	421	2.04
	LSD (P=0.05)	3.0	1.9	8.1	108	0.74

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

Soybean

Soybean was grown after wheat during rainy season, 2012. Major weed flora were: *Echinochloa colona*, *Commelina benghalensis*, *Cyperus iria*, *Phyllanthus niruri*, and *Dinebra* sp. The lowest weed density and biomass were recorded under T_7, T_5, T_6 and T_3 as compared to control (Table 17). Seed yield of soybean was comparable among FYM + stalebed + HW (2.33 t / ha), FYM + 2 hand weedings (2.27 t / ha), FYM + *Sesbania* incorporation (2.20 t / ha), 50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding (2.19 t / ha) while control yielded 0.86 t / ha.

A view of experimental crop of soybean

Table 17: Effect of treatments on weed density and biomass at 60 DAS, and seed yield of soybean (2012)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Pods/plant	Seed yield (t/ha)
T1	FYM @ 10 t/ha + stale seed bed *fb* 1 HW at 25 DAS	7.7 (61.8)*	4.9 (25.8)	105	2.33
T2	FYM @ 10 t/ha + stale seedbed *fb* reduced spacing (30 cm)	6.5 (43.8)	10.5 (109.2)	79	1.46
T3	FYM @ 10 t/ha + *Sesbania* incorporation 30 DAS	4.4 (18.8)	3.9 (17.6)	101	2.20
T4	FYM @ 10 t/ha + mechanical weeding at 25 and 45 DAS	6.2 (38.2)	11.5 (133.1)	81	1.15
T5	FYM @ 10 t/ha + 2 hand weedings at 25 and 45 DAS	3.7 (14.3)	1.8 (2.8)	104	2.27
T6	Recommended NPK (30-40-20) kg/ha + herbicide	3.8 (14.5)	6.4 (44.3)	92	1.82
T7	50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding at 25 DAS	3.2 (9.8)	2.2 (4.4)	102	2.19
T8	Unweeded / unfertilized control	8.1 (65.8)	14.0 (196.6)	42	0.86
	LSD (P=0.05)	1.6	1.7	34	0.21

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

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

Tomato

Tomato was grown after okra during winter season 2011–12. Major weed flora were: *Medicago denticulata*, *Cichorium intybus*, *Physalis minima*, *Chenopodium album*, *Paspaladium* sp. and *Vicia sativa*. Results revealed that the lowest weed density and biomass were recorded under FYM + black polythene mulch. The highest tomato yield was also recorded under FYM with black polythene mulch (23.9 t/ha), which was at par with T_7 (22.7 t/ha) as compared to control (2.59 t/ha) (Table 18). The very low fruit yields in T_1, T_3 and T_4 were due to heavy weed infestation.

Table 18: Effect of treatments on weed density and biomass at 60 DAS and yield of tomato (2011–12)

	Treatment	Weed density (no./m²)	Weed dry biomass (g/m²)	Fruit yield (t/ha)
T1	FYM @ 10 t/ha + stale seedbed	11.2 (127)*	4.9 (25)	6.82
T2	FYM @ 10 t/ha + black polythene mulch	0.7 (0)	0.7 (0)	23.87
T3	FYM @ 10 t/ha + straw mulch	10.3 (106)	3.7 (14)	6.59
T4	FYM @ 10 t/ha + radish intercrop	11.9 (145)	7.9 (71)	4.53
T5	FYM @ 10 t/ha + 2 hand weedings at 25 and 45 DAS	9.4 (89)	4.5 (21)	19.08
T6	Recommended NPK (120-60-40) kg/ha + herbicide	9.9 (102)	5.2 (27)	14.27
T7	50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding at 45 DAS	9.1 (84)	2.4 (5)	22.71
T8	Unweeded / unfertilized control	16.8 (290)	12.3 (153)	2.59
	LSD (P=0.05)	3.2	2.8	3.31

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

Okra

Okra was grown after tomato during rainy season, 2012. Major weed flora were: *Commelina benghalensis*, *Echinochloa colona*, *Cyperus iria*, *Dinebra* sp, *Phyllanthus niruri* and *Physalis minima*. The lowest weed density and biomass were recorded under FYM + black polythene mulch *fb* FYM + 2 HW (Table 19). The highest pod yield of okra was recorded under FYM + black polythene (13.84 t/ha), which was about 3 times more than control (3.84 t/ha).

Table 19: Effect of treatments on weed density and biomass at 60 DAS, and yield of okra (2012)

	Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Pod yield (t/ha)
T1	FYM @ 10 t/ha + stale seedbed	12.5 (156.6)*	10.1 (103.3)	2.43
T2	FYM @ 10 t/ha + black polythene mulch	0.7 (0.0)	0.7 (0.0)	13.84
T3	FYM 10 t/ha + straw mulch	8.8 (77.7)	9.9 (100.4)	9.54
T4	FYM 10 t/ha + *Sesbania* intercrop *in situ* mulch at 30 DAS	7.7 (61.0)	5.7 (33.9)	9.29
T5	FYM @ 10 t/ha + 2 hand weeding at 25 and 45 DAS	6.3 (39.0)	1.8 (3.0)	10.64
T6	Recommended NPK (120-60-40) kg/ha + herbicide	8.3 (54.3)	12.0 (149.2)	8.62
T7	50% FYM + 50% NPK+ herbicide *fb* 1 hand weeding at 45 DAS	7.4 (54.3)	4.0 (16.9)	12.79
T8	Unweeded / unfertilized control	14.9 (227.0)	13.1 (171.2)	3.84
	LSD (P=0.05)	2.1	2.4	2.1

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

A view of experiment crop of okra under organic weed management

2.3. Improving input-use efficiency through efficient weed management

2.3.1. Long-term effect of herbicides on nodulation in soybean and blackgram

Long-term field experiments were initiated during rainy season 2010 to study the effect of herbicides on symbiotic N_2 fixation in soybean and blackgram.

In soybean, treatments comprised of 2 hand weedings, repeated as well as rotated application of quizalofop (50 g/ha), imazethapyr (100 g/ha) and fenoxaprop (100 g/ha), and weedy check. Soybean var. 'JS-9560' was sown in the last week of June, 2012.

It was noted that the population of *Echinochloa colona* was negligible in the plots receiving application of quizalofop and fenoxaprop every year, and it was significantly lower than the count recorded in imazethapyr treated plots. However, both quizalofop and fenoxaprop failed to control *Cyperus iria*. The population of C. *iria* in quizalofop and fenoxaprop treated plots was significantly higher than rest of the treatments including weedy plots. Further, the population of *E. colona* was inversely related with the population count of *C. iria* in soybean. The population of *Phylanthus niruri* and also the total weed count were not affected by any of given herbicide treatments. All the herbicide treatments showed significantly lower weed dry matter production at 40 DAS compared to weedy control. Due to heavy pressure of weeds, weedy check showed the lowest crop growth as well as nodulation at 40 DAS (Table 20). Compared to 2 HWs, none of the herbicide treatments showed any depressing effect on count and dry matter of nodule in soybean, indicating that the tested herbicides are safe from the soybean-*Rhizobium* symbiosis point of view (Figure 3).

Table 20: Long-term effect of herbicides on weed infestation in soybean at 40 DAS (2012)

Treatment	Weed count/m^2				Weed dry matter (g/m^2)	Soybean growth		
	Echinochloa colona	*Cyperus iria*	*Phylanthus niruri*	Total		Nodule count/ plant	Root dry matter (g/plant)	Shoot dry matter (g/plant)
Imazethapyr	6.2 (38)**	6.5 (43)	4.7 (23)	10.7 (116)	3.7 (14)	37.8	0.25	2.18
Fenoxaprop	2.2 (35)	12.1 (158)	5.7 (43)	15.9 (263)	3.8 (14)	36.8	0.27	2.21
Quizalofop	0.7 (0)	12.5 (163)	5.0 (31)	14.9 (227)	3.4 (12)	32.1	0.24	1.88
Herbicide rotation*	6.9 (52)	6.2 (46)	5.4 (29)	12.0 (147)	2.7 (7)	36.8	0.31	2.35
2 HWs	6.9 (50)	4.5 (27)	3.9 (16)	10.3 (107)	2.3 (5)	36.2	0.31	2.32
Weedy	9.8 (99)	9.9 (99)	6.6 (52)	16.4 (270)	7.5 (57)	23.9	0.16	1.24
LSD (P=0.05)	2.5	4.4	NS	3.9	1.3	7.6	0.06	0.59

*Received imazethapyr in the current year. **Data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses.

In blackgram, treatments comprised of repeated as well as rotational application of quizalofop (50 g / ha, PO), clodinafop (60 g / ha, PO) and pendimethalin (1000 g / ha, PE), 2 HWs and weedy check. Blackgram var. 'ATU-1' was sown in the last week of June, 2012. All the herbicide treatments significantly reduced the population of *E. colona* and total weed dry matter production. However, no suppressing effect of herbicides was noticed on *C. iria* and *P. niruri* count. Overall, pendimethalin showed the lowest total weed count and nodulation among the applied weed control measures. Compared to HWs, no adverse effect of clodinafop and quizalofop was noticed on blackgram nodulation (Table 21).

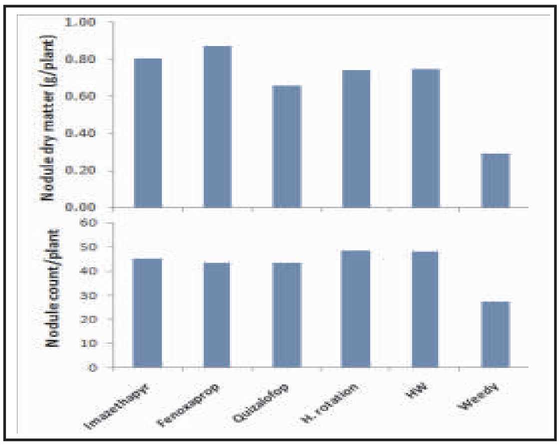


Figure 3: Effect of long-term herbicide application on nodulation in soybean at 40 DAS

Table 21:Long-term effect of herbicides on weed infestation and nodulation in blackgram at 40 DAS (2012)

Treatment	Weed count/m²				Weed dry matter (g/m²)	Nodules/ plant
	Echinochloa colona	*Cyperus iria*	*Phylanthus niruri*	Total		
Pendimethalin	3.1 (12)**	9.8 (107)	8.9 (80)	14.5 (214)	5.31 (29)	54.4
Clodinafop	3.0 (24)	19.4 (376)	8.9 (82)	22.7 (514)	4.97 (24)	70.3
Quizalofop	0.7 (0)	16.7 (278)	8.8 (77)	19.6 (386)	4.24 (18)	67.0
Herbicide rotation*	3.3 (17)	11.9 (141)	9.3 (88)	16.8 (283)	5.29 (30)	72.9
2 HWs	6.1 (48)	9.8 (101)	7.8 (62)	15.0 (231)	2.99 (9)	63.8
Weedy	13.0 (172)	10.9 (119)	8.4	19.3	9.16	53.7
LSD (P=0.05)	4.7	3.4	NS	3.4	1.82	9.9

*Received imazethapyr in the current year. **Data subjected to $\sqrt{x+0.5}$ transformation. Original values are in parentheses.

2.3.2. Weed management studies in soybean

A field trial on integrated weed management in soybean was conducted during rainy season 2012 in randomized complete block design replicated three times. Area of each plot was 22.5 m^2. Ten treatments were: T_1 – pendimethalin-xtra (pre-emergence, PE) @ 750 g / ha *fb* imazethapyr @ 100 g / ha at 30 DAS, T_2 – pendimethalin-xtra (PE) @ 750 g / ha *fb* chlorimuron-ethyl @ 9 g / ha at 25 DAS, T_3 – metribuzin (PE) @ 500 g / ha *fb* imazethapyr @ 100 g / ha at 30 DAS, T_4 – metribuzin (PE) @ 500 g / ha *fb* chlorimuron-ethyl @ 9 g / ha at 25 DAS, T_5 – imazethapyr @ 100 g / ha at 30 DAS, T_6 – imazethapyr @ 150 g / ha at 30 DAS, T_7 – chlorimuron-ethyl @ 9 g / ha at 25 DAS, T_8 – chlorimuron-ethyl @ 13.5 g / ha at 25 DAS, T_9 – 2 HWs at 25 DAS and 45 DAS, T_{10} – weedy check.

Major weed flora were: *Cyperus rotundus*, *Echinochloa colona*, *Physalis minima*, *Phyllanthus niruri*, *Macardonia procumbens*, *Dinebra retroflexa* and *Paspaladium flavidum*. Pre-emergence herbicides were less effective to suppress the population of *C. rotundus* at 25 DAS. Imazethapyr in combination with PE herbicides and sole application of chlorimuron-ethyl effectively reduced the biomass of *C. rotundus* at 60 DAS as compared to sole application of imazethapyr. Dry weight of *E. colona* was effectively reduced by imazethapyr and chlorimuron-ethyl in combination with PE herbicides and sole application of imazethapyr at higher dose (150 g / ha), but sole application of chlorimuron-ethyl was not effective to control *E. colona* at 60 DAS. All the weed control measures significantly reduced total weed population and dry weight at 60 DAS as compare to weedy check. Maximum yield was recorded with 2 hand weedings (1.69 t / ha), which was at par with imazethapyr @ 150 g / ha (1.54 t / ha) and metribuzin (PE) @ 500 g / ha *fb* imazethapyr @ 100 g / ha (1.47 t / ha) (Table 22).

Table 22: Effect of weed management practices on weed density and dry weight, and soybean yield (2012)

Treatment	*C. rotundus* at 25 DAS (no./m^2)	Dry weight of *C. rotundus* at 60 DAS (g/m^2)	Dry weight of *E. colona* at 60 DAS (g/m^2)	Total weed population at 60 DAS (no./m^2)	Total weed dry weight at 60 DAS (g/m^2)	Seed yield (t/ha)
T1	4.97 (24.7)*	1.33	8.40	7.32 (53.3)	12.85	1.13
T2	5.74 (32.7)	0.88	14.53	9.53 (90.7)	20.57	1.17
T3	6.05 (36.7)	1.13	4.67	9.19 (85.3)	10.52	1.47
T4	5.50 (30.7)	0.22	17.47	7.84 (64.0)	20.64	1.13
T5	8.24 (68.0)	2.13	43.33	12.71 (161.3)	61.20	1.11
T6	6.62 (47.3)	3.30	6.87	11.02 (121.3)	17.20	1.54
T7	7.53 (56.7)	0.29	46.93	12.44 (158.7)	69.42	0.98
T8	7.53 (56.7)	1.60	50.53	12.63 (161.3)	71.20	0.93
T9	5.55 (31.3)	0.53	4.86	9.12 (85.3)	12.15	1.69
T10	8.95 (82.7)	1.53	63.01	16.08 (258.7)	80.23	0.68
LSD (P=0.05)	2.24	1.69	23.61	2.68	29.85	0.40

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


Unweeded control


Pre-emergence pendimethalin

2.3.3. Efficacy of post-emergence herbicides with and without surfactant in soybean

Bioefficacy of post-emergence herbicides with and without surfactant was studied in soybean during rainy season 2012. Weed flora were dominated by: *Echinochloa colona*, *Commelina benghalensis*, *Phyllanthus niruri* and *Euphorbia geniculata*. All the weed control treatments significantly reduced the dry weight of complex weed flora, although they differed in their effect on monocot and dicot weeds. Among the post-emergence herbicides, imazethapyr + imazamox @ 60 g/ha proved more effective in decreasing weed population and weed biomass than other treatments. Application of imazethapyr @ 100 g/ha was found at par with tank-mix application of chlorimuron + quizalofop-p-ethyl in reducing the dry weight production of total weeds (Table 23). There was no difference in application of adjuvant with all the herbicides. Weed-free check gave maximum seed yield of 1002 kg/ha as against only 162 kg/ha under unweeded control. The weed-free treatment was found superior to all weed control treatments, except imazethapyr + imazamox @ 60 g/ha as post-emergence which was at par with each other. The per cent increase in seed yield due to weed-free and imazethapyr + imazamox was 518 and 497%. On the basis of visual observation on 0-10 point scale, none of the herbicide was found phytotoxic.

Table 23: Effect of treatments on weed population, weed biomass and seed yield of soybean (2012)

Treatment	Dose (g/ha)	Weed population (no./m^2)	Weed dry weight (g/m^2)	Seed yield (kg/ha)
Imazethapyr	100	5.3 (28)*	18	799
Chlorimuron + quizalofop	6+50	5.8 (33)	44	622
Chlorimuron + fenoxaprop-p-ethyl	6+100	5.3 (28)	28	807
Imazethapyr + imazamox	60	4.7 (22)	15	967
Imazethapyr + APSA 80	75	6.1 (37)	17	703
Chlorimuron + quizalofop + APSA 80	4+40	7.2 (51)	26	599
Chlorimuron + fenoxaprop-p-ethyl + APSA 80	4+80	5.9 (35)	19	745
Imazethapyr + imazamox + APSA 80	40	5.2 (27)	20	887
2 hand weedings		3.0 (9)	4	1002
Weedy check		6.8 (46)	136	162
LSD (P=0.05)		0.8	18	112

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

2.3.4. Herbicides combinations for control of complex weed flora in direct-seeded rice

An investigation was planned to study the bio-efficacy of combination of herbicides against weed complex and their effect on growth and yield of direct-seeded rice. The weed flora consisted of *Echinochloa colona, Commelina benghalensis, Alternanthera sesillis, Physalis minima, Caesulia auxillaris* and *Cyperus iria.* All the weed control treatments significantly reduced the weed population and biomass over weedy check (Table 24). Minimum weed count and biomass were recorded under three mechanical weedings applied at 20, 40 and 60 DAS. Application of pendimethalin @ 1.0 kg/ha, followed by bispyribac-sodium at 25 g/ha and manual weeding at 25 DAS caused reduction of weed density and dry weight. The highest grain yield was achieved with weed-free (3 hand weedings), mechanical weeding thrice and pendimethalin @ 1.0 kg/ha, followed by bispyribac-sodium and hand weeding at 25 DAS. The yield obtained under these treatments increased by 40% over weedy check due to lower weed competition.

Table 24: Effect of weed control treatments on weed count and biomass, and grain yield of rice (2012)

Treatment	Dose (g/ha)	Time of application	Weed count (no./m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)
Bispyribac-sodium	25	20 DAS (3-4 leaf stage)	2.7 (7)*	37	3.30
Pendimethalin *fb* bispyribac	700 *fb* 25	0-2 *fb* 25 DAS	2.9 (8)	30	3.53
Oxadiargyl *fb* bispyribac	100 / 25	0-2 *fb* 25 DAS	2.9 (8)	53	3.31
Pyrazosulfuron *fb* bispyribac	20/25	0-3 *fb* 25 DAS	2.9 (8)	12	3.63
Pendimethalin *fb* bispyribac *fb* manual weeding	700 *fb* 25	0-2 *fb* 20DAS (3-4 leaf stage) *fb* 45 DAS	1.9 (4)		3.60
Pendimethalin *fb* manual weeding	700	0-2 *fb* 25-30d	1.9 (4)	9	3.44
Bispyribac + (chlorimuron + metsulfuron)	20 + 4	20 DAS	3.0 (9)	15	3.82
Three mechanical weedings (cono / rotary weeder)	-	20, 40, 60 DAS	0.99 (1)	8	4.10
HW at 20, 40 and 60 DAS	-	-	0.71 (0)	-	4.00
Weedy check	-	-	5.3 (28)	110	2.52
LSD (P=0.05)			0.8	13	0.73

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

2.3.5. Evaluation of post-emergence herbicides in chickpea

A total of 10 treatments comprising various doses of imazethapyr, chlorimuron + quizalofop, ready-mix combination of saflufenacil 17.8% + imazethapyr 50.2% and pendimethalin 38.7% CS along with weed-free and weedy check were evaluated during *rabi* in randomized block design replicated thrice. Major weed flora consisted of *Chenopodium album*, *Phalaris minor*, *Cichorium intybus*, *Medicago denticulate* and *Physalis minima.* Weed-free treatment recorded the highest values of pod/plant, 100-grain weight and grain yield, followed by pre-emergence application of pendimethalin-xtra. The highest seed yield of chickpea was recorded in pendimethalin 38.7% CS @ 700 g/ha, followed imazethapyr (Table 25). The lowest yield was recorded with chlorimuron-ethyl due to its phytotoxicity on chickpea. Post-emergence application of imazethapyr @ 75 g/ha caused slight injury to chickpea but the crop recovered subsequently.

Table 25:Effect of treatment on weed density, weed biomass and seed yield of chickpea (2011-12)

Treatment	Dose (g/ha)	Weed count (no./m²)	Weed dry weight (g/m²)	Pods/ plant	Seeds/ plant	Test weight (g)	Seed yield (t/ha)
Imazethapyr	60	3.8 (14.3)*	18	23.2	27.1	18.7	2.64
Imazethapyr	75	2.7 (7.0)	5	27.0	33.3	20.2	2.84
Chlorimuron + quizalofop	3+40	3.7 (13.6)	10	21.3	23.0	16.7	2.20
Chlorimuron + quizalofop	4+50	4.3 (18.3)	11	21.6	24.7	17.2	1.93
Chlorimuron + quizalofop	6+75	3.3 (11.0)	7	20.3	21.6	18.3	1.30
Pendimethalin xtra	700	3.1 (9.6)	8	28.2	31.3	20.5	3.04
Saflufenacil + imazethapyr	85	4.3 (18.6)	17	23.3	29.1	17.5	2.57
Saflufenacil + imazethapyr	102	3.8 (14.0)	13	25.0	31.8	17.8	2.61
2 HWs	750	2.7 (7.0)	2	27.0	29.0	19.6	3.21
Unweeded control	-	7.3 (53.0)	31	16.2	20.4	17.3	0.99
LSD (P=0.05)		0.32	5	4.7	8.6	1.3	0.40

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

2.3.6. Efficacy of post-emergence herbicides in wheat under high weed pressure

A field experiment was conducted during winter season 2011-12 to evaluate the efficacy of pre-mix combination of mesosulfuro + iodosulfuron, metsulfuron + sulfosulfuron, carfentrazon + sulfosulfuron, penoxsulum + cyhalofop with alone application of pinoxaden, clodinafop, sulfosulfuron and carfentrazon along with weed-free and weedy check. All weed control treatments significantly reduced the population and dry weight of weeds over weedy check. Pre-mix combination of mesosulfuron + iodosulfuron and penoxsulum + cyhalofop provided effective control of *Avena ludoviciana*, *Medicago denticulata*, *Cichorium intybus*, *Phalaris minor*, *Physalis minima* and *Chenopodium album*. All the weed control treatments brought out a significant effect on yield of wheat crop as compared to control (Table 26). The reduction of grain yield in weedy check was 62% as compared to weed-free. The highest grain yield (5.17 t/ha) was obtained in weed-free, followed by mesosulfuron + iodosulfuron and penoxsulum + cyhalofop as post-emergence.

Table 26: Effect of treatments on weed count and dry weight, and grain yield of wheat (2011-12)

Treatment	Dose (g/ha)	Weed count (no./m²)	Weed dry weight (g/m²)	Grain yield (t/ha)
Clodinafop	60	4.4 (19.3)*	19	3.25
Clodinafop + 2,4-D	60+500	5.1 (26.0)	15	3.96
Pinoxaden	75	6.0 (36.0)	29	2.76
Sulfosulfuron	25	6.6 (43.6)	30	2.80
Metsulfuron + carfentrazon	25	6.1 (37.6)	52	2.37
Metsulfuron + 0.2% NIS	700	6.1 (37.0)	39	2.89
Carfentarzon + sulfosulfuron	45	6.3 (40.3)	44	2.70
Mesosulfuron + sulfosulfuron	40	5.6 (31.6)	25	3.73
Mesosulfuron + iodosulfuron	400	4.8 (23.3)	12	4.70
Penoxsulum + cyhalofop	105	4.8 (23.3)	13	4.60
Carfentrazon	25	5.7 (32.3)	38	2.82
2 hand weedings	750	2.4 (5.6)	9	5.17
Untreated control	-	8.9 (79.3)	91	1.94
LSD (P=0.05)		0.32	12	0.70

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

2.3.7. Effect of herbicides for weed management in bottle gourd

An experiment was carried out on summer bottle gourd (April–June, 2012) with eight treatments, viz. halosulfuron @ 60 and 120 g / ha compared with imazethapyr @ 60 and 75g / ha, pendimethalin (38.7% CS) @ 700 g / ha as pre-emergence along with 2 hand weeding and weedy check. There was a significant reduction in weed count due to application of herbicides compared with untreated control (Table 27). Application of halosulfuron @ 120 g / ha reduced the population of *Cyperus iria* to a greater extent as compared to other treatments. However, pendimethalin @ 700 g / ha reduced the overall weed population compared to other treatments. The reduction in weed population under pendimethalin was superior to imazethapyr and halosulfuron. A similar trend was observed in weed dry weight.

Loss in fruit yield of bottle gourd due to weeds was estaimated to be 40%. The yield obtained with pendimethalin @ 700 g / ha was 40% more than unweeded control, and on par with 2 hand weedings. No visual symptoms of injury or phytotoxicity were observed under halosulfuron @ 60 and 120 g / ha but at 240 g / ha slight phytotoxicity was observed. Imazethapyr was phytotoxic @ 75 g / ha. It was concluded that halosulfuron @ 120 g / ha controlled *Cyperus iria* effectively in bottle gourd. However, pendimethalin @ 700 g / ha resulted in the lowest weed infestation and registered the highest fruit yield.

Table 27: Effect of treatments on weed count, weed biomass and yield of bottle gourd (2012)

Treatment	Dose (kg/ha)	Weed count (no./m^2)	Weed dry weight (g/m^2)	Fruit yield (t/ha)
Halosulfuron	60	13.22 (175)*	225	9.90
Halosulfuron	120	11.21 (127)	166	16.60
Halosulfuron	240	10.30 (108)	128	10.60
Imazethapyr	60	13.37 (178)	223	3.70
Imazethapyr	75	12.55 (160)	172	5.02
Pendimethalin 38.7% CS	700	4.80 (24)	38	20.03
2 HWs	-	4.70 (22)	33	20.80
Weedy check	-	14.62 (215)	237	8.01
LSD(P=0.05)		2.12	14	3.72

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

2.4. Standardization of spraying techniques and mechanical tools for weed management

2.4.1. Evaluation of spray application techniques for weed management in crops

Spraying techniques are broadly classified as high volume, medium high volume, low volume, very low volume and ultra low volume according to total volume of spray solution to be applied per unit of ground area (Table 28). High volume spraying technique is used commonly in herbicide applications besides other pesticides. Studies were carried out to evaluate the different spray application techniques for herbicides used in field crops as detailed below:

Table 28 : Different spraying application techniques according to volume of spray applied in field crops

Spraying techniques	Volume rate (l/ha)	Recommended spraying volume for /field crops (l/ha)
High volume spraying	400	Above 400 for crops
Medium high volume spraying	300	200 to 400 crops
Low volume spraying	200	125-200
Medium low volume spraying	100	50-125
Very low volume spraying	40-50	5-50
No control measures	-	-
Weed free	-	-

To achieve desired spray volume to be applied, different spraying nozzles were tested in laboratory for their discharge rate, operating pressure, swath width, speed of operation. Brass fan nozzles, floodjet / flat fan nozzles and HDP fan nozzle (of different coloured tips) were tested (Figure 3) and data is given in Table 29.

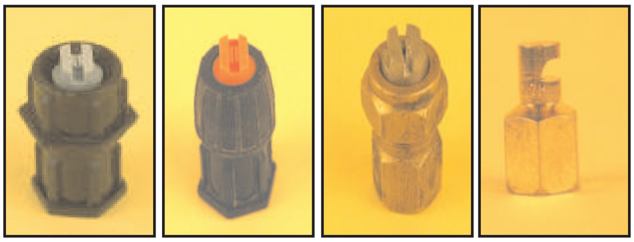


Figure 4: Hydraulic spray nozzles used in different spraying treatments

Table 29: Discharge rate, liquid pressure, swath width and speed of operation attained with different spray nozzles during spraying operation

Nozzle type	Discharge rate (cc/min)	Liquid pressure (psi)	Swath width (cm)	Speed of operation (m/min)
Fan nozzle (HDP) orange tip	250	10	60	40
Fan nozzle (HDP) blue tip	434	10-15	65	38-40
Fan nozzle (brass) 60675	674	10	75	40
Flat fan nozzle (brass)	856	15	70	40
Spinning disc atomizer	41	Atmospheric pressure	35	32

A field experiment was carried out having 7 treatments with 3 replications in randomized block design The herbicide imazethapyr was applied in soybean for its weeding efficacy at application rate of 1.0 l/ha at different spraying treatments (volumes of spray representing different spray application techniques). Results indicated that herbicide imazethapyr was effective in all the spray volumes applied in different treatments compared to no control treatment, and reduced the weed count by 44.5-56.4% and weed dry weight by 43.7-49.9% (Table 30). The very low volume application by spinning disc atomizer at 40 l/ha was found equally effective when comparing the weed control efficiency to that with low volume, medium high volume and high volume sprayings treatment carried out by knapsack sprayer using different fan nozzles and floodjet (flat-fan) nozzle. The weed control efficiency achieved in different spraying treatments was found highly significant compared to no weed control measure. The yield of soybean varied from 2.35-3.14 t/ha, with higher yields of 2.78-3.14 t/ha in imazethapyr treatments.

Table 30 :Weed control efficiency and seed yield of soybean in different spraying treatments (2012)

Spraying technique	Spray volume (l/ha)	Weed control efficiency (%)		Seed yield (t/ha)
		Weed count	Dry weight	
High volume spraying	100	46.5	45.9	2.96
Medium high volume spraying	200	56.4	49.9	2.96
Low volume spraying	300	49.1	43.7	3.14
Medium low volume spraying	400	53.4	45.5	3.07
Very low volume spraying	40	44.5	49.1	2.78
No control measures	-	0.0	0.0	2.35
Weed free	-	74.3	76.3	3.01
LSD (P=0.05)	-	24.2	6.04	0.42

It was concluded that formulation of imazethapyr should be improved upon by supplements i.e. adjuvant and spreader. It is possible that herbicide is effective in all the spray volumes applied from 40-400 l/ha representing different spray application techniques.

Exploratory trials

(i) Effect of different weed management practices on performance of greengram

An exploratory trial was conducted during summer season of 2012 to see the effect of herbicides on growth and yield of greengram cv. 'SML 668'. The dominant weed species were: *Cyperus rotundus, Convolvulus arvensis, Physalis minima* and *Dinebra retroflexa.* Significantly higher yield (491 kg/ha) and number of pods and branches/plant were obtained from two hand weedings, followed by post-emergence application (20 DAS) of imazethapyr @100 g/ha (Table 31). There was heavy infestation of white fly and yellow mosaic virus in the field, which resulted in poor yield of greengram.

Table 31: Growth and yield of greengram cv. 'SML 668' as influenced by different weed management practices (2012)

Treatment	Plant height (cm)	Branches /plant	Pods/ plant	Yield (kg/ha)
Imazethapyr @ 100 g / ha	35.3	4.00	13.5	427
Quizalofop @ 50 g / ha	36.7	3.22	10.8	359
Two hand weedings	37.6	4.99	14.1	491
Weedy check	38.3	3.11	9.6	343
LSD (P=0.05)	NS	1.3	3.9	47

(ii) Impact of weed management practices on performance of zero-till summer legumes after wheat

An exploratory trial was conducted with three summer legumes, viz. greengram, cowpea, and dhiancha during summer season of 2012. These crops were sown on 13 April, 2012 under zero-till condition after wheat harvest. Four weed control treatments were applied, viz. imazethapyr @ 100 g / ha at 20 DAS, quizalofop @ 50 g / ha at 20 DAS, one hand weeding and weedy check.

Greengram: Weed control measures did not affect significantly root weight and plant height (Table 32). Maximum number of branches / plant, LAI, plant dry weight and seed yield (671 kg / ha) were recorded with one hand weeding, followed by imazethapyr.

Table 32: Effect of different weed management practices on greengram (2012)

Treatment	Root weight (g)	Plant height (cm)	Branches/ plant	LAI	Estimated seed yield (kg/ha)
Imazethapyr @ 100 g / ha	0.77	21.9	8.11	2.70	650
Quizalofop @ 50 g / ha	0.77	19.0	6.22	2.60	554
One HW	0.58	19.9	8.78	2.79	671
Weedy check	0.72	19.0	6.00	2.39	445
LSD (P=0.05)	NS	NS	1.27	0.3	118

Blackgram: Weed management treatments significantly affected LAI, plant dry weight and yield (Table 33). The maximum LAI, plant dry weight and seed yield were observed with one hand weeding, followed by imazethapyr @ 100 g / ha, and both of them were significantly superior to other treatments.

Table 33: Effect of different weed management practices on blackgram (2012)

Treatment	Root weight (g)	Plant height (cm)	Branches /plant	LAI	Estimated yield (kg/ha)
Imazethapyr @ 100 g / ha	0.77	11.3	7.56	1.66	319
Quizalofop @ 50 g / ha	0.73	11.1	6.78	1.64	280
One HW	0.89	12.1	7.22	1.90	385
Weedy check	0.74	12.4	6.78	1.24	269
LSD (P=0.05)	NS	NS	NS	0.37	53

Cowpea: Leaf area index, plant dry weight and yield of cowpea were significantly affected by weed management practices. Maximum pod yield was recorded with one hand weeding (822 kg / ha), followed by imazethapyr @ 100 g / ha (764 kg / ha) (Table 34).

Table 34: Effect of different weed management practices on cowpea (2012)

Treatment	Root weight (g)	Plant height (cm)	Branches/ plant	LAI	Estimated yield (kg/ha)
Imazethapyr @ 100 g / ha	2.48	25.43	8.11	1.82	764
Quizalofop @ 50 g / ha	2.04	23.02	7.33	1.65	675
One HW	2.43	33.18	10.00	1.98	822
Weedy check	2.34	25.44	8.67	1.52	571
LSD (P=0.05)	NS	NS	NS	0.11	165

(iii) Performance of sesame during post-rainy season under different weed management practices

A trial was conducted during post-rainy season of 2012 to explore the possibility of growing sesame with pre- and post-emergence herbicides. Three sesame varieties were sown on 22 September, 2012 and 5 weed management practices were followed. Dominant weed flora were: *Cyperus rotundus*, *Convolvulus arvensis*, *Physalis minima*, *Amaranthus viridis* and *Dinebra retroflexa*. There was no significant difference among sesame varieties but weed management options differed with respect to growth and yield performance. The lowest weed dry weight was observed in quizalofop treated plot. Pre-emergence herbicides, viz. pendimethalin, metribuzin and imazethapyr showed good control on weeds but there was adverse effect of metribuzin and imazythapyr on germination and growth of sesame (Table 35). Pendimethalin also reduced crop growth

Table 35: Weed growth and yield of sesame varieties as affected by weed control measures (2012)

Treatment	Plant height (cm)	Branches/ plant	Weed cover at 40 DAS	Weed dry weight (g)			Grain yield (kg/ha)
				40 DAS		At harvest	
				Grassy	BLW	Total	
Varieties							
'RT-127'	44.8	3.75	0.80	20.4	2.0	34.8	365
'MT-75'	48.8	3.67	0.68	22.5	2.5	36.9	300
'TKG-22'	50.1	3.39	0.65	15.5	2.6	40.7	299
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	-
Weed management							
Metribuzin @ 500 g/ha	38.9	4.27	0.81	13.9	0.9	48.9	-
Pendimethalin @ 750 g/ha	50.8	3.76	0.87	11.4	4.3	14.1	-
Imazethapyr @ 75 g/ha	47.2	4.09	0.44	17.4	4.3	43.2	-
Quizalofop @ 50 g/ha	59.8	2.93	0.40	6.2	1.1	17.1	367
Weedy check	42.7	2.96	1.02	48.4	1.1	64.2	296
LSD (P=0.05)	NS	NS	0.37	11.4	1.6	9.8	-

and delayed flowering as compared with quizalofop. Due to early onset of winter, the harvestable yield was obtained with only quizalofop and weedy check. The maximum seed yield (365 kg/ha) was observed with variety 'RT-127'.

(iv) Influence of crop establishment practices, green manuring and weed control measures on yield of rice

An exploratory trial was conducted to observe the performance of zero-till direct-seeded rice, green manuring with *Sesbania* and weed control measures during rainy season 2012. Rice crop was established through transplanting, direct seeding with residue incorporation and zero-till with residue mulch. Green manure crops of sunhemp and *Sesbania* were also grown and weed management practices included brown manuring in direct-seeded and zero-till rice, and pretilachlor, bispyribac-sodium + metsulfuron methyl + chlorimuron-ethyl, bispyribac alone and weedy check. The field was heavily infested with diverse weed flora mainly *Echinochloa colona*, *Cyperus rotundus*, *Cyperus iria*, *Alternanthera* spp. and *Commelina benghalensis*. Maximum yield of rice was obtained with transplanting followed by (DSR) direct-seeded rice after sunnhemp. Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl resulted in higher yield. Grain yield obtained in weedy check with transplanting was at par with best weed management in DSR with residue incorporation and ZT with residue mulch. It was observed that better weed suppression was found with ZT with residue mulch as compared with DSR with residue incorporation.

(v) Exploratory trial on weed management in cotton

This trial was conducted on Bt cotton during rainy season 2012. Cotton was sown on 26 May and herbicides, viz. pendimethalin @ 1.0 kg/ha as pre-emergence, quizalofop @ 50 g/ha and fenoxaprop @ 60 g/ha at 45 DAS and directed spray of glyphosate were tried. Dominant weed species were: *Echinochloa colona*, *Cyperus rotundus*, *Cyperus tenuispica*, *Cyperus iria*, *Alternanthera* spp., *Commelina benghalensis* and *Abutilon indicum* The number of bolls per plant ranged from 12-35, seed cotton weight per boll from 3.5-5.2 g and seed per ball 25-36. Seed cotton yield was up to 2.9 t/ha. Application of pendimethalin resulted in efficient control of all weed species during early stages except *Commelina benghalensis*. Post-emergence application of quizalofop and fenoxaprop controlled grassy weeds effectively without any adverse effect on cotton. Directed spray of glyphosate with hood was better than that with wick applicator.

Cotton at an early stage

Harvesting of seed cotton

3. RESEARCH PROGRAMME - 2

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

Problems of weed management are becoming more intense due to vulnerability to global climate changes. Differential response of plants to changing climatic factors makes weed management a complex proposition. With changes in the temperature and rainfall pattern, vegetation over a region is facing new phase of competition for survival. It is assumed that the vegetation tolerating high temperature, drought and having high CO_2-use efficiency would perform better than other species. Behaviour of crop-weed interactions including reproductive success with changing climatic regimes is poorly understood. In addition, sustained selection pressures due to repeated use of herbicide and/or herbicides with similar sites of action prompt recurrence of herbicide resistance in weeds. This research programme has been initiated to understand complex behaviour of the weeds including development of herbicide resistance under the regime of climate change. This will help in development of strategies for efficient weed management in the changing climate scenario.

Sub-programmes	Experiments	Associates
2.1. Effect of climate change on crop-weed interactions, herbicide activity and bioagents	2.1.1. Impact of elevated CO_2 on greengram and associated weeds: physiological and biochemical aspects	Bhumesh Kumar and Meenal Rathore
	2.1.2. Effect of elevated CO_2 on herbicidal activity of *Parthenium* leaves	D.K. Pandey and Bhumesh Kumar
	2.1.3. Effect of elevated CO_2 on damage potential of *Zygogramma bicolorata*	Sushil Kumar and Bhumesh Kumar
2.2. Physiological and molecular basis of herbicide resistance development in weeds and evaluation of herbicide tolerant crops	2.2.1. Tolerance to bispyribac in *Echinochloa* species	D.K. Pandey and Bhumesh Kumar
	2.2.2. Herbicide tolerance in common rainy season weeds against glyphosate	D.K. Pandey and Bhumesh Kumar
2.3. Development of weed seed identification tools and weed risk analysis	2.3.1. Germination of seeds immersed in the liquid preservative	D.K. Pandey
	2.3.2. Germination of *Chenopodium album* seeds aged for different durations	D.K. Pandey
Others	i. Relative phytotoxicity of allelochemical crude of *Parthenium* leaf and inflorescence on rice and representative aquatic weeds	D.K. Pandey
	ii. Relative phytotoxicity of allelochemical crude of *Lantana* leaf on rice and representative aquatic weeds	D.K. Pandey
	iii. Relative phytotoxicity of allelochemical crude of *Solanum viarum* leaf and seed on rice and representative aquatic weeds	D.K. Pandey

3.1. Effect of climate change on crop-weed interactions, herbicide activity and bioagents

3.1.1. Impact of elevated CO_2 on greengram and associated weeds: physiological and biochemical aspects

Effect of elevated CO_2 on summer mungbean and weed species (*Brachiaria reptans* and *Eragrostis diarrhena*) was studied in Free Air CO_2 Enrichment (FACE) facility. 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 maturity of mungbean.

Results showed that enrichment of atmospheric CO_2 had a positive effect on overall growth of mungbean plants as well as weed species. Promotion in growth at elevated CO_2 could be attributed to the higher dry matter accumulation to above ground parts (Figure 1A). Increase in dry matter accumulation at elevated CO_2 was 19.5% in mungbean, 90.8% in *B. reptans* and 75.6% *E. diarrhena* as compared to that at ambient CO_2. Rate of photosynthesis (Figure 1B) and instantaneous water-use efficiency (Figure 1C) increased, while stomatal conductance (Figure 1D) and rate of transpiration (Figure 1E) decreased in mungbean, *B. reptans* and *E. diarrhena* at elevated CO_2 as compared to that at ambient CO_2. Exposure of plants to elevated CO_2 had a positive effect on activity of carbonic anhydrase in all the three species (mungbean, *Brachiaria reptans* and *Eragrostis diarrhena*). However, increase in carbonic anhydrase activity at elevated CO_2 was more in two weed species as compared to mungbean (Figure 1F) and may be a contributing factor to the observed higher rates of photosynthesis at elevated CO_2. CO_2 enrichment treatment led to differential pattern of peptide when resolved on 10% SDS-PAGE (Figure 2). It was found that among three species, *Eragrostis diarrhena* showed least number of bands (peptides). Upregulation of a high molecular weight (≈200 kDa) peptide in mungbean while a down regulation of this peptide in *Brachiaria reptans* was evident from protein profile. Similarly, a 68 kDa peptide was found to be upregulated at elevated CO_2 in all the three species, thus appeared to be high CO_2 specific. Species and stage specific differences in protein profiles were observed in response to elevated CO_2.

Activity of catalase, superoxide dismutase, ascorbate peroxidase and glutathione reductase decreased in mungbean but increased in *B. reptans* and *E. diarrhena* at elevated CO_2 as compared to that at ambient CO_2. As a small variation, activity of glutathione peroxidase decreased at elevated CO_2 as compared to that at ambient CO_2 level in mungbean, while no such decrease was observed in *B. reptans* and *Eragrostis diarrhena*. On the other hand, activity of guaiacol peroxidase decreased at elevated CO_2 as compared to ambient CO_2 level irrespective of the species. Important point emerged from the results was that weed species (*Brachiaria reptans* and *Eragrostis diarrhena*) possessed higher activity of all the antioxidant enzymes constitutively as well as at elevated CO_2 as compared to mungbean (Figure 3).

Activity of nitrate reductase increased in mungbean and two weed species at elevated CO_2 as compared to that at ambient CO_2 level. At elevated CO_2, increase in nitrate reductase activity figured 14.1, 16.9 and 18.6% in mungbean, *B. reptans* and *E. diarrhena*, respectively (Figure 4A). Enrichment of atmospheric CO_2 resulted in a considerable decrease (11.7%) in seed yield of mungbean (Figure 4B). In developing as well as maturity stage, seed protein content decreased at elevated CO_2 as compared that at ambient CO_2. At 28 days after pod initiation, a decrease of 0.7% in seed protein was noticed (Figure 4C). On the other hand, exposure of mungbean plants to elevated CO_2 resulted in an increase in total carbohydrates content in developing seeds as well as developed seeds. An increase of 3.1% in seed carbohydrates was noticed at 28 days of pod initiation (Figure 4D). Results showed that in addition to decrease in yield, enrichment of atmospheric CO_2 can potentially lower the quality of mungbean seed with diminished protein content and enhanced carbohydrates content.

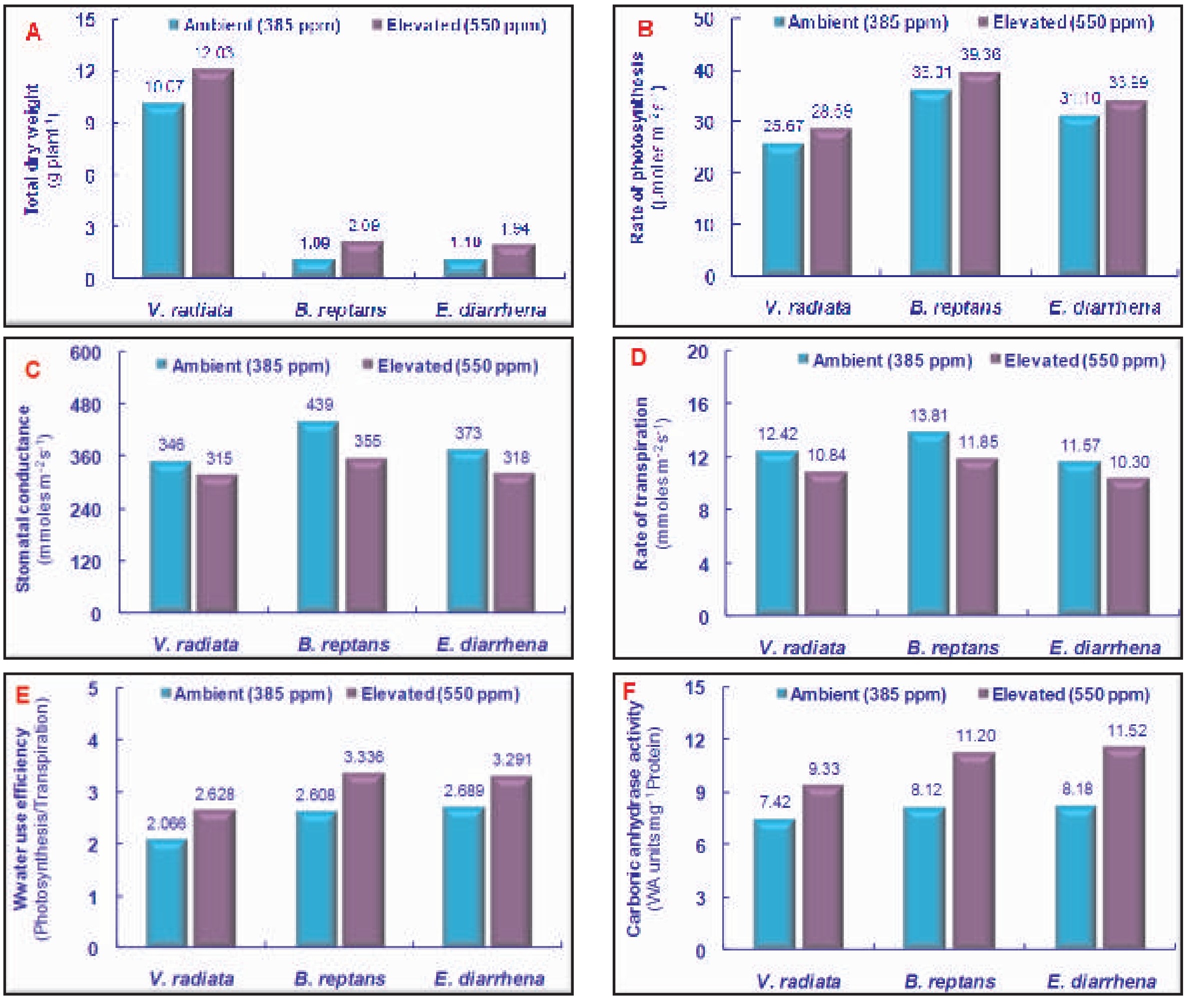


Figure 1: Effect of elevated CO_2 on dry matter (A), photosynthesis (B), stomatal conductance (C), transpiration (D), instantaneous water use efficiency (E) and activity of carbonic anhydrase (F) in *Vigna radiata* and associated weeds *(B. reptans* and *E. diarrhena)* at 42 days after treatment

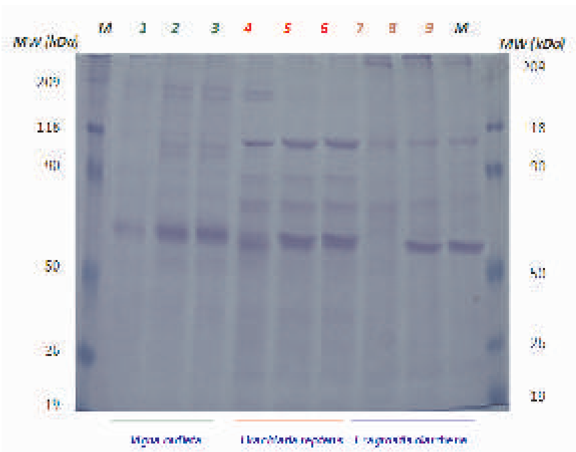


Figure 2: Effect of elevated CO_2 on SDS-protein profile in *Vigna radiata* and associated weeds *(B. reptans* and *E. diarrhena)* at 42 days after treatment

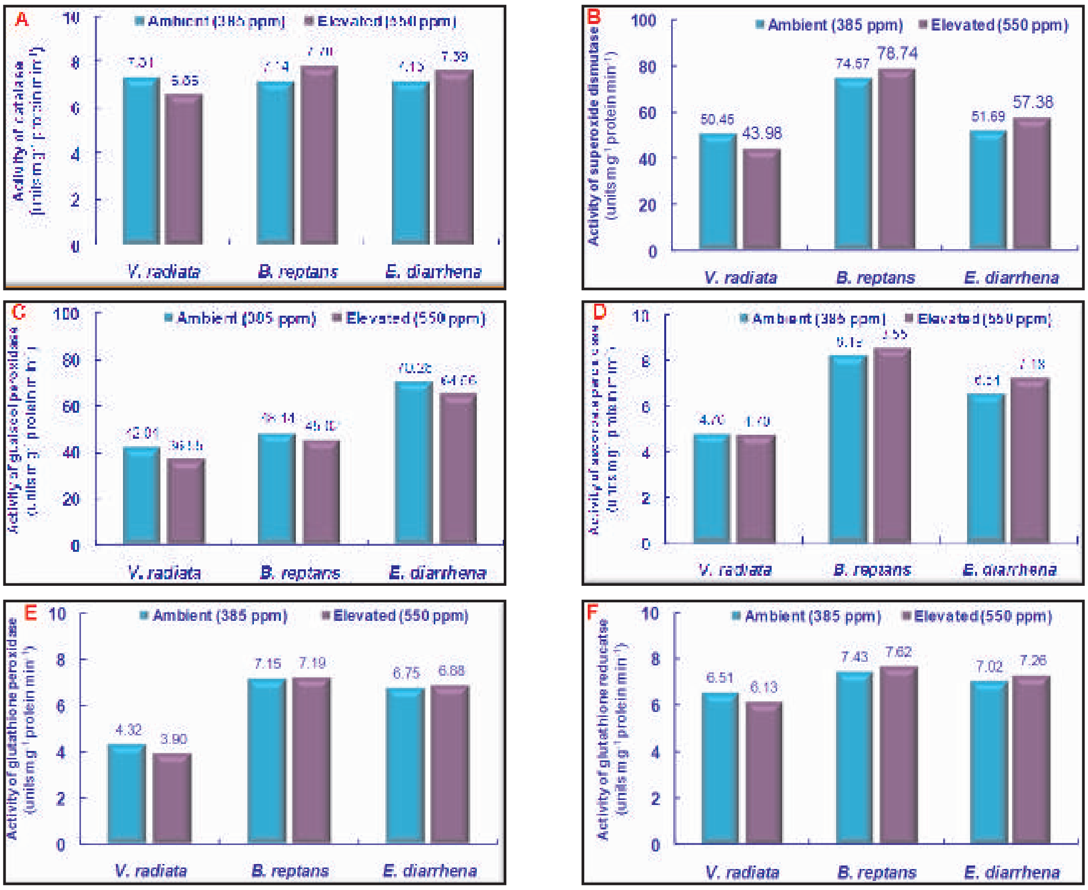


Figure 3: Effect of elevated CO_2 on activity of catalase (A), superoxide dismutase (B), guaiacol peroxidase (C), ascorabte peroxidase (D), glutathione peroxidase (E) and glutathione reductase (F) in *Vigna radiata* and associated weeds *(B. reptans* and *E. diarrhena)* at 42 days after treatment

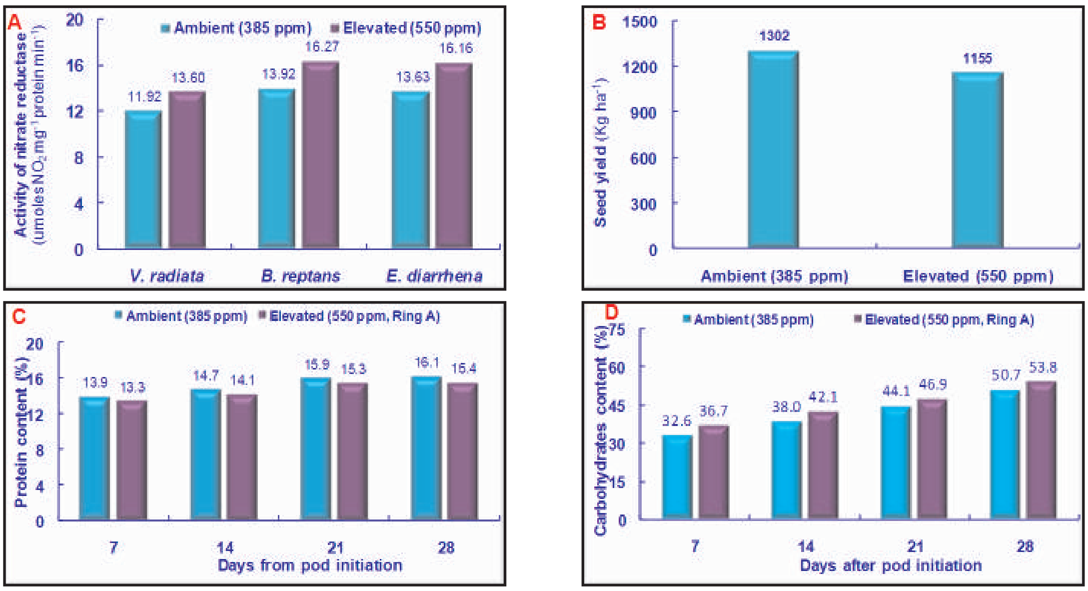


Figure 4: Effect of elevated CO_2 on activity of nitrate reductase (A), seed yield (B), seed protein content (C) and seed carbohydrate content (D) in mungbean

3.1.2. Effect of elevated CO_2 on herbicidal activity of *Parthenium* leaves

An experiment was planned to understand fate of phytotoxic secondary metabolites (including allelochemicals) in *Parthenium hysterophorus* leaves under changing climatic regimes involving elevated CO_2. *Parthenium* leaves were sampled from its stands grown at ambient and elevated (550±50 ppm CO_2) during rainy season, 2012. The leaves were quickly washed; blot dried and further dried under the shade. The dry matter was powdered to pass through an 80 mesh sieve (0.178 mm). The leaf residue was evaluated for herbicidal activity on five floating weeds, viz. *Eichhornia crassipes*, *Pistia stratiotes*, *Azolla pinnata*, *Spirodela polyrrhiza* and *Lemna pausicostata*; and four submerged weeds, viz. *Hydrilla verticillata*, *Ceratophylum demersum*, *Najas graminea* and *Potamogeton crispus*. Results showed almost similar phytotoxicity in the leaf residues obtained from plants grown in the CO_2 regimes.

Parthenium leaves have phenolics (mostly water soluble) and terpenoids (water insoluble) as major phytotoxic constituents implicated in its interactions with other species in its environment. Hence, the leaf samples from the plants grown in the CO_2 regimes were analysed for the phenolics using tannic acid (Sigma, USA) as a standard by Folin Denis Reagent method. Results showed that the leaves of plants grown in the elevated CO_2 had significantly higher phenolics (5.46%, w / w) than those grown at ambient CO_2 (3.40%; LSD 0.19, $P<0.05$).

3.1.3. Effect of elevated CO_2 on damage potential of *Zygogramma bicolorata*

An experiment was conducted to find out the effectiveness of bioagent *Zygogramma bicolorata* against *Parthenium* under elevated CO_2 (550±10 ppm). The seeds of *Parthenium* (2 g each) were shown in the Open Top Chambers (OTC) with and without elevated CO_2. The whole area of OTC was divided into four equal parts and *Parthenium* population was counted from each part by quadrate (0.25 m^2). Observations on plant height and flowers were recorded at 30 and 45 days. Adults of *Z. bicolorata* (150 no.) were released at 20 DAS in each OTC. Results revealed that elevated CO_2 enhanced growth of *Parthenium*. There was higher defoliation by beetles coupled with reduction in plant height as compared to control after 25 days of exposure (Figure 5A, 5B).

Figure 5A: Effect of *Zygograma bicolorata* on *Parthenium* under elevated (left) and control situations (right)

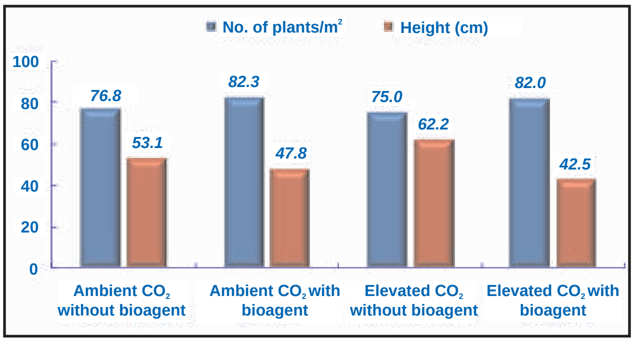


Figure 5B: *Parthenium* density and height under elevated and non-elevated CO_2 at 30 days after sowing

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

3.2.1. Tolerance to bispyribac in *Echinochloa* species

Echinochloa crusgalli, *Echinochloa colona* and *Echinochloa glabrascens* obtained from Jabalpur, Pantnagar and Anand were tested for bispyribac tolerance (10% w / v, SC). The weeds were sown in 20 cm apart rows (2 x 2 m plots) and bispyribac was sprayed at pre-flowering stage at x (25 g / ha), 2x, and 4x levels. Mortality of the treated plants and phytotoxicity were monitored. Some of the plants showed tolerance to the herbicide. Seeds from the plants withstanding the herbicide have been obtained to repeat the experiment in the next year to ascertain status of herbicide resistance in the weed.

3.2.2. Herbicide tolerance in common rainy season weeds against glyphosate

Rainy season weeds, viz. *Ageratum conyzoides*, *Alternanthera sessilis*, *Caesulia auxillaris*, *Cassia sericea*, *Cassia tora*, *Cichorium intybus*, *Corchorus trilocularis*, *Commelina benghalensis*, *Commelina communis*, *Corchorus capsularis*, *Corchorus olitorius*, *Cyperus difformis*, *Cyperus esculentus*, *Cyperus iria*, *Cyperus rotundus*, *Dactyloctenium aegyptium*, *Digitaria sanguinalia*, *Dinebra retroflexa*, *Echinochloa colona*, *Echinochloa crusgalli*, *Echinoclhoa glabrascens*, *Eclypta alba*, *Eleusine indica*, *Euphorbia geniculata*, *Ipomoea hederacea*, *Ischaemum rugosum*, *Ligacia molis*, *Malachra capitata*, *Malvasturm coromandelianum*, *Phyllanthus niruri*, *Physalis minima*, *Setaria glauca*, *Phyllanthus urinaria*, *Sida acuta* and *Malachra corchorifolia* were sown (30 cm apart in rows) in microplots (2 x 2 m) in June, 2012. The rows were sprayed with x (2 kg/ha), 2x and 4x glyphosate (isopropyl-amine salt, 41% w/w SL, Monsanto) before flowering in August and observed for phytotoxicity and mortality. All the weeds were killed in 15-20 days. Preliminary findings showed no indication of development of glyphosate resistance in the rainy season weeds included in the study.

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

3.3.1. Germination of seeds immersed in liquid preservative

Evaluation of potential of the liquid seed preservative - an entirely new concept developed for extending longevity of crop and weed seeds at ambient temperature - was undertaken. Results showed potential of the preservative for extending longevity of seeds by more than two decades at ambient temperatures (Table 1).

3.3.2. Germination of *Chenopodium album* seeds aged for different durations

(a) *Alternating temperature facilitating germination*

Chenopodium album seeds aged for different durations (0-10 years) at ambient temperatures did not germinate at 30°C in the dark. Subsequent incubation at 15/25°C (day/night) for another 20 days promoted germination especially in the seeds aged for 1-3 years. Similarly, the seeds failed to show germination at 25°C but again exposure to 15/25°C (day/night) for another 20 days promoted germination in some seed lots. Germination was highest in the seed lot aged for 3 years. Thus, alternating temperatures 15/25^{0}C promoted germination, and this probably has bearing on the emergence of the weed under field conditions (Table 2).

Table 1: Germination of seeds immersed in the liquid preservative for more than two decades

Species	Germination in the dark at 30^{0}C unless otherwise specified in 2012 (%)
*Parthenium hysterphorus**	95±5 (20^{0}C)
*Cassia tora**	97±1 (scarified)
*Cassia sericea**	99±1 (scarified)
*Chenopodium album**	60±1.5 (15/25^{0}C)
*Phalaris minor**	86±1 (18^{0}C)
*Echinochloa crusgalli**	87±3.2
*Cichorium intybus**	77±10
*Rumex dentatus**	88±2 (15/25^{0}C)
*Melilotus alba**	91±1
Wheat*	77
Pea*	96
Lentil*	94±3
Mustard*	98±1
French bean**	100
Cowpea**	71
Finger millet**	100
Rice**	42±2
Grain amaranth**	95±5
Vegetable amaranth**	98±2

* and **, 1992 and 1989 seeds, respectively. The values are means of three replications ± SD. The values without SD are based on single observation

Table 2: Germination (after 20 days in each case) of *Chenopodium album* seeds (aged for different durations) at different temperatures in the dark

Seed age (years)	Temperature^{0}C			
	30^{0}C (A)	A followed by 15/25^{0}C (night/day)	25^{0}C (B)	B followed by 15/25^{0}C (night/day)
0	0	3?4	0	2?3
1	0	13?7	0	8?4
2	0	13?6	0	3?3
3	0	46?7	0	18?8
4	0	4?2	0	0
5	0	2?3	0	0
7	0	0	0	0
10	0	0	0	0

(b) *Promotion of Chenopodium album seed germination by temperature and KNO_3*

One mM KNO_3 was ineffective in promoting germination of seeds of *Chenopodium album* (Table 3).

Five mM KNO_3 slightly improved germination of seeds at 15/25°C over the temperature alone. However, maximum promotions of germination of the seeds were at 10 mM KNO_3 in combination with the alternating temperatures. The germination improvement was consistent with all ageing seed lots, except in the seeds of higher age which might have lost viability.

Table 3: Effect of KNO_3 and temperature on germination (20 days after initiation of imbibition) of *Chenopodium album* seeds (aged for different durations) in the dark

Seed age (years)	1 mM KNO_3		5 mM KNO_3		10 mM KNO_3		
	At 25^{0}C (A)	A followed by 15/25^{0}C (d/n)	At 25^{0}C (B)	B followed by 15/25^{0}C (d/n)	At 25^{0}C (C)	C followed by 15/25^{0}C (d/n)	15/25^{0}C (d/n)
0	3?0*	0	2?3	1?2	1?2	14?4	53?4
1	2?2	4?3	0	13?10	1?2	56?19	72?15
2	0	63?3	2?3	43?20	0	75?13	96?2
3	0	3?5	0	59?4	3?0	63?5	87?12
4	0	0	0	0	0	5?6	5?2
5	0	0	0	1?2	0	1?2	0
7	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0

*Values are means of three replications ± SD

Others

(i) Relative phytotoxicity of allelochemical crude of *Parthenium* leaf and inflorescence on rice and representative aquatic weeds

Allelochemical crude from the plant parts of *Parthenium* was obtained by soaking in water at 1% (w/v) for 24 hours with occasional stirring, allowing moisture to settle, decanting the solution and evaporating at ambient temperatures. The allelochemical crude was suspended in water at 0.05, 0.10, 0.25, 0.75 and 1.0% (dry w/v) and pre-weighed aquatic weeds or rice (var. 'Kranti') seedlings (20 days old) were placed in the suspensions with controls and incubated outdoors. Phytotoxicity and biomass were monitored.

Parthenium leaf allelochemical crude was lethal to rice as well as aquatic weeds, viz. floating weed *Pistia stratiotes* and submerged aquatic weeds *Hydrilla verticillata* and *Ceratophylum demersum* at and above 0.1% (w/v). *Parthenium* inflorescence allelochemical crude was lethal to rice seedlings at as low as 0.1%. However, it was not lethal to the aquatic weeds at 0.1%, but was lethal at and above 0.25%. Thus, the allelochemical crude of *Parthenium* inflorescence had higher toxicity to rice than to the aquatic weeds.

(ii) Relative phytotoxicity of allelochemical crude of *Lantana* leaf on rice and representative aquatic weeds

Lantana leaf allelochemical crude was lethal to rice seedlings at and above 0.5%, whereas *Pistia stratiotes*, though inhibited, was not killed by it even up to 1%. However, *Hydrilla verticillata* and *Ceratophylum demersum* were killed at and above 0.25%.

(iii) Relative phytotoxicity of allelochemical crude of *Solanum viarum* leaf and seed on rice and representative aquatic weeds

Solanum viarum leaf allelochemical was lethal to rice seedlings and submerged aquatic weed *Hydrilla verticillata* at and above 0.1%, to *Ceratophylum demersum* at and above 0.25%, and to *Pistia stratiotes* at and above 0.5%. *Solanum viarum* seed allelochemical crude was lethal to rice and submerged aquatic weeds at and above 0.1%. However, it was lethal to *Pistia stratiotes* at and above 0.25%.

4. RESEARCH PROGRAMME - 3

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

Some of the weeds have assumed serious proportions in cropped and non-cropped situations. The weeds like wild oat (*Avena fatua*), canary grass (*Phalaris minor*). lambsquarters (*Chenopodium* sp.) *Cyperus rotundus*, field bind weed (*Convolvulus arvensis*), *Echinochloa* spp., weedy rice, *Orobanche*, *Cuscuta*, etc. are well known problematic weeds in different cropping situations. In non-cropped situations also, the weeds like *Parthenium hysterophorus*, *Lantana camara*, *Eupatorium adenophorum*, *Chromolaena odorata*, *Saccharum spontaneum*, *Mikania micrantha*, etc. have become the weeds of national importance. In aquatic situations, troublesome weeds like water hyacinth, alligator weed, *Pistia stratiotes*, *Ipomoea aquatica*, etc. have gained the status of worst weeds. Further, submerged weeds like *Hydrilla verticillata* is a big menace in aquatic situations. This weed-specific research programme has been taken up to study biology and management of such 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 Kumkar, Shobha Sondhia and Yogita Gharade
	3.3.2. Effect of inoculation of *Alternaria alternata* and *A. eichhorniae* in water hyacinth on fishes	C. Kannan

4.1. Biology and management of problematic weeds in cropped areas

4.1.1. Characterization of weedy rice biosimilars

A total of 112 weedy rice accessions collected from 8 states of India and 6 lines of wild rice were sown by DSR in experimental field along with 10 cultivated rice varieties in an augmented block design. Morphological parameters, viz. tiller color, presence of ligule, auricle color, collar color, plant height, tiller number; and physiological parameters using IRGA were observed and documented at 45 DAS. Ligule was present in all rice biotypes. Majority of the weedy rice (78 accessions) had green tillers while a few (26 accessions) had pink ones. Notable variation in auricle and collar colour was visible. The collar was mostly green while few accessions (7) had a pink collar or a black collar (3). Auricles were largely greenish in the accessions but some (6) were pink in colour while others were black (6). Variations in the physiological parmeters assessed were also visible. Plant height and tiller number were observed 45 and 60 DAS. The adjusted mean table generated after statistical analysis in ABD for plant height at 60 DAS revealed grouping of the accessions studied in to 13 groups with 9 of 10 controls to fall into a single group along with 21 weedy rice accessions. The other control grouped with T42 weedy rice accession. There were 8 groups that had a single member each and they were all weedy rice. This represents high variation amongst weedy rice for plant height (Table 1). Observations were analyzed for significant variation amongst weedy rice accessions and with checks using statistical programmes. The analysis revealed that :

- there was significant morphological variation amongst weedy rice accessions and with control at both 45 and 60 DAS;
- significant variation in transpiration rate (Figure 1) and leaf-air temperature difference at 60 DAS among weedy rice accessions and with control; and
- there was no significant difference in SPAD values at 45 and 60 DAS.

Continuous data of 49 accessions of weedy rice biosimilars collected from Central India, 5 cultivated rice and 2 wild rice species were analyzed using Cluster Analysis procedure of statistical package SAS 9.3 (SAS Institute Inc.). Dissimilarity coefficients were calculated using average linkage method of Cluster Analysis procedure. The dendrogram developed shows that at 80% variability the accessions were grouped into three clusters and two independent accessions, namely 23 and 55 (Figure 1, 2). The clustering pattern of weedy rice accessions indicated high variability between the three clusters generated and the independent accessions. The dendrogram also suggested weedy rice accessions of cluster 2 to be more close to cultivated rice and those in cluster 3 to be more close to the wild *O. rufipogon*. Accessions falling in cluster 1 and accession no. 23 need to be further assessed for genetic diversity amongst themselves and with cultivated / wild rice by molecular fingerprinting.

Table 1: Means of plant height at 60 DAS and the groups into which they fall as revealed by statistical analysis. Control C2 and weedy rice T42 fall into same group(G) shown in red.

Treatment No	Adjusted Mean	Group Letter	Treatment No	Adjusted Mean	Group Letter	Treatment No	Adjusted Mean	Group Letter	Treatment No	Adjusted Mean	Group Letter	Treatment No	Adjusted Mean	Group Letter
C1	90.95	CDEFG	T13	78.0725	BCDEFG	T35	83.2975	BCDEFG	T58	74.2475	CDEFG	T83	93.1825	ABCDEFG
C2	72.475	G	T14	89.8725	BCDEFG	T36	80.3975	BCDEFG	T59	69.2475	CDEFG	T83b	70.4825	CDEFG
C3	83.225	CDEFG	T15	59.8725	EFG	T36b	66.6975	CDEFG	T60	80.2475	BCDEFG	T84	59.8825	FG
C4	89.375	CDEFG	T16	89.8725	BCDEFG	T37	66.2975	CDEFG	T61	85.2475	BCDEFG	T85	103.7825	ABCDEFG
C5	81.675	CDEFG	T16b	78.8725	BCDEFG	T38	65.1975	CDEFG	T62	77.2475	CDEFG	T86	75.8825	CDEFG
C6	82.35	CDEFG	T17	85.8725	BCDEFG	T39	69.5975	CDEFG	T63	64.2475	DEFG	T87	76.5825	CDEFG
C7	89.575	CDEFG	T18	87.7725	BCDEFG	T39b	81.3975	BCDEFG	T64	111.2475	ABCDEFG	T88	76.8825	CDEFG
C8	86.4	CDEFG	T19	93.0725	ABCDEFG	T40	84.6975	BCDEFG	T65	110.2475	ABCDEFG	T89	92.7825	ABCDEFG
C9	87.2125	CDEFG	T20	96.9725	ABCDEFG	T41	67.6975	CDEFG	T66	106.2475	ABCDEFG	T89b	116.2825	ABCDEFG
C10	92.4375	CDEFG	T21	89.1725	BCDEFG	T42	56.1975	G	T67	122.2475	ABCDEFG	T90	144.9825	AB
T1	91.2725	BCDEFG	T22	88.6725	BCDEFG	T43	69.4975	CDEFG	T68	102.2475	ABCDEFG	T91	125.8825	ABCDE
T2	93.9725	ABCDEFG	T23	105.6725	ABCDEFG	T44	118.1975	ABCDEFG	T69	160.2475	A	T92	89.8825	BCDEFG
T3	102.4725	ABCDEFG	T24	102.9725	ABCDEFG	T45	112.4975	ABCDEFG	T70	131.2475	ABC	T93	94.7825	ABCDEFG
T4	99.3725	ABCDEFG	T25	94.3725	ABCDEFG	T46	99.7975	ABCDEFG	T71	126.2475	ABCDEF	T94	127.9825	ABCD
T5	98.8725	ABCDEFG	T25b	97.6725	ABCDEFG	T47	98.0975	ABCDEFG	T72	107.2475	ABCDEFG	T95	81.0825	BCDEFG
T6	86.7725	BCDEFG	T26	95.7975	ABCDEFG	T48	119.8975	ABCDEFG	T73	115.2475	ABCDEFG	T96	119.1825	ABCDEFG
T7	75.5725	CDEFG	T27	90.2975	BCDEFG	T48b	106.5975	ABCDEFG	T74	106.2475	ABCDEFG	T96b	70.6825	CDEFG
T8	95.0725	ABCDEFG	T28	87.9975	BCDEFG	T50	91.1975	BCDEFG	T75	131.2475	ABC	T96c	89.5825	BCDEFG
T9	88.8725	BCDEFG	T28b	85.7975	BCDEFG	T51	68.2475	CDEFG	T76	87.1825	BCDEFG	T97	98.8825	ABCDEFG
T10	103.4725	ABCDEFG	T29	75.8975	CDEFG	T52	80.2475	BCDEFG	T77	81.4825	BCDEFG	T98	97.5825	ABCDEFG
T10b	112.8725	ABCDEFG	T30	85.4975	BCDEFG	T53	77.2475	CDEFG	T77b	100.2825	ABCDEFG	T99	91.8825	BCDEFG
T11	94.6725	ABCDEFG	T31	83.9975	BCDEFG	T54	82.2475	BCDEFG	T78	78.2825	CDEFG			
T11b	95.3725	ABCDEFG	T32	93.5975	ABCDEFG	T55	81.2475	BCDEFG	T79	92.2825	BCDEFG			
T12	78.9725	BCDEFG	T33	79.4975	BCDEFG	T56	77.2475	CDEFG	T81	62.6825	EFG			
T12b	87.2725	BCDEFG	T34	88.9975	BCDEFG	T57	101.2475	ABCDEFG	T81b	107.6825	ABCDEFG			
									T82	64.8825	CDEFG			

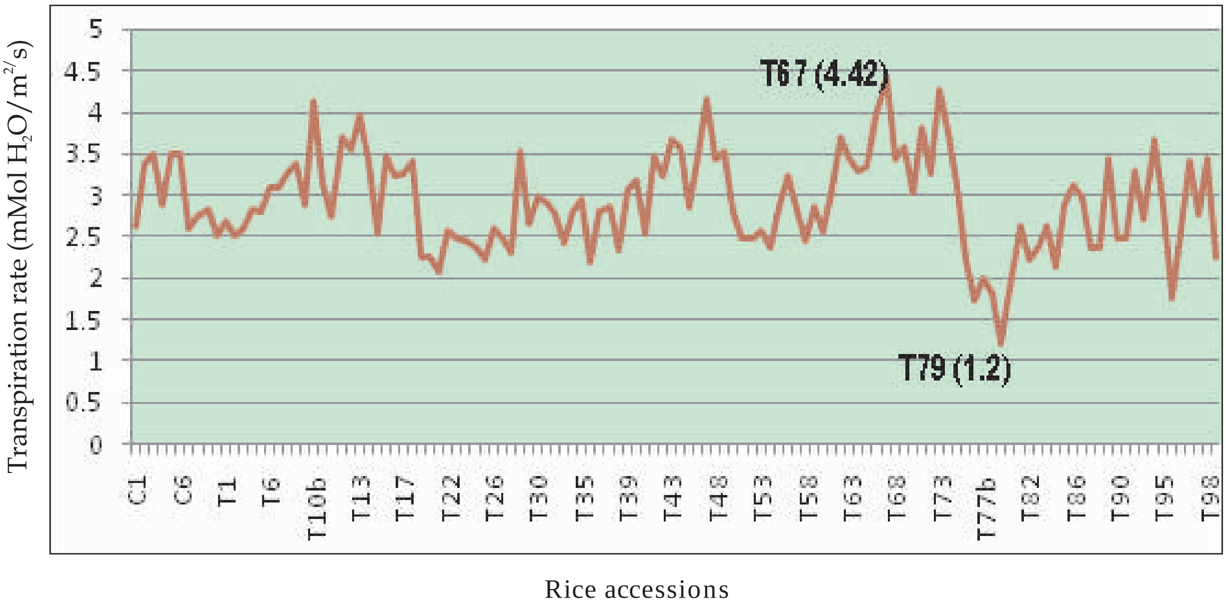


Figure 1: Graph of mean average values of transpiration rate in rice accessions studied. C: cultivated rice, T: weedy rice. The weedy rice accession T67 recorded highest value of transpiration rate while T79 recorded the lowest value.

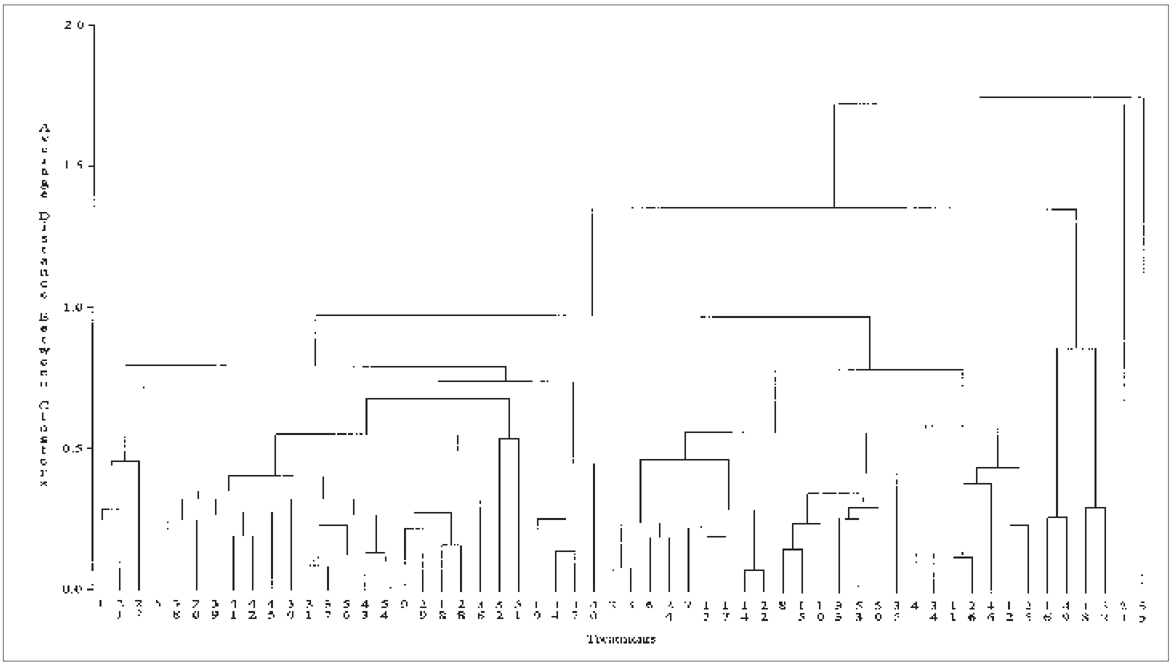
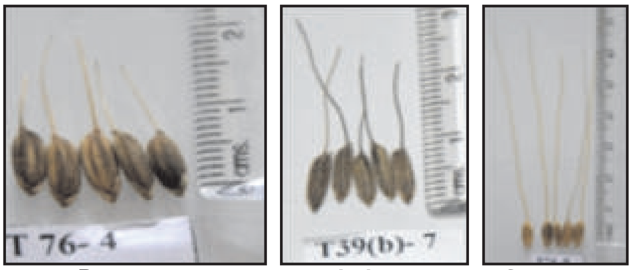


Figure 2: Tree dendrogram generated based on dissimilarity coefficient. C1: Weedy Rice accessions (WR) C2: WR, 'Kranti', 'Mahamaya', 'IR 64' C3: WR, O. rufipogon, 'PB-1', 'IR 64'

The weedy rice grains harvested were assessed for awn traits. 68 of 111 accessions were awned with varying color and length of awn (Figure 3). Awn length was found to vary between 0.8 cm (T28b) and 8 cm (T74)



Brown awn Black awn Straw awn

Figure 3: Grain of weedy rice having brown, black, straw coloured awns

Total genomic DNA of the weedy rice biosimilars accessions, wild rice and cultivated rice varieties was extracted using DNEasy Midi kit of Qiagen and stored for further use. The cultivated rice JR 201 d a weedy rice accession were used to standardize the SSR protocol in present lab conditions (Figure 4).

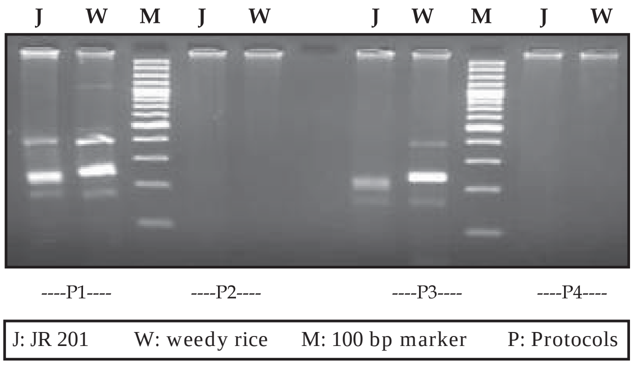


Figure 4: A 3% agarose gel revealing amplification in different protocols tested (P) using two test samples

4.1.2. Bio-efficiency screening and estimation of induced systemic resistance

An experiment was conducted to study the germination of *Orobanche*, and process of infection and estimation of systemic resistance in the host plant (mustard). It was observed that *Orobanche* required a conditioning period of 2-3 months in the pots kept in the containment chamber. The host seed were sown after treatment with the isolated antagonistic microbes by soaking the seeds with spore suspension of the isolated microbes. Similarly, fungicide Ridomil* (metalaxyl 0.01%) and salicylic acid (0.01%) were included for seed treatments. Soil drenching of microbes and chemicals were done on 30, 45 and 60 DAS. Results indicated that *Orobanche* emergence was recorded after 40-45 DAS of mustard, and a maximum number of 9 flowering stalks per pot of two mustard plants were recorded. *Orobanche* germination was very erratic, and there was no emergence in many of the treatments.

4.1.2. Incidence of *Orobanche* on different varieties of mustard

All 12 varieties of mustard, viz. 'Coral 437', 'R. Suflan', 'NRCHB-506', 'Maya', 'Rohini', 'NRCHB-101', 'Pusa Jaikisan', 'NDRE-7', 'Pitambari', 'GM-3', 'NRCDR-2', and 'PBR-357' were found susceptible to *Orobanche*. *Orobanche* stalks were recorded in range of 2-28 per pot. The varieties 'Rohini' and 'NRCDR-2' were found to have maximum number of stalk / pot (25-28), while the varieties 'Pusa Jaikisan' and 'Pitambari' were found to have lowest number of stalk / pot (2-7).

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

4.2.1. Integrated management of *Chromolaena odorata*

Chromolaena odorata, a problematic weed of Western Ghats, Karnataka and Tamil Nadu was not found in Baster area of Chhattisgarh about a decade back. However, in a short span, it has invaded large areas of forest, community and waste lands in and around Jagdalpur. It was observed that weed is spreading fast on road side leading from Jagdalpur to Raipur.

To manage this weed by biological means, about 3000 galls infested with gall fly (*Cecidocharus connexa*) collected from Bengaluru were released during November, 2011. Survey done during December, 2012 did not reveal the establishment of bioagents at the released sites. The reason of failure in establishment of bioagent in the released area may be due to the fire during May 2012, which might have killed the developing bioagents in the area. Therefore, again during December, 2012, about 1500 infested galls have been collected and released in the three different sites of Jagdalpur.

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

A gall fly emerged from the galls (in inset) made on *Chromolaena odorata* twigs

4.3. Biology and management of aquatic weeds

4.3.1. Integrated management of *Pistia stratiotes*

Pistia stratiotes, a problematic weed of aquatic bodies is found throughout India. In India, no work has been done on management of *Pistia* by herbicides and their effect on water quality, residue and fish mortality, besides its management by biological means. Therefore, this experiment was planned to address the immediate need of its management through various methods like biological, chemical, mechanical and even by way of utilization.

A survey was made to find out the occurrence and infestation of *Pistia strateotis* in and around Jabalpur. The weed infestation was found in many small water bodies besides severe infestation in a big pond (Gulaua). The infestation was so severe that the weed had formed a dense mat over the entire water surface of the pond. Earlier, this weed was found only in a small corner and never occurred in such abundance during last 20 years. Hence, this was considered a recent invasion in such a large area in Jabalpur.

Initial survey for search of native bioagent revealed the mild attack by lepidopteran larvae and aphids. But none of the insect species was found host-specific. Both the species were of polyphagous nature.

An attempt to make vermicompost from this weed biomass revealed that good quality vermicompost can also be made from this weed. There was fast decomposition of the weed and earthworms released started to produce the vermicompost within a short time.

A severely infested pond by *Pistia stratiotes* (a single plant in the inset)

4.3.2. Effect of inoculation of *Alternaria alternata* and *A. eichhorniae* in water hyacinth on fishes

About 15 fingerlings ('Rohu') were introduced in tanks containing 10 water hyacinth plants. After 5 days of acclimatization period in the tanks, *Alternaria alternata* and *A. eichhorniae* were sprayed on water hyacinth. Tanks with only water hyacinth and fishes were maintained as control. It was observed that both fungi did not have any effect on fish health.

Healthy fishes collected after 2 months of trial

Rohu fingerling kept for acclimatization

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 rain and irrigation, the persisting residues are likely to move towards sub-surface soil and contaminate ground water. Thus, a project on monitoring, degradation and mitigation of herbicide residues and other pollutants in the environment was initiated. Crop, water and soil samples were evaluated to see persistence and bio-accumulation of various herbicides in fishes and crops under field conditions.

Sub-programmes	Experiments	Associates
4.1. Impact of herbicides in soil, water and non-targeted organisms and herbicide mitigation measures	4.1.1. Dissipation of herbicides during rice growing season	Shobha Sondhia
	4.1.2. Dissipation of herbicides in soil during wheat growing season	Shobha Sondhia
	4.1.3. Effect of herbicides on water quality and fish mortality in ponds	Shobha Sondhia
	4.1.4. Evaluation of major degradation products of pyrazosulfuron and penoxsulum in soil by LC-MS/MS	Shobha Sondhia
	4.1.5. Major degradation products of penoxsulam obtained from the degradation by *Aspergillus flavus* in soil	Shobha Sondhia
	4.1.6. Major degradation products of penoxsulam obtained by *Aspergillus niger* in soil by LC-MS/MS	Shobha Sondhia
	4.1.7. Evaluation of risk of ground water contamination by continuous use of herbicides	Shobha Sondhia
	4.1.8. Adsorption behaviour of cyhalofop-p-butyl in sandy-clay loam and clayey soil	Shobha Sondhia
	4.1.9. Herbicide residues in direct-seeded rice-based cropping system	Shobha Sondhia
4.2. Degradation of herbicides in the environment	4.2.1. Phototransformation of herbicides on leaf cuticle surface and environment	P.P. Choudhury
	4.2.2. Photolysis of propaquizafop in water and soil	P.P. Choudhury
	4.2.3. Photolysis of sulfosulfuron in soil	P.P. Choudhury
4.3. Bio-remediation of pollutants using terrestrial / aquatic weeds	4.3.1. Efficacy of terrestrial weed species for treatment of drain water in phytoremediation facility	P.J. Khankhane
	4.3.2. Evaluation of terrestrial weed species for lead tolerance and accumulation	P.J. Khankhane

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

Persistence of herbicides in soil and water, and their effect on non-target organisms were evaluated in rice-based cropping system. Penoxsulam, pyrazosulfuron-ethyl and pretilachlor were applied at 25, 25 and 750 g/ha, respectively during rainy season, 2012 to rice and carfentrazone, pinoxaden and fenoxaprop-p-ethyl at 100, 25 and 100 g/ha, respectively were applied to wheat in winter season.

Herbicide dissipation was determined in water, soil and fishes at different time intervals.

Herbicide residues in soil, rice, wheat and water at 0, 15, 30, 60, 90 and 120 days were evaluated. Water and fish samples were collected after herbicide application and rain event in rainy season, and after flood irrigation in winter season from 0 to 100 days. Effect of herbicides on fish mortality and water quality was also evaluated. All samples were processed and analyzed for residues by HPLC.

5.1.1. Dissipation of herbicides during rice growing season

Initially 0.0595 and 0.714 µg/g residues of pyrazosulfuron-ethyl and pretilachlor were found in rice soil, which dissipated to 0.00103 and 0.017 µg/g at 30 days. At 90 days, the residues of pyrazosulfuron-ethyl and pretilachlor were <0.001 and 0.003 µg/g in soil (Table 1). Half-lives of pyrazosulfuron-ethyl and pretilachlor were found to be 8.02 and 13.08 days (Table 2). Dissipation patterns of pyrazosulfuron-ethyl and pretilachlor in soil are presented in Figure 1.

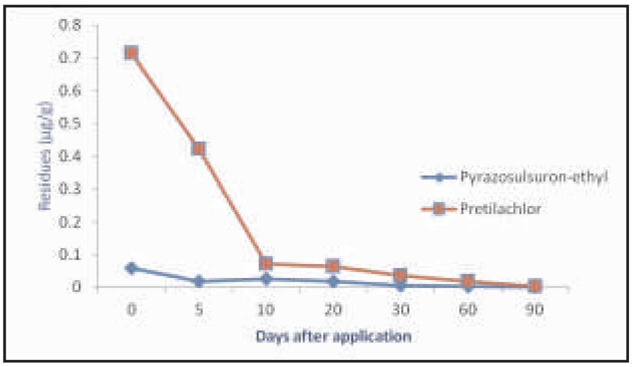


Figure 1: Dissipation of pyrazosulfuron-ethyl and pretilachlor residues in soil (rainy season, 2012)

At 10 days, 0.033 and 0.025 µg/mL residues of pyrazosulfuron-ethyl and pretilachlor, respectively were found in pond water, which dissipated to 0.0167 and 0.016 µg/mL at 20 days. Residues of pyrazosulfuron-ethyl were below <0.001 µg/mL after 30 days. However, 0.0044 µg/mL pretilachlor residues were detected at 30 days which were found below <0.001 µg/mL after 60 days in pond water (Table 2). In the fishes, 0.0056 and 0.063 µg/g residues of pyrazosulfuron-ethyl and pretilachlor, respectively were found after 30 days. At 60 days, pyrazosulfuron-ethyl and pretilachlor residues in fishes were <0.001 and 0.010 µg/g, respectively. Residues of pyrazosulfuron-ethyl were found 0.116, and 0.036 µg/g in green plant at 1 and 20 days, while the residues of pretilachlor (0.92, 0.063, 0.051 µg/g) were found in plants at 1, 20 and 30 days, respectively. The residue was below detection limit (<0.001 µg/g) at 60 days. Pyrazosulfuron-ethyl residue was not found in grain and straw at harvest.

Table 1: Residues (µg/g) of pyrazosulfuron-ethyl and pretilachlor in water (rainy season, 2012)

Days after application	Residues (µg/g)			
	Water		Young rice plant	
	Pyrazosulfuron-ethyl	Pretilachlor	Pyrazosulfuron-ethyl	Pretilachlor
10	0.0330	0.0250	0.116	0.092
20	0.0167	0.0160	-	-
30	<0.001	0.0044	0.036	0.063
60	<0.001	<0.001	<0.001	0.051
90	<0.001	<0.001		-

Table 2: Rate kinetics, R^2 and half-life of herbicides in soil during rainy and winter season

Season/ herbicides	Rate kinetics equation	R^2	Half-life (days)
Rainy season 2012			
Pyrazosulfuron-ethyl	y = - 0.020x + 0.773	0.93	8.02
Pretilachlor	y = - 0.023x + 0.773	0.90	13.08
Winter season 2012-13			
Carfentrazone	y = - 0.030x + 1.646	0.94	10.03
Pinoxaden	y = - 0.051x + 1.795	0.90	5.90
Fenoxaprop-p-ethyl	y = - 0.081x + 1.480	0.99	7.39

5.1.2. Dissipation of herbicides in soil during wheat growing season

Dissipation of herbicides in soil of wheat field followed first order rate kinetics. Residues of fenoxaprop-p-ethyl, carfentrazone and pinoxaden were found below detection limit from fishes collected from ponds at 90 days. Carfentrazone residues were dissipated to 0.001 µg/g after 90 days. Regression equation and half life of fenoxaprop-p-ethyl, carfentrazone and pinoxaden in wheat soil are presented in Table 2.

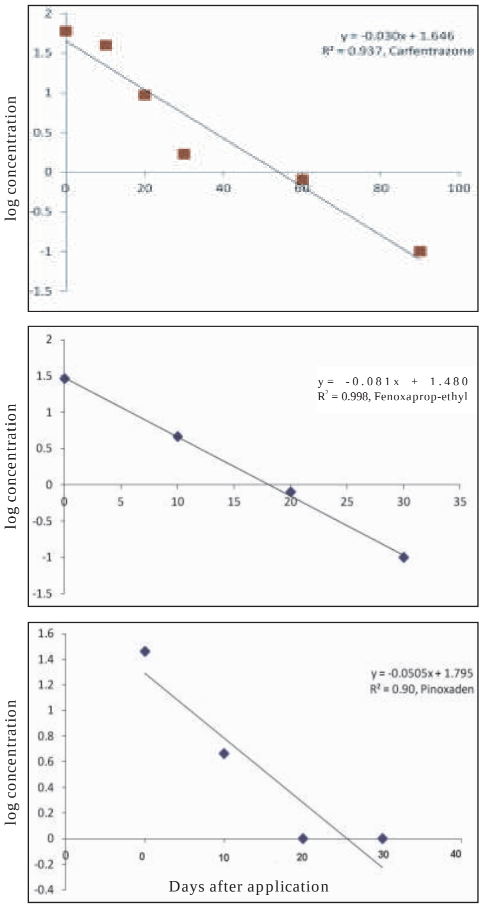


Figure 2: Dissipation of herbicides in soil during wheat-growing season

5.1.3. Effect of herbicides on water quality and fish mortality in ponds

There was slight increase in pH (7.6-8.1) and EC (287-395 µS/cm) of pond water receiving runoff due to flood irrigation in wheat. The increase was higher where carfentrazone was applied, followed by pinoxaden and fenoxaprop-p-ethyl. TDS was slightly increased (275 to 253 mg/L) and DO was found to vary from 7.0 to 12.0. Herbicidal treatments did not alter water quality significantly. pH of the pond water varied from 7.2 to 7.85, while EC varied from 648 to 805 µS/cm during the period from 0-90 days (Table 4 and 5).

Fish mortality and toxicity symptoms were recorded initially in the pond where herbicides entered through runoff water (Figure 3). Residues of pretilachlor, 0.063, and 0.010 µg/g were found in fishes at 30 and 60 days; and 0.0056 µg/g pyrazosulfuron-ethyl residues were found in fishes at 30 days afterwards residues were below detection limit (<0.001 µg/g) at 60 days (Table 3).

Table 3: Residues of herbicides in fish (µg/g)

Days after application	Pyrazosulfuron-ethyl	Pretilachlor
30	0.0056	0.063
60	<0.001	0.010
100	<0.001	<0.01

Fish toxicity and mortality in ponds during rainy season, 2012

Table 4: Changes in pH and EC of the soil due to herbicide application in rice (rainy season, 2012)

Days	Control		Pretilachlor		Penoxsulam		Pyrazosulfuron-ethyl	
	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)
0	7.55	64.7	7.15	58.8	7.50	45.0	7.60	79.2
5	7.35	72.4	7.30	50.6	7.40	47.0	7.45	70.0
10	7.75	50.8	7.50	59.1	7.45	36.8	7.40	31.1
20	7.90	52.5	7.65	44.6	7.50	35.0	7.35	74.6
30	7.40	69.6	7.95	45.2	7.50	52.6	7.50	51.6
60	7.30	43.2	7.20	58.0	6.40	69.3	6.75	55.6
90	7.25	102.2	7.05	66.2	7.60	55.8	6.95	41.2

Table 5: Change in pH and EC of the pond water due to herbicide application in rice (rainy season, 2012)

Days	Control		Pretilachlor		Penoxsulam		Pyrazosulfuron-ethyl	
	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)
0	7.30	675	7.15	656	7.30	648	7.05	778
5	7.45	692	7.30	742	7.40	650	7.30	805
10	7.70	650	7.50	670	6.55	635	7.50	725
20	7.35	617	7.65	654	6.55	632	7.60	728
30	8.05	394	7.95	403	6.50	542	7.85	497
60	7.20	381	7.20	591	6.65	529	7.10	636
90	7.10	519	7.05	553	7.00	503	7.15	426

5.1.4. Evaluation of major degradation products of pyrazosulfuron and penoxsulum in soil by LC-MS/MS

Metabolites of pyrazosulfuron-ethyl and penoxsulam were detected from soil and pond water which were identified by LC/MS/MS. Three major products of pyrazosulfuron-ethyl with $[M+H]^+$ ions at m/z 386 (I), 234 (II), 205 (III) and 156 (V) were detected from rice field. These 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 (Figure 3).

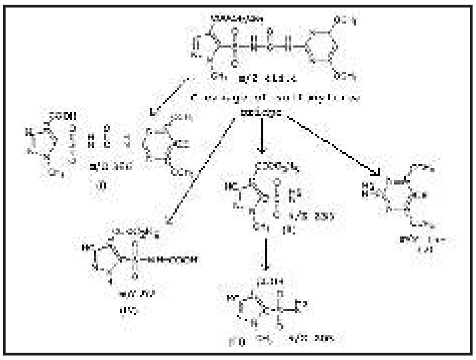


Figure 3: Major degradation products of pyrazosulfuron-ethyl in soil

Four major degradation products of penoxsulam in field soil were : 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine, 5,8 dicarboxylic acid (I); 2-(2,2-difluoroethoxy) -6 (trifluromethyl) benzenesulfonamide (IV); 3-[[[2-(2,2-difluoroethoxy)-N-[1,2,4] triazole [1,5c]-6-trifluromethyl) benzene sulfonamide carboxylate m/z (Figure 4).

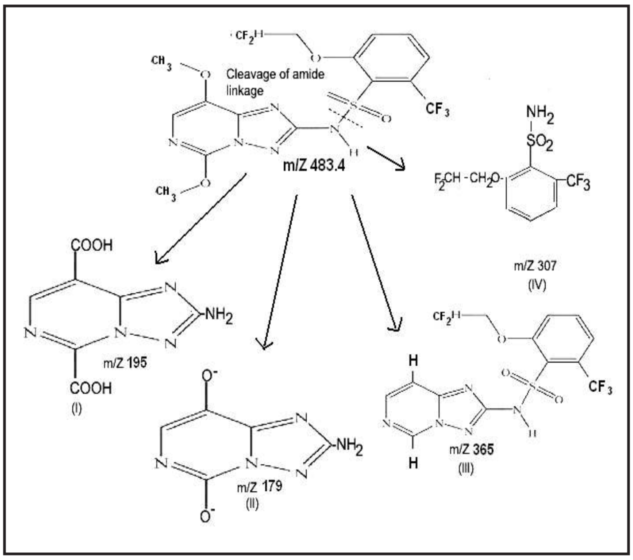


Figure 4: Transformation products of penoxsulam in soil

5.1.5. Major degradation products of penoxsulam obtained by *Aspergillus flavus* in soil

Five metabolites of penoxsulam degradaed by *Aspergillus flavus* were identified by LC / MS / MS from field soil of rice crop as: methyl 3-[[[2-(2,2-difluoroethoxy)-*6*-(trifluromethyl) phenyl] sulfonyl]amino]-1H-1,2,4 triazole 5-carboxylate m / z 373 (I); 5-hydroxyl, 8- methoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine (III); 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine, 5, 8 dicarboxylic acid (I); 2-(2,2-difluoroethoxy) -6 (trifluromethyl) benzenesulfonamide (IV); 5,8 dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine (II) and 2-(2,2-difluoroethoxy)-*N*-1H-1,2,4 triazole 3-yl-6 (trifluromethyl)benzenesulfonamide (V) (Figure 5).

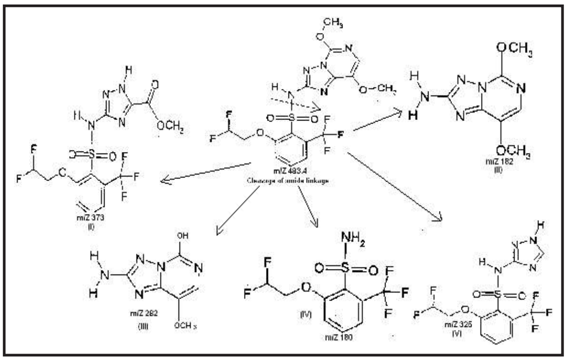


Figure 5: Transformation products of penoxsulam obtained by *Aspergillus niger* in soil

5.1.6. Major degradation products of penoxsulam obtained by *Aspergillus niger* in soil by LC-MS/MS

Four metabolites of penoxsulam were identified from soil inoculated with by *Aspergillus niger*: Methyl 3-[[[2-(2,2-difluoroethoxy)-*6*-(trifluromethyl) phenyl]sulfonyl]amino]-1H-1,2,4 triazole 5-carboxylate m / z 373 (I); 5,8 dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine m / z 179(II); 2-(2,2-difluoroethoxy)-*6*-(trifluromethyl) phenyl] sulfonyl]amino]-1H-1,2,4 triazole 5-carboxylic acid m / z 365 (III) and 5,8 dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidine 2 yl sulfamic acid m / z 195 (IV).

The cleavage of sulfonamide bridge of penoxulam by chemical and microbial action resulted in the formation of major transformation products. *Aspergillus flavus* and *A. niger* were found to be more effective to degrade penoxsulam, resulting in more number of degradation products. *Penicillium chrysogenum* was found to be more effective to degrade pyrazosulfuron-ethyl in soil as compared to *A. niger and A. alternate* by the cleavage of sulfonylurea bridge, resulting in the formation of two major metabolites which further cleaved to several minor products.

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

An experiment was conducted to study the mobility and leaching potential of herbicide under natural rainfall conditions in lysimeter made of cement of 1, 2, and 3 m. Pyrazosulfuron-ethyl was sprayed at 25 and 50 g / ha to the lysimeter under field conditions, and allowed to receive natural rain (approximately 1300 mm). Soil samples up to 0-25, 25-50, 50-75, 75-100, 100-125, 125-150, 150-175, 175-200, and 200-225 cm depth were collected and analyzed by HPLC to see the movement of pyrazosulfuron-ethyl in soil and to predict possible risk of ground water contamination through herbicide. Leachates were also collected and analyzed to see the movement of pyrazosulfuron-ethyl. Pyrazosulfuron-ethyl residues were detected from leachates of 1 m lysimeter as compared to 2 and 3 m lysemeter. There was increase in pH (7.20 to 8.65) of soil and leachates after pyrazosulfuron-ethyl application, while the EC in leachates was decreased with passage of time (Table 6).

Residues were higher in surface soil and detected up to 50 cm in 1 m depth lysimeter. However, the residues and metabolites of pyrazosulfuron-ethyl were found up to 100 and 150 cm in 2 and 3 m depth lysimeter. There was increase in pH of leachates from 7.20 to 8.60 after pyrazosulfuron application, which showed movement of residues and their major metabolites at various depths. Changes in EC and pH due to pyrazosulfuron-ethyl in soil columns and leachates are presented in Table 6.

Pyrazosulfuron metabolites were found in soil, and water after 10 days, and these were in higher quantity after 20 days as compared to pyrazosulfuron. Two major metabolites 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.

Table 6: Changes in EC due to pyrazosulfuron-ethyl application in leachates (rainy season 2012)

Treatment		Date of sampling											
		July					August					September	
		6	9	17	23	30	6	13	17	21	27	1	22
EC (µS/cm)													
1 m	T1	1975	1721	1356	1006	673	1065	687	958	833	538	626	547
	T2	2000	1970	1730	1009	628	1375	768	1033	873	1041	667	757
2 m	T1	1654	1660	1504	1412	1019	970	656	845	652.5	732	570	395
	T2	901	1994	1650	1470	1026	1001	644	891	770	754	705	410
3 m	T1	NL	1812	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL
	T2	NL	2170	1298	1543	1751	NL	960	NL	950	NL	NL	NL
pH													
1 m	T1	7.2	7.5	7.6	7.8	7.8	7.9	7.6	7.7	8.2	8.2	8.4	7.2
	T2	7.8	7.9	7.8	7.9	8.2	8.0	7.7	7.9	8.65	8.4	8.5	7.3
2 m	T1	7.2	7.3	7.2	7.6	7.8	8.1	7.4	7.6	8.35	8.3	8.5	7.6
	T2	7.5	7.6	7.5	7.8	8.0	8.4	7.4	7.7	8.6	8.5	8.7	7.8
3 m	T1	NL	7.15	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL
	T2	NL	7.1	7.6	7.6	7.3	NL	7.0	NL	7.5	NL	NL	NL

Residues of pyrazosulfuron-ethyl at various soil depths in 1 m lysimeter at 0-50 cm depths after 1 to 30-days were found to be 0.039 to 0.0059 µg/g at upper depth, 0.027 to 0.006 µg/g at 0-25 cm depth. In the 2 and 3 m depth soil lysimeters, 0.058 to 0.0046 µg/g pyrazosulfuron-ethyl residues were detected. In 3 m depth lysimeter, amount of pyrazosulfuron residues were 0.0223 to 0.003 µg/g at upper depth. Pyrazosulfuron-ethyl residues were below detection limit in lower depth in 3 m lysimeter (Table 7).

Table 7: Residues of pyrazosulfuron-ethyl in soil at various depths in lysimeter of 1-3 m depths

Depths	Residues of pyrazosulfuron-ethyl at various depths (µg/g)														
	1-day			3-day			10-day			30-day			60-day		
	1 m	2 m	3 m	1 m	2 m	3 m	1 m	2 m	3 m	1 m	2 m	3 m	1 m	2 m	3 m
Upper	0.039	0.058	0.044	0.0223	0.0210	0.025	0.016	0.0189	0.020	0.0059	0.0046	0.003	0.0015	0.0010	0.0010
0-25	0.027	0.053	0.023	0.0212	0.0127	0.022	0.010	0.0125	-	0.0060	0.0068	-	0.0031	0.0042	-
25-50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.067	0.079	-	0.0072	0.0088	-	0.0034	0.0022	-
50-75	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	0.049	0.093	0.0073	0.0154	0.004	<0.001	<0.001	<0.001
75-100		-	-		-	-		0.059	0.025		0.0050	0.0037	<0.001	<0.001	<0.001
100-125		-	-		-	-		0.066	0.059		0.0025	0.0043		<0.001	<0.001
125-150		-	-		-	-		0.029	0057		<0.001	0.0039		<0.001	0.0019
150-175			-			-			0.029		<0.001	0.0068		<0.001	<0.001
175-200			-			-			<0.001			<0.001			<0.001
200-225			-			-			<0.001			<0.001			<0.001

5.1.8. Adsorption behaviour of cyhalofop-p-butyl in sandy-clay loam and clayey soil

Cyhalofop-p-butyl adsorption was determined using batch equilibrium method at 1 : 25 soil : water ratio (w/v) using different concentrations (0, 0.5, 1, 2, 5, 10, 20 ppm) of cyhalofop-p-butyl in the glass centrifuge tube. Blank (without soil) sample containing 25 ml of $CaCl_2$ solution of cyhalofop-p-butyl served as control. The K_{oc} values were calculated by normalizing adsorption constant K_d with organic C content of the sorbate.

Adsorption isotherm indicated that cyhalofop-p-butyl was highly adsorbed in clayey than sandy-clay loam. Adsorption coefficient (K_f) was high in clayey soil (13.39), whereas it was low in sandy clay (K_f=2.26). The value of 1/n (slope) <1 indicated non-linear relationship between herbicide concentration and adsorption, and can be characterized as L type isotherm. The L type adsorption isotherm showed that clayey soil had high affinity to cyhalofop-p-butyl. A significant correlation between K_f and organic C content indicated major role of organic C content for cyhalofop-p-butyl adsorption in different soil. The K_{oc} value ranged from 265.9 and 2092.2 in sandy-clay loam and clayey soil, respectively (Table 8).

Table 8: K_f (Fruendlich constant), K_d (Coefficient of determination), 1/n (slope) and K_{oc} (organic C constant) values of cyhalofop-p-butyl in sandy clay loam and clayey soil

Soil type	Equation	K_f	1/n	R^2	K_d	K_{oc}
Sandy-clay loam	Y = 0.162x - 0.355 R^2 = 0.915	2.26	0.162	0.915	1.38	265.88
Clayey	y = 0.299x - 1.127 R^2 = 0.952	13.39	0.299	0.952	11.48	2092.18

5.1.9. Herbicides residues in direct-seeded rice-based cropping system

Wheat and rice plants were collected at maturity and analyzed by HPLC to see persistence of pendimethalin (1.25 kg/ha), oxyfluorfen (0.20 kg/ha) and quizalofop-p-ethyl (0.60 kg/ha) residues in chickpea; and cyhalofop (90 g/ha), bispyribac (25 g/ha) and fenoxaprop-p-ethyl (60 g/ha) in rice. At harvest, the residues of pendimethalin, oxyfluorfen and quizalofop-p-ethyl in chickpea soil were: 0.011, 0.002 and <0.001 µg/g, respectively. In chickpea seeds and straw, 0.020 and 0.008 µg/g residues of pendimethalin were found. However, quizalofop-p-ethyl and oxyfluorfen residues were found to be <0.001 and 0.003 µg/g, respectively in grains and straw (Table 9).

Table 9: Herbicide residues (µg/g) in soil and chickpea samples

Matrix	Pendimethalin	Quizalofop-p-ethyl	Oxyfluorfen
Soil	0.011	0.002	<0.001
Grain	0.020	<0.001	<0.001
Straw	0.008	<0.001	<0.003

At harvest, residues of cyhalofop-p-butyl, bispyribac-sodium and fenoxaprop-p-ethyl in rice soil were 0.004, <0.01, and <0.001 µg/g, respectively. In rice, the respective herbicide residue was: 0.001, <0.01 and 0.006 µg/g in grain, and 0.025, <0.01 and <0.001 µg/g in straw samples (Table 10).

Table 10: Herbicide residues in soil and chickpea plant samples

Matrix	Cyhalofop-p-butyl	Bispyribac-sodium	Fenoxaprop-p-ethyl
Soil	0.004	<0.01	<0.001
Grain	0.001	<0.01	0.006
Straw	0.025	<0.01	<0.001

5.2. Degradation of herbicide in the environment

5.2.1. Phototransformation of herbicides on leaf cuticle surface and environment

To investigate phototransformation of 2,4-D on leaf cuticle surface, experiments were conducted on thin-film of cutin under sunlight. After irradiation, the degradates were extracted in suitable solvents, processed and analyzed by LC-MS/MS and GC-MS/MS.

5.2.2. Photolysis of propaquizafop in water and soil

To investigate the phototransformation of propaquizatop, an experiment was conducted in aqueous phase and on soil under sunlight. The major photoproducts were isolated by column chromatography and preparative TLC. The structure of the products was elucidated by mass spectrum from LC-MS/MS (Figure 6).

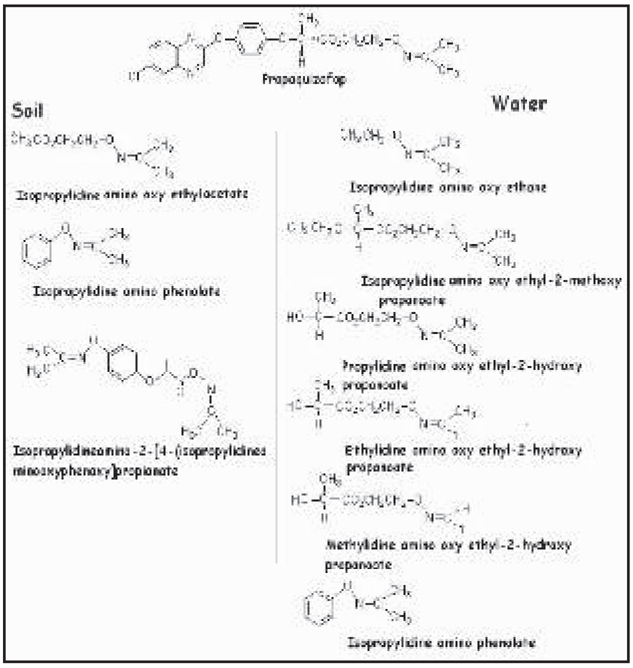


Figure 6: Phototransformation of propaquizafop in soil and water

5.2.3. Photolysis of sulfosulfuron in soil

Sulfosulfuron was irradiated on soil and innert glass surface, and the generated photoproducts were isolated by column chromatography and preparative TLC. The structure of the products was elucidated by mass spectrum from LC-MS/MS. A similar experiment was carried out on glass surface. In both cases, the routes of degradation were the cleavage of sulfonyl-urea bridge and the cleavage of sulphonyl-amide linkage (Figure 7).

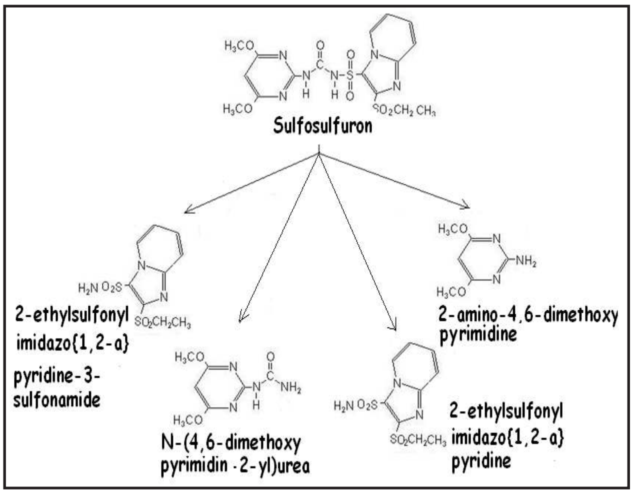


Figure 7: Photoproducts of sulfosulfuron on soil surface

5.3. Bio-remediation of pollutants using terrestrial/aquatic weeds

5.3.1. Efficacy of terrestrial weed species for treatment of drain water

An investigation was carried out to test the efficacy of weed-based phytoremediation system using *Arundo donax* for remediation of heavy metals in industrial drain water. The constructed wetland system consisted of pre-treatment overhead settling zone and treatment zone having three pairs of sequential tanks (3 m x 2 m x 0.75 m). The fast growing *Arundo* was planted hydroponically in first pair of tanks and in angular gravel media in surface and sub-surface tanks. The polluted water from waste water carrying drain was injected into pre-treatment overhead tanks, and after settling of solid particles at bottom, the water was directed to sequential treatment tanks for treatment. Water samples collected from the system were analyzed for nitrates, phosphates and different heavy metals at outlet point of sedimentation, hydroponic, surface and sub-surface tanks after treatment.

It was observed that extensive root system was developed in hydroponically grown tanks and the plant roots were also entangled with angular gravels in surface and sub-surface tanks. As compared to untreated drain water, the concentration of iron, cadmium, lead and nitrate was reduced to the extent of 68.2, 51.4, 76.9 and 88.4%, respectively in treated water collected from the outlet of last pair of sequential tanks (Table 11). Lower efficacy of phosphorus (46.3%) was observed in treated water. The concentrations of iron as 403, 507 and 407.3 ppm and cadmium as 4.7, 0.20 and 0.80 ppm were observed in *Arundo* plant grown under sequential tanks of hydroponics, surface and subsurface tanks, respectively.

Table 11: Changes in contaminants of drain water treated in *Arundo*-based phytoremediation system

Treatment	pH	Concentration (ppm)				
		Fe	Cd	Pb	NO_3	PO_4
Sedimentation	7.45	1.66	0.0062	0.036	19.5	2.72
Tank I (hydroponics)	7.35	1.25	0.0051	0.025	9.4	1.90
Tank II (surface tank)	7.32	0.92	0.0048	0.001	8.8	1.71
Tank III (sub-surface tank)	7.25	0.55	0.0036	0.009	2.3	1.56
Waste water (untreated)	7.60	1.73	0.007	0.039	20.3	2.91
Efficiency (%)	-	68.2	51.42	76.9	88.4	46.3

Having reduced the pollutant concentration in treated water, *Arundo*-based wetland system has indicated its usefulness for removal of heavy metals (Cd and Pb) in industrial drain water prior to irrigation use. Reduction of nitrate in treated water also has implications for protection of pond water quality where aquaculture is practiced. The drastic change in the colour of treated water after its treatment was observed as compared to untreated waste water.

Waste water carrying drain

Arundo grown in angular gravel media (without soil)

5.3.2. Evaluation of terrestrial weed species for lead tolerance and accumulation

A pot experiment was carried out to evaluate the potential of four plant species, viz. *Vetiveria zizinoides, Typha latifolia, Acorus calamus* and *Arundo donax* exposed to different Pb levels, viz. 0, 25, 100, 200 and 400 ppm. Significant differences among plant species were observed with regard to lead removal. Results indicated two to three times higher Pb content in shoots of *Arundo donax* (104.8 mg / kg), followed by *Vetiveria ziznoides* (56.8 mg / kg), *Typha latifolia* (38.3 mg / kg) and *Acorus colamus* (20.9 mg / kg). Higher Pb transfer factor (from root to shoot) was observed in case of *Vetiveria zizinoides* (2.22). At the higher levels (200-400 ppm), except *Vetiveria*, most of Pb accumulation by *Arundo donax, Typha latifiolia* and *Acorus calamus* was retained in their roots (Table 12).

Table 12: Pb accumulation in shoot and root of different weed species exposed to varying levels

Pb levels (ppm)	Pb accumulation in shoot (mg/kg dry weight)				Pb accumulation in root (mg/kg dry weight)			
	Vetiveria zizinoides	*Typha latifolia*	*Acorus calamus*	*Arundo donax*	*Vetiveria zizinoides*	*Typha latifolia*	*Acorus calamus*	*Arundo donax*
0	2.1	3.2	1.4	3.8	3.1	1.8	1.2	6.2
25	68.4	36.6	18.8	39.3	22.5	19.2	20.3	91.1
100	97.3	64.1	43.7	139.6	25.8	30.5	36.4	119.7
200	59.3	48.0	23.4	162.0	30.3	54.8	388.5	312.8
400	57.1	39.5	17.1	179.5	45.8	103.4	338.8	671.3
Mean	56.9	38.3	20.9	104.8	25.5	41.9	157.1	240.2
LSD (P=0.05)	12.9	22.8	10.2	51.8	NS	NS	NS	NS

6. RESEARCH PROGRAMME - 5

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

Inproved weed management technologies are in great demand by the farmenrs. This is because of the acute labour scarcity and high cost of manual weeding throughout the country. Unfortunately, there is not enough awareness among the farmers about improved weed management practices, even in areas not far away from the cities and research institutions. It is also often argued that scientists are doing their research work without any regard to the real problems faced by the farming community. In order to understand the weed related problems faced by the farmers and find solutions, this on-farm research programme has been initiated to understand farmers' problems and undertake necessary interventions through farmer participatory approach.

Sub-programme	Experiments	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)	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)	Anil Dixit, 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
Others		
Weed spatial variability in field condition		Yogita Gharde, K.K. Barman and V.P. Singh

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

Winter season, 2011-12

Wheat

Thirty-five demonstrations were laid out on farmers' fields in 3 locations (Panagar, Sihora and Patan) of Jabalpur. Technologies consisted of post-emergence application of herbicides such as clodinafop @ 60 g/ha + metsulfuron @ 4 g/ha, mesosulfuron + iodosulfuron @ 18 g/ha, clodinafop @ 60 g/ha, sulfosulfuron + metsulfuron @ 32 g/ha in wheat crop. Major weeds were: *Lathyrus sativa, Vicia sativa, Chenopodium album, Medicago hispida* and *Melilotus alba* among broad-leaved weeds, and *Avena* sp. (wild oat) and *Phalaris minor* among grasses.

Herbicides were applied according to available weed flora at the location. All the treatments controlled weeds effectively and increased the yield of wheat (27-39%) as compared to farmers practice. Results revealed that post-emergence application of mesosulfuron + iodosulfuron and clodinafop + metsulfuron) gave broad-spectrum weed control and higher benefit of ` 13,500 (Table 1).

Table 1: Demonstration of improved weed management technologies in wheat at Panagar, Sihora and Patan locality of Jabalpur

Location (no. of FLDs)	Treatment	Weed count (no./m^2)	Dry weight (g/m^2)	Grain yield (t/ha)	Economic benefit over FP (`/ha)	B:C ratio
Panagar and Sihora (02)	Farmers' practice	180	68	2.89	-	1.88
	Clodinafop + metsulfuron methyl @ 60 + 4 g/ha	46	30	4.01	13,524	2.37
Panagar, Sihora and Patan (18)	Farmers' practice	214	71	2.90	-	1.87
	Mesosulfuron + iodosulfuron @ 18 g/ha (Po)	57	32	3.98	13,528	2.41
Sihora and Patan (12)	Farmers' practice	250	79	2.71	-	1.75
	Clodinafop @ 60 g/ha	107	36	3.62	11,215	2.20
Sihora and Panagar (3)	Farmers' practice	155	65	3.08		1.99
	Sulfosulfuron + metsulfuron methyl @ 32 g/ha	63	34	3.92	10,273	2.37

Farmers' practice (FP) - no weeding operation; cost of weed management treatment was ` 1905, 1395, 1305 and 1375 per ha at the four locations, respectively. Wheat price was taken as ` 13850/t

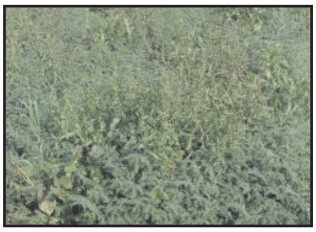
Chickpea

Five demonstrations were conducted in the villages, viz. Mahangwa, Padaria and Bharda. Treatments consisted of pre-emergence application of pendimethalin (stomp-xtra) @ 800 g/ha and mechanical weeding (hoeing) at 30-35 DAS. Fields were mainly infested with *Avena* sp., *Phalaris minor*, *Chenopodium album*, *Medicago hispida*, and *Lathyrus sativa*. Results revealed that pendemethalin effectively controlled weeds and gave higher weed control efficiency (WCE 59%) with additional benefit of ` 10,530 per ha (Table 2).

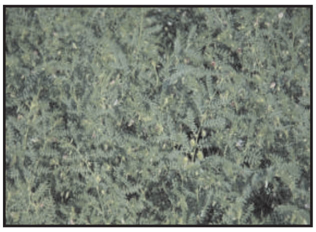
Table 2: Demonstration of improved weed management technologies in chickpea at Mahangawa, Padaria and Bharda

Location (no. of FLDs)	Treatment	Weed count (no./m^2)	Dry weight (g/m^2)	Grain yield (t/ha)	Economic benefit over FP (`/ha)	B:C ratio
Mahangawa, Bharda and Padaria (3)	Farmers' practice	210	134	1.23	-	1.51
	Pendimethalin @ 800 g/ha	84	55	1.73	10530	2.00
Mahangawa and Bharda (2)	Farmers' practice	206	133	1.23	-	1.52
	Mechanical weeding (hoeing at 30-35 DAS)	128	100	1.56	6850	1.84

*Farmers practice (FP)- No Weeding operation/deep summer ploughing



Weedy check



Treated with pendimethalin

Mustard

Five demonstrations were laid out in two locations, viz. Tagar Mahangwa and Umariya. Improved technologies consisted of pre-emergence application of pendimethalin (stomp-xtra) @ 800 g/ha and one hoeing at 30 DAS. Dominant weed flora were: *Chenopodium album*, *Medicago hispida*, *Vicia sativa*, *Parthenium hysterophorus* and *Cyperus* spp. Results revealed that pendimethalin was more effective than hoeing, and gave additional benefit of ` 11,415 per ha (Table 3).

Table 3: Demonstration of improved technology in chickpea in the villages of Tagar Mahangwa and Umariya

Location and no. of demonstrations	Treatment	Weed count (no./m^2)	Dry weight (g/m^2)	Grain yield (t/ha)	Economic benefit over FP (`/ha)	B:C ratio
Tagar Mahangawa and Umaria (3)	Farmers' practice	128	93	1.11	-	1.35
	Pendimethalin @ 800 g/ha	42	28	1.74	11,415	1.96
Tagar and Umaria	Farmers' practice	130	94	1.10	-	1.36
	Mechanical weeding (hoeing) at 30 DAS	78	51	1.48	6,460	1.70

Rainy season, 2012

To further intensify the OFR/ demonstration programme and also keeping in view the possible initiation of `Farmers First' programme, a project was initiated from rainy season 2012 to transfer as well as to evaluate the improved weed management technologies at the farmer's field in and around Jabalpur district. The aim of this programme was to enhance adoption level of weed management technologies with simultaneous increase in productivity as well as improvement in the socio-economic condition of the farmers in a sustainable manner.

Initially, different localities of Jabalpur district were identified and surveyed with regard to cropping pattern, location-specific weed problems and management practices being adopted. Accordingly, six localities with little technical-knowhow in terms of existing weed management practices were selected. Subsequently, 7-8 farmers representing all sections of farmers were selected randomly in each locality. OFR/ demonstration using improved weed management technologies were laid out in rice, soybean and maize during rainy season and wheat, chickpea and field pea during winter season. Trials were conducted in a participatory mode with active involvement of farmers.

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

On-farm evaluation and demonstrations were conducted in soybean at 5 farmers' fields each in the villages of Pola and Dhora of Majholi region. Application of chlorimuron-ethyl @ 10 g/ha + fenoxaprop-p-butyl @ 100 g/ha at 20-25 DAS in village Pola, and imazethapyr @ 100 g/ha at 20 DAS in village Dhora were made. Farmers of both the localities perform weeding by cycle wheel hoe depending upon the field condition. In each location, crop was infested with mixed weed flora, viz. *Echinochloa colona*, *Dinebra retroflexa*, *Cyperus* spp., *Digera arvensis*, *Commelina communis*, *Euphorbia geniculata*, *Cynotis* sp., *Cucumis melo* and *Parthenium hysterophorus.* Results revealed that improved weed management practice registered lower weed growth and higher seed yield of soybean over farmers' practices at all locations (Table 4, 5). The net returns of

` 26,020-33,115/ha were obtained under improved weed management practices at both the sites which were much higher as compared to farmers' practices (` 15,325- 21,183/ha). Similarly higher B:C ratio has also been recorded with improved weed management practices over farmers' practice. It was concluded that with the adaption of improved weed management technique, higher income of ` 11,314/ha could be achieved over farmers' practice.

Table 4: Demonstration of improved weed management technology (chlorimuron-ethyl @ 10 g/ha + fenoxaprop-p-butyl @ 100 g/ha) in soybean at Pola village (Majholi)

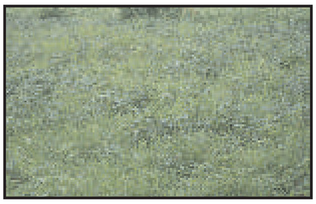
Demonstration sites (Village: Pola)	Weed population (nos./m^2)	Weed biomass (g/m^2)	Weed control efficiency over FP (%)	Seed yield (t/ha)	Net returns (`/ha)	B:C ratio
1. Farmer's practice	169	57.4	-	1.13	9,075	1.48
Improved technology	38	12.3	79	1.75	23,295	2.14
2. Farmer's practice	137	59.9	-	1.60	20,950	2.10
Improved technology	22	7.9	87	2.03	30,295	2.48
3. Farmer's practice	89	41.8	-	1.75	24,700	2.30
Improved technology	12	3.9	79	1.90	27,045	2.32
4. Farmer's practice	57	23.7	-	1.10	8,450	1.44
Improved technology	6	2.1	91	1.67	21,170	2.04
5. Farmer's practice	108	49.5	-	1.30	13,450	1.71
Improved technology	12	4.1	92	1.95	28,295	2.38
Overall performance (mean of 5 farmers)						
Farmer's practice	112	46.5	-	1.38	15,325	1.81
Improved technology	18	6.1	86	1.86	26,020	2.27

FP: Farmers practice, 1: Atal Bihari Patel, 2: Lochan Patel, 3: Raghuveer Prasad Singh Gaur, 4: Subhash Patel and 5: Virendra Patel

Table 5: Demonstration of improved weed management technology (imazethapyr @ 100 g/ha) in soybean at Dhora village (Majhauli)

Demonstration site (Village: Dhora)	Weed population (nos./m^2)	Weed biomass (g/m^2)	Weed control efficiency over FP (%)	Seed yield (t/ha)	Net returns (`/ha)	B:C ratio
1. Farmer's practice	130	44.74	-	1.60	19,615	2.10
Improved technology	24	6.35	86	2.30	37,115	2.82
2. Farmer's practice	117	48.37	-	1.50	18,450	1.97
Improved technology	48	15.85	67	1.85	25,865	2.27
3. Farmer's practice	65	26.55	-	1.40	15,950	1.84
Improved technology	41	18.57	30	2.15	33,365	2.64
4. Farmer's practice	68	33.40	-	1.70	23,450	2.23
Improved technology	42	15.48	54	2.15	33,365	2.64
5. Farmer's practice	64	28.89	-	1.90	28,450	2.49
Improved technology	55	16.78	42	2.25	35,865	2.76
Overall performance (mean of 5 farmers)						
Farmer's practice	89	36.40	-	1.62	21,183	2.13
Improved technology	42	14.60	56	2.14	33,115	2.63

FP: Farmers' practice, 1: Ram Kumar Patel, 2: Rajesh Patel, 3: Bhagvat Patel, 4: Shyam Sunder Patel and 5: Kumbhaj Patel



Weedy crop of soybean

Herbicide treated soybean

Scientists visiting on-farm trials on soybean at Majholi

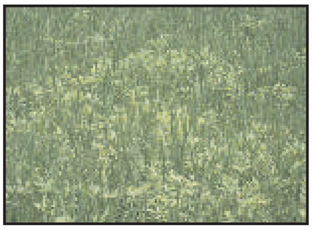
6.1.2. On-farm research and demonstration of weed management technologies in direct-seeded rice-based cropping system (Bankhedi locality)

On-farm trials were conducted in direct-seeded rice near Bankhedi Block in village Amna about 40 km away from Jabalpur. Application of bispyribac-sodium at 25 g / ha with 2,4-D (amine salt) at 500 g / ha at 25 days after sowing was done to control grassy, broadleaved weeds and sedges. The fields of eight farmers were mainly infested with *Echinochloa colona, Commelina communis, Cyperus sp. Phyllanthus niruri, Physalis minima, Caesulia auxillaris* and *Alternanthera sessilis.* Farmer's field with Application of bispyribac-sodium and 2,4-D were recorded the lower weed infestation as compared to farmer's practice (one hand weeding) (Table 6). An increase of 10% in yield was recorded with the use of improved weed management technologies over farmer's practice. Net returns of ` 34,079 / ha and benefit : cost ratio of 2.8 were obtained under the same practice as compared to farmers practice (` 26,604). Thus, an additional income of ` 8,000 was fetched with demonstrated technology over the farmer's practice. Successful demonstration on application of bispyribac-sodium with 2,4-D convinced other farmers of the area to adopt this technology.

Table 6: Effect of farmer's practice and improved technologies on weed growth, crop productivity and income at Amna village, Bankhedi

Demonstration site (Village: Amna)	Weed density (no./m²)	Weed dry weight (g/m²)	Weed control efficiency (%)	Rice grain yield (t/ha)	Net returns (`/ha)	B:C ratio
1. Farmer's practice	97	36		3.58	24,992	2.15
Improved technology	27	13	64	3.92	31,921	2.68
2. Farmer's practice	51	24		3.50	23,900	2.10
Improved technology	41	14	42	3.67	28,671	2.50
3. Farmer's practice	66	35		4.33	34,742	2.60
Improved technology	62	21	66	4.75	42,750	3.25
4. Farmer's practice	97	68		4.58	37,979	2.75
Improved technology	35	21	40	5.17	48,171	3.53
5. Farmer's practice	105	46		3.08	18,492	1.85
Improved technology	57	21	63	3.42	25,421	2.33
6. Farmer's practice	61	36		3.50	23,900	2.10
Improved technology	47	14	70	3.92	31,921	2.68
7. Farmer's practice	72	37		3.58	24,979	2.15
Improved technology	35	17	51	4.00	33,000	2.73
8. Farmer's practice	74	43		3.50	23,900	2.10
Improved technology	41	15	63	3.83	30,842	2.62
Overall performance (mean of 8 farmers)						
Farmer's practice	78	41		3.71	26,604	2.23
Technology demonstrated	43	15	65	4.08	34,079	2.79

No. of farmers (8); 1: Gagan Dubey, 2: Omkar Singh, 3: Madan Kumar, 4: Ajay Kumar Singh, 5: Madhv Singh, 6: Prakash Thakur, 7: Kushal Singh, 8: Premlal



Unweeded rice fields

Treated rice field

Scientists interacting with the farmer

Faulty spray being adopted by village boys

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

These on-farm trials were conducted in two villages of Panagar block, viz. (i) Mahangawa on direct-seeded rice, and (ii) Baher on transplanted rice. The holding size of the farmers was follows:

Mahangawa		Baher	
Name of farmer	Holding size (acres)	Name of farmer	Holding size (acres)
Mahesh Prasad Tiwari	4.0	Vipin Patel	4.0
Yogendra Kumar	12.5	Prashant Patel	3.0
Vishnu Tiwari	13.0	Uday Lodhi	7.0
Rajesh Patel	9.5		
Sunil Uapadhayaya	50.0		

Weed control efficiency ranged from 79.4-93.2% in direct-seeded rice and 79.5-87.7% in transplanted rice. In direct-seeded rice, 6-18% higher grain yield was recorded with improved management practice over farmer's practice, while in transplanted rice, the increase in yield was 7-10% compared with farmer's practice (Table 7).

Table 7: Effect of farmers' practice and improved technologies on weed growth, crop productivity and income

Name of village/ farmer	Farmer's practice		Treated		Grain yield (t/ha)		Benefit : cost ratio	
	Weed count (no./ m^2)	Dry weight (g/m^2)	Weed count (no./ m^2)	Dry weight (g/m^2)	Farmer's practice	Treated	Farmer's practice	Treated
Mahangawa (Direct-seeded rice)								
Mahesh Prasad Tiwari	167	87.6	42	18.0	3.13	3.33	2.34	2.79
Vishnu Tiwari	59	43.5	6.1	3.0	3.48	4.12	2.57	3.33
Rajesh Patel	56.5	42.7	5.7	4.1	3.38	3.800	2.45	3.06
Yogendra Kumar Sunil Uapadhayaya	Due to erratic pattern of rain and lack of irrigation water (First long dry spell after sowing, then heavy water logging), very poor germination was evident; hence no systematic data could be recorded.							
Baher (Transplanted rice)								
Vipin Patel	79.5	43.6	22.6	8.9	3.52	3.83	2.12	2.53
Prashant Patel	74	45.5	7.7	7.1	3.60	3.97	2.17	2.62
Uday Lodhi	71	60.5	9.6	7.4	3.80	4.05	2.30	2.68

Effect of bispyribac-sodium on farmers' field in Mahangawa village

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

On farm trials were conducted by a team of DWSR scientists in Kirsod and Bhamki villages in Shahpura block, about 30 km away from Jabalpur. Application of bispyribac-sodium at 25 g/ha with Almix (chlorimuron + metsulfuron) at 4 g/ha was sprayed at 25 days after sowing to control all grassy, broadleaved weeds and sedges. Fields of eight farmers were mainly infested with *Alternanthera sessilis*, *Commelina communis*, *Caesulia axillaris*, *Echinochloa colona*, *Cyperus* sp., *Phyllanthus niruri* and *Physalis minima*. Application of bispyribac-sodium and almix recorded the lower weed infestation as compared to farmer's practice (one hand weeding). Yield improved to the tune of 5-9% by improved weed management technologies over farmer's practice. Grain yield and benefit : cost ratio were also higher in improved practices in comparison to farmers' practice (Table 8). Demonstrations encouraged other farmers of the villages to adopt technologies suggested by DWSR.

Table 8: Effect of farmers' practice and improved technologies on weed growth, crop productivity and income

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
Village: Kisrod									
Magan Singh Thakur	31	16.79	284	199.38	91.58	3.80	3.38	3.10	2.49
Munim Kushwaha	27	11.67	386	225.28	94.82	3.97	3.47	3.24	2.56
Suresh Tiwari	36	30.18	186	148.36	79.66	3.57	3.18	2.91	2.34
Surjan Bai	29	22.36	238	183.2	87.79	3.48	3.13	2.84	2.30
Village: Bhamki									
Purushottam Patel	95	63.22	444	287.92	78.04	3.47	3.10	2.83	2.28
Durga Prasad Patel	66	29.06	238	147.44	80.29	3.80	3.30	3.10	2.44
Kamla Prasad	44	13.06	422	200.46	93.48	3.87	3.35	3.15	2.48
Brijesh Dubey	32	15.47	312	203.36	92.39	3.83	3.33	3.13	2.46

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

To disseminate the improved technology for weed management in rice, eight demonstrations were conducted on transplanted rice during rainy season 2012 in the village Paudi-Kala and Gosalpur. Londax Power, a combination product of bensulfuron-methyl 0.6% + pretilachlor 6%, was applied to control a broad-spectrum of weeds, viz. *Echinochloa crusgalli* and *Echinochloa colona* in grasses, *Cyperus iria, Cyperus difformis, Cyperus rotundus* and *Fimbristylis miliacea* in sedges, and *Ludwigia parviflora, Marsilea quadrifolia, Sphenoclea zeylancia, Eclipta alba* and *Ammania baccifera* in broadleaved weeds. It was observed that in farmer's practice, the weed count was as high as 173 plants / m^2, whereas in treated plots, the weed counts were within the range of 7-21plants / m^2. Weed control efficiency ranged from 62 to 95% (Table 9). Farmers were satisfied with the performance of londax power in terms of weed control and yield.

Table 9: Effect of farmers' practice (FP) and improved technologies on weed growth and rice productivity

Name of farmer (land holding)	Weed population (no./m²)		Weed dry biomass (g/m²)		Weed control efficiency (%)	Grain yield (t/ha)	
	FP	Treated	FP	Treated		FP	Treated
Rakesh Kumar Sahu (7 acre)	160	7.5	117.1	5.6	95.2	3.93	4.63
Santoshi Yadav (8 acres)	173.5	18.1	103.1	9.7	90.6	3.18	4.00
Ganesh Sahu (3 acres)	77.0	21.9	38.0	8.7	77.2	5.10	5.44
Manoj Vishwakarma (6 acres)	69.0	14.3	36.1	13.5	62.5	4.58	4.75
Dilip Sahu (15 acres)	130.5	15.7	78.9	8.0	89.8	3.08	3.75
Dev Vishwakarma (4 acres)	65.5	10.12	31.9	7.9	75.1	4.50	4.58

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

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.

Eight on-farm demonstrations on maize were conducted in these villages. Crop was infested with mixed weed flora, viz. *Echinochloa colona, Dinebra retroflexa, Cyperus* spp., *Commelina communis, Ageratum conizoides* and *Euphorbia geneculata*. Pre-emergence application of atrazine @ 1.0 kg/ha followed by one hand weeding at 30-35 DAS was most effective, and gave the additional benefit of ` 13,126 per ha (Table 10). The grain yield with improved technology was 60% higher than farmers practice. Similarly, higher B:C ratio was recorded with improved weed management practices over farmer's practice. It was concluded that with the adaption of improved weed management technique, higher income could be achieved over farmers' practice. Farmers were highly satisfied with demonstrated technologies.

Table 10: Effect of farmers' practice and improved technologies on weed growth, maize productivity and income in Kundam villages

Treatment	Weed count (no./m^2)	Dry weight (g/m^2)	Grain yield (t/ha)	Economic benefit due to treatment (`/ha)	B:C ratio
Farmers' practice (1 HW)	129	49	1.52	-	1.21
Atrazine @ 1.0 kg/ha + 1 HW at 35 DAS	33	15	2.51	13,126	1.92


Weedy maize


Treated maize


Scientists visiting maize field


Healthy cobs of treated maize fields

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

Socio-economic impact assessment

A study was conducted at Panagar and Sehora localities in 2011-12 using the stratified random sampling technique. Results revealed that most of the farmers followed rice-wheat cropping system. Weed control in rice is a highly cumbersome operation as it involves more labourers, which are mostly not available at the time of need and is capital intensive. The cost of improved weed management practices was only ` 1200-1500/ha, while the conventional practices (manual weeding) required around ` 4000/ha. The difference in income realization between the adopters and non-adopters of integrated weed management was studied. Results revealed that IWM adopters obtained an increased yield of 0.9–1.0 t/ha and additional income of ` 9000-10000/ha compared with non-adopters.

Collaborative study through KVKs

This Directorate made an attempt in association with Zonal Project Directorate (Zone VII) to introduce and demonstrate improved weed management technologies for different crops under various farming situations across Madhya Pradesh, Chhattisgarh and Orissa during 2010-12. A total of 20 improved weed management technologies were demonstrated by conducting 1400 OFTs/FLDs in wheat, soybean, tomato, rice and groundnut through 67 KVKs. All the improved technologies that have been demonstrated under this programme decreased weed intensity compared to the prevailing farmers' practices (one hand weeding) and showed highly encouraging outcome in terms of increased productivity (18-22%), decreased cost of production and increased B:C ratio. This indicates that further intensification of this programme by providing training to more number of farmers through KVKs and conducting more OFTs / FLDs in a participatory mode would result in a significant increase in the overall productivity of the region.

Others

Weed spatial variability in field condition

Weed spatial variability was studied at the research farm of the Directorate using geo-statistical method called kriging. Kriging was performed on soil seed bank data and actual weed count data on field. Weed count data for many weed species, viz. *Ammania baccifera*, *Echinochloa colonum*, *Cyprus iria*, *Commelina communis*, *Phylanthus niruri*, and *Ludvigia parviflora* were obtained. The analysis was performed using Variowin and SAS 9.2 (SAS Institute Inc., USA) softwares. After transformation, a semivariogram was calculated, which describes the variation between measurements separated by a certain distance. Thereafter, a model was fitted to the semivariogram and the parameters from the model were used in the estimation of weed maps by kriging. Soil seed bank data and actual weed counts data were analyzed separately.

Analysis showed that distribution of weeds was random and violated the assumption of Randomized Block Design (RBD) which is originally framed to account for mainly soil fertility variations (Figure 1). Therefore, when RBD is used for weed control trials, there is possibility that it may ignore the major contributor of the variation and thus lead to misleading inferences in weed control trials. This analysis also showed that kriging weed densities based on weed counts collected in 5×5 m^2 plots provided additional information which can be used to modify the existing design to obtain precise estimate. Distribution maps of different weeds were obtained which also showed the random pattern of distribution.

A B C

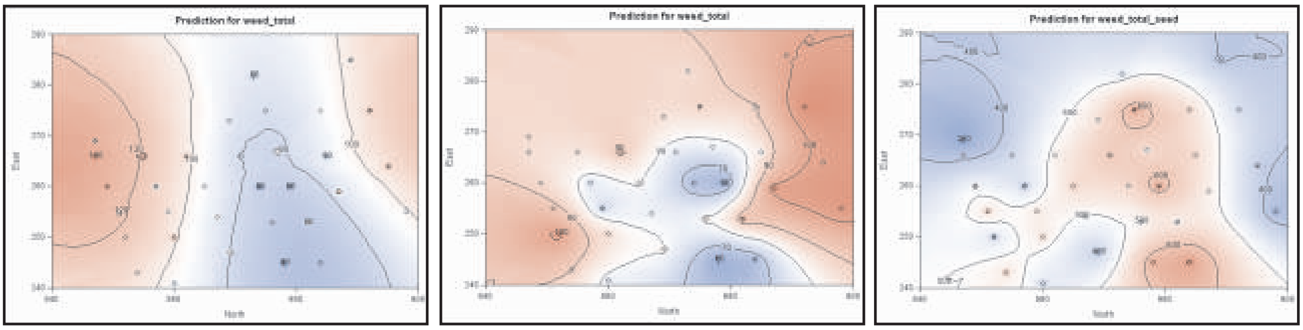


Figure 1: Prediction surface using weed count data at 30 DAS (A) and 60 DAS (B) and using soil seed bank data (C)

Dark red colour shows high intensity of weeds while very light blue colour depicts the presence of few weeds in the field. Actual weed count data does not agree with the soil seed bank data (A, B & C). Reasons behind this is that all the seeds present in the soil might not find favourable conditions (temperature, moisture, etc.) for their growth and development in that season which was present in huge numbers, while other seeds may be in dormant conditions. Some weed species like *Ludvigia parviflora* find favourable condition and emerge as major weed flora in that season. Prediction surface obtained using weed count data also shows some minor differences in some places where water logging was present at the time of observation at 30 DAS, while at 60 DAS it shows more weed population in those places where waterlogging condition was not present.

7. EXTERNALLY-FUNDED PROJECTS

Two externally-funded projects were implemented at the Directorate during 2012-13 as follows :

	Title of project	Source of funding	Principal Investigator	Associates
7.1	**Precision farming technologies - based on microprocessor and decision support systems for enhancing input application efficiency in production agriculture**	NAIP	V.P. Singh	Raghwendra Singh and C. Kannan
	7.1.1. Interference of variable density of weeds in rice, soybean and wheat			
	7.1.2. Precision nitrogen management based on SPAD values in rice-wheat cropping system			
7.2	**Development and formulation of microbial metabolites for the management of *Orobanche* in mustard**	MPBT	C. Kannan	P.P. Choudhury
	7.2.1. Isolation of native antagonistic fungi from the farmers' field infested with *Orobanche*			
	7.2.2. Extraction of cell free culture extracts from the microbes			
	7.2.3. Microbial metabolites as elicitor to induce systemic resistance in host for biological management of the root parasitic weed - *Orobanche*			

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

7.1.1. Interference of variable density of weeds in rice, soybean and wheat

Increasing density of weeds in all crops showed corresponding reduction in yield and yield attributes. In rice grown during rainy season 2012, a critical density of *Echinochloa colona (*15 plants/m^2) caused significant reduction in plant height, effective tillers and yield attributes like panicle length and 100-grain weight, which ultimately reduced the grain yield of rice by 40%. In soybean, a critical density of *Echinochloa* (20/m^2) started causing significant reduction in number of pods, seeds/pod and seed yield. On the other hand, a critical density of *Euphorbia geniculata* (30/m^2) caused reduction in pods/plant (9.5%), seeds/pod (12.8%) and seed yield (18.4%). In case of wheat grown during 2011-12, a critical density of *Phalaris minor* (75/m^2) caused significant reduction in effective tillers, spike length and grain weight/spike, leading to reduction in grain yield by 10%. On the other hand, a critical density of *Avena ludoviciana* even at 15/m^2 caused significant reduction in effective tillers (34.4%), which ultimately reduced the grain yield by 36.9%. However, a critical density of *Cichorium intybus* (30/m^2) and *Chenopodium album* (40/m^2) caused significant reduction in effective tillers by 11% and grain yield by 13-20%.

Spectral signatures

Spectral signatures of constant density of crops and their respective variable densities of major weeds i.e., (i) rice with *Echinochloa colona* and *Alternanthera sessilis,* (ii) soybean with *Echinochloa colona* and *Euphorbia geniculata* and (iii) wheat with *Phalaris minor, Avena ludoviciana, Cichorium intybus* and *Chenopodium album* weed were taken with spectro-radiometer during critical period of crop-weed competition staring from 30 DAS at 1 m height and using 25^0 (fiber optic light guide) FOV (Figure 1). Reflectance at wavelengths 650 and 750 nm was recorded to calculate NDVI for arriving at the spectral signature of the particular crop/weed. Chlorophyll

(b) had a negative correlation with NDVI. NDVI was highly variable under the natural conditions, and hence NDVI will be estimated under artificial conditions with different light filters, especially in red and green range, for developing the crop/weed specific spectral signatures. Chlorophyll index (a/b ratio) of weeds was higher as compared to rice. In case of soybean, it was at par with the crop. Similarly, during winter season, the chlorophyll index (a/b ratio) of *Cichorium intybus* was higher than wheat crop. Chlorophyll index (a/b ratio) had a positive correlation with NDVI. In crop mimic weed like *Echinochloa* with rice and *Euphorbia geniculata* with soybean, the NDVI values were at par. The weeds having a higher chlorophyll index (a/b ratio) than crops also had more NDVI. It was concluded that the chlorophyll ratio had a strong correlation with stability of spectral reflectance data, which would form the spectral signature data.

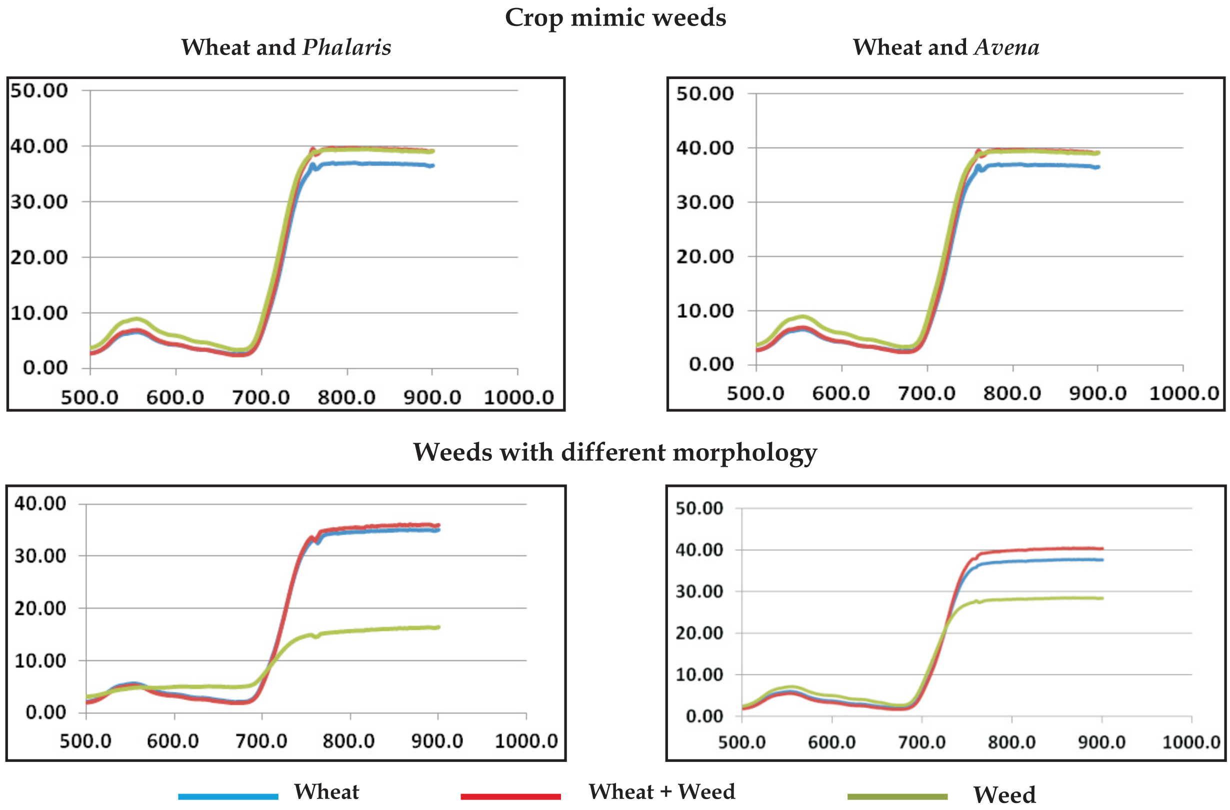


Figure 1: Spectral signatures recorded in wheat with variable density of respective weeds

7.1.2. Precision nitrogen management based on SPAD values in rice - wheat cropping system

A field experiment with treatments consisting of 3 SPAD values, viz. 34, 36 and 38 in rice; and 38, 40 and 42 in wheat along with 3 N levels, viz. (15, 25 and 35 kg/ha was conducted in strip-plot design during rainy season 2012. Results revealed that different yield attributes like 100-grain weight, grain weight/panicle and number of grains/panicle were non-significant due to treatments in rice (Table 1). However, the highest values for all characters were observed with SPAD at 38 and 35). Among SPAD treatments, the maximum grain yield (3.55 t/ha) was obtained with SPAD 38, followed by SPAD 36 (3.53 t/ha) and SPAD 34 (3.48 t/ha). Among N levels, maximum grain yield (3.66 t/ha) was recorded with 35 kg N/ha. Interaction was not significant, however, the maximum grain yield (3.91 t/ha) was observed with SPAD 40 and 35 kg N/ha, with total application of 165 kg N/ha.

In wheat (2011-12), different yield attributes, viz. 100-grain weight, grain weight/spike and number of grains/spike were also not influenced significantly due to various treatments. However, the highest values for all characters were observed with SPAD 42 and 35. The highest grain yield of wheat was recorded at SPAD values of 42 (5.73 t/ha) and 35 (5.35 kg/ha) with total application of 188 kg N/ha.

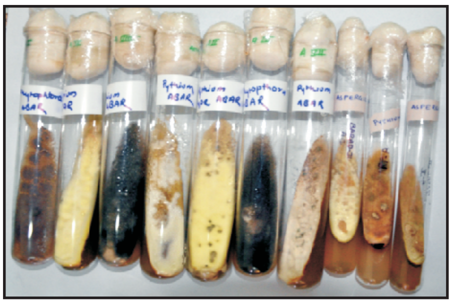
Table 1: Yield attributes and grain yield of rice (2012) and wheat (2011-12) as influenced by N levels at different SPAD Values

Treatment	Total amount of N applied (kg/ha)		Grain weight/panicle or spike (g)		Number of grains/ panicle or spike		Grain yield (t/ha)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
SPAD values								
34 (R) / 38 (W)	108	123	3.43	2.27	135.3	48.7	3.48	5.10
36 (R) / 40 (W)	133	143	3.63	2.29	147.4	49.4	3.53	5.22
38 (R) / 42 (W)	137	160	4.37	2.31	161.0	49.6	3.55	5.73
LSD (P=0.05)			NS	NS	NS	NS	NS	NS
N levels (kg/ha)								
15	107	116	3.57	2.25	148.8	48.9	3.41	4.69
25	129	143	3.93	2.32	140.8	49.3	3.49	5.14
35	142	165	3.93	2.30	154.2	49.4	3.66	5.35
LSD (P=0.05)	-	-	NS	NS	NS	NS	NS	**0.18**

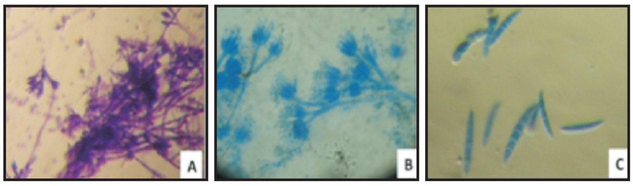
7.2. Development and formulation of microbial metabolites for the management of *Orobanche* in mustard

7.2.1. Isolation of native antagonistic fungi from farmers' field infested with *Orobanche*

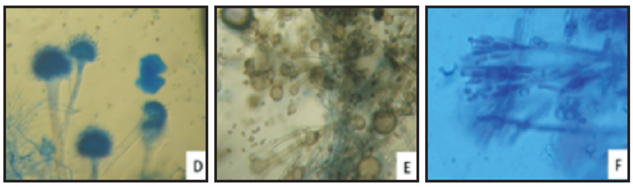
A survey was conducted in the fields infested with *Orobanche* in and around Gwalior and Bharatpur in July 2012 for sampling of rhizosphere soil microbes. Isolation of the soil fungi was done using serial dilution technique and pure cultures were obtained by hyphal tip techniques, which were maintained in PDA slants at 4^{0}C for further use. The cultures were recultured in fresh media fortnightly to prevent attenuation. The fungi, viz. *Trichoderma* sp., *Fusarium* sp., *Pythium* sp., *Penicillium* sp., and *Aspergillus* sp., were identified from the soil samples.



Microbes isolated from *Orobanche*



A. *Trichoderma viride*, B. *Gliocladium virens*, C. *Fusarium* sp.



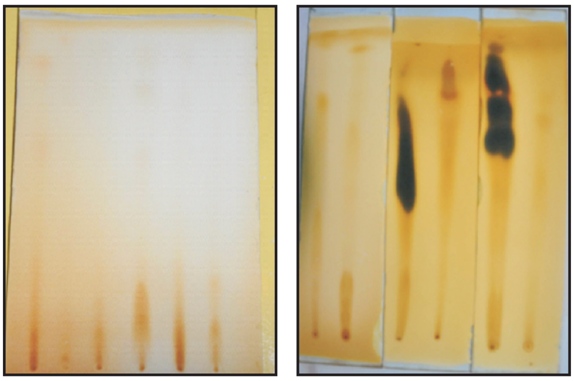
D. *Aspergillus* sp., E. *Pythium* sp., F. *Penicillium oxalicum*

Microbes isolated from *Orobanche* in test tubes and their enlarged views

7.2.2. Extraction of cell free culture from microbes

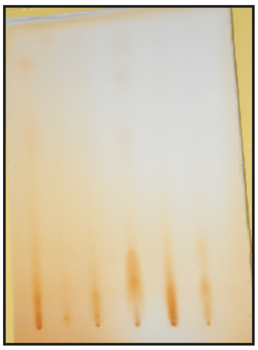
With the aim of standardization of culture media for better growth and production of metabolites, different broths, viz. Richard's broth, malt extract broth, potato dextrose broth, potato sucrose broth, dextrose peptone broth, dextrose broth, were tested. Isolated microbes were inoculated in the different broths as mentioned above in 1000 ml conical flasks and kept at 28±2^{0}C for 2 weeks. Robust growth of the fungi was observed in PD and PS broths.

Extraction of crude fraction was standardized by using different solvent, viz. dichloromethane, ethyl acetate, and chloroform. The results obtained from the TLC studies suggested that chloroform was not able to extract the microbial compounds in quantity. Among the other two solvents, dichloromethane was able to extract more quantity of microbial metabolites when compared to ethyl acetate, as observed by intensity of the bands.



Intensity of microbial compounds in ethyl acetate and dichloromethane

Extracts of different microbes in DCM



Spots from left to right

1. Potato dextrose broth
2. Richard's broth
3. Potato sucrose broth
4. Malt extract broth
5. Dextrose broth
6. Dextrose peptone broth

TLC of extracts from *Trichoderma viride* cultured on different broth media

7.2.3. Microbial metabolites as elicitor to induce systemic resistance in host for biological management of root parasitic weed *Orobanche*

A simple and rapid technique to germinate *Orobanche* under laboratory conditions that would facilitate the identification of *Orobanche* in the contaminated seed lots, using limited space and time was developed. The seeds were surface sterilized and about 100 seeds were placed in autoclaved moist filter paper of size Whatman No.1 kept in glass petriplates. The plates were covered with black polythene sheets and wrapped again with aluminum foil to provide complete darkness and incubated at 28±2^{0}C for 10 days for pre-conditioning. The pre-conditioned seeds were then aseptically transferred on a bed made of sterilized sand, cotton and filter paper, in a 1000 ml clear glass beaker. Simultaneously surface sterilized host plant seeds (mustard and tomato) were placed for germination in moist chamber petriplates. After germination, 10 seedlings of mustard/tomato germinated separately were carefully transferred to the beaker containing the preconditioned *Orobanche* seeds. The beakers were then covered to maintain dark conditions and kept at room temperature for 10 days. Beakers were used to provide sufficient space for the growth of host plant seedlings. To avoid fungal contamination, bavistin 0.01% was sprayed in the beaker. Observations were taken periodically for different stages of germination of *Orobanche* and their attachment with the host.

An overall germination percentage of 70 was recorded on mustard and 63 on tomato on 20th day of observation. This technique can be used for quantification of weed seed bank present in the soil for management of *Orobanche*.

Set-up for rapid germination of *Orobanche cernua* under controlled conditions

8. CONTRACT RESEARCH, CONSULTANCY AND SERVICE PROJECTS

Directorate has undertaken contract research and consultancy projects sponsored by herbicide industry and government departments, which have resulted in generation of substantial amount of revenue. In addition, service-oriented projects were also undertaken at the Directorate. The details of all such projects taken up in 2012-13 are given below:

	Title	Sponsors	Amount (₹ in lakhs)	Principal Investigator
8.1.	**Contract research projects**			
	8.1.1. Evaluation of fluroxypyr-methyl w/v (45.5% w/w) EC for efficacy on weeds in onion	Dow Agro-sciences	1.79	Anil Dixit
	8.1.2. Evaluation of penoxsulum 2.5%OD w/v (2.67% w/w) for the control of weeds in transplanted rice	Dow Agro-sciences	2.46	Anil Dixit
	8.1.3. Evaluation of biological studies of alachlor 50% EC (Lasso) in soybean	Sinochem	2.87	Anil Dixit
	8.1.4. Evaluation of fluazifop-p-butyl 12.5%+fomesafen 12.5% (Fusilex 25%SL) for weed control in soybean	Syngenta India Ltd.	2.69	Anil Dixit
	8.1.5. Evaluation of bioefficacy and phytotoxicity of AE 1887196-20% + AEF 095404- 10%-30% WG against broad-spectrum weeds in transplanted and direct-seeded upland rice, and their residues on succeeding crop	Bayer Crop Science, Mumbai	5.39	Anil Dixit
	8.1.6. Weed control efficacy of K-salt glyphosate formulation against weeds of cotton and corn	Monsanto India Ltd.	15.00	Anil Dixit
8.2.	**Consultancy projects**			
	8.2.1. Survey, training, release and monitoring of bioagent *Zygogramma bicolorata* for biological control of *Parthenium* in Saoner and Kamleswar Taluka of Nagpur region	Govt. of Maharashtra	30.00	Sushil Kumar
	8.2.2. Analysis of wheat grains for *Striga* seed infestation	Food Corporation of India	4.30	Bhumesh Kumar and D.K. Pandey
8.3.	**Service projects**			
	8.3.1. Supply of Mexican beetles and monitoring at released sites	DWSR	-	Sushil Kumar
	8.3.2. Vermicompost from weed and agro-waste biomass	DWSR	-	Sushil Kumar
	8.3.3. Evaluation of commercial herbicide formulations for active ingredient	DWSR	-	Shobha Sondhia, P.P. Choudhury and M.S. Raghuvanshi
	8.3.4. Analysis of herbicide residues in soil and plant samples of farmers' fields	DWSR	-	Shobha Sondhia

8.1. Contract Research Projects

8.1.1. Evaluation of fluroxypyr-methyl w/v (45.5% w/w) EC for efficacy on weeds in onion

A trial was conducted to screen several newly-released herbicides for effective control of weeds in onion. A new herbicide molecule fluroxypyr-meptyl 48% w/v (45.5% w/w) EC was evaluated during winter season 2011-12. Important broadleaved weeds at 45 days after transplanting were: *Chenopodium album, Physalis minima* and *Medicago denticulate;* whereas among grassy weeds, *Paspalidium* sp. and *Cyperus* sp. were noticed. The weed population in the weedy check was significantly higher than all the other herbicide treated plots.

Application of fluroxypyr-meptyl 48 EC at all the doses reduced broadleaved weed density and biomass to a significantly lower level when compared with weedy check (Table 1). Fluroxypyr-meptyl at 360 g/ha applied 18 days after transplanting reduced the broadleaved weed density and biomass to a significantly lower level compared to all other treatments and was on par with pendimethalin and fluroxypyr-meptyl 48EC @ 324 g/ha. Maximum weight of weeds was recorded in weedy check and it was significantly higher than all other treatments. Application of fluroxypyr-meptyl @ 360 g/ha obtained the highest yield among the herbicidal treatments, which was at par with pendimathalin @ 1000 g/ha and fluroxypyr-meptyl @ 324 g/ha. The yields obtained from all treatments with fluroxypyr-meptyl were superior to weedy check.

Table 1: Effect of fluroxypyr-meptyl 48 EC on broadleaved weeds at 45 DAT and yield of onion (2011-12)

Treatment	Dose (g a.i/ha)	Weed count (no./m^2)	Weed dry weight (g/m^2)	Bulb yield (t/ha)
Fluroxypyr-meptyl 48% EC	252	10.0 (101)*	126	10.07
Fluroxypyr-meptyl 48% EC	300	8.6 (74)	115	11.85
Fluroxypyr-meptyl 48% EC	324	8.7 (75)	76	13.29
Fluroxypyr-meptyl 48% EC	360	7.3 (54)	68	13.57
Pendimethalin 30% EC	1000	6.8 (45)	52	14.55
Hand weeding	-	5.7 (33)	37	16.37
Untreated control	-	13.8 (190)	164	7.50
LSD(P=0.05)		**1.09**	**33**	**1.9**

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

8.1.2. Evaluation of penoxsulum 2.5% OD w/v (2.67% w/w) for the control of weeds in transplanted rice

A field study was carried out to evaluate the efficacy of penoxsulum (25% OD formulation) with chlorpyriphos and carbendazim during rainy season 2012. Peoxsulum @ 20.0, 22.5, 25.0, 50.0 g/ha and tank-mix application of peoxsulum + chlorpyriphos, carbendazim and urea 2% were compared with bispyribac-sodium and pretilachlor. Major weed flora were: *Echinochoa colona, Cyperus rotundus, Commelina benghalensis* and *Phyllanthus niruri.* Result indicated that tank-mix application of penoxsulum + urea, followed by penoxsulum + carbendazim or chloripyrphos resulted in significantly lower weed density and biomass production. All weed control treatments increased grain yield of rice compared with untreated control (Table 2). Maximum grain yield of 4.7 t/ha was recorded under penoxsulum @ 25 g/ha + urea as against 2.7 t/ha under unweeded control. The per cent increase in grain yield due to penoxsulum @ 50 g/ha, penoxsulum + urea, bispyribac-sodium and penoxsulum + carbendazim was 158, 135, 245 and 168, respectively, over weedy check. On the basis of visual observation on 0-10 point scale, none of the herbicide was found phytotoxic on crop.

Table 2: Effect of different weed control treatments on weed population, weed dry weight and yield of rice (2012)

Treatment	Dose (g/ha)	Weed count (no./m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)
Penoxsulum 25% OD	20.0	2.9 (8)*	18	3.09
Penoxsulum	22.5	2.8 (7.8)	15	3.30
Penoxsulum	25.0	2.3 (32.3)	9	3.96
Penoxsulum	50.0	2.0 (9.3)	5	4.47
Penoxsulum + chlorpyriphos	22.5	2.6 (21.3)	10	2.90
Penoxsulum + carbendazim	80.0	2.2 (20.0)	8	4.30
Penoxsulum + urea 2%	25.0	3.1 (18.0)	13	4.72
Bispyribac-sodium	25.0	1.9 (26.0)	11	3.85
Pretilachlor	750	2.7 (29.3)	19	3.37
Weed free		0.71 (0)	-	4.00
Untreated control		2.3 (70.0)	56	2.71
LSD(P=0.05)		**0.5**	**7**	**0.64**

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

8.1.3: Evaluation of biological studies of alachlor 50% EC (Lasso) in soybean

A study was conducted to examine the effect of alachlor 50% on the weeds of soybean during rainy season 2012. Weed flora were dominated by *Echinochloa colona, Commelina benghalenesis, Phyllanthus niruri, Dinebra retroflexa* and *Euphorbia geniculata*. Pre-emergence application of alachlor @ 1.25 kg/ha although provided good weed control but the sponsored sample was better than market sample (Table 3). Application of alachlor at 1.25 kg/ha reduced the weed density and weed biomass to a greater extent, and was superior over pre-emergence application of pendimethalin. Post-emergence application of fenoxaprop also curtailed weed growth. Two hand weedings recorded the highest seed yield (0.96 t/ha), followed by alachlor @ 1.25 kg/ha (sponsored sample).

Table 3: Efficacy of alachlor on species-wise weed count, weed dry weight and seed yield of soybean (2012)

Treatment	Weed population (no./m^2)						Weed dry weight (g/m^2)	Seed yield (kg/ha)
	Echinochloa colona	*Commelina benghalensis*	*Phyllanthus niruri*	*Dinebra* sp.	*E. geniculata*	Total		
Alachlor 50% @ 1250 g/ha (sponsored sample)	15	3	6	7	3	5.8 (33)*	80	721
Alachlor 50% @ 1250 g/ha (market sample)	14	4	4	6	4	5.8 (33)	101	561
Pendimethalin @ 1000 g/ha	30	4	6	1	3	6.8 (46)	88	636
Chlorimuron-ethyl @ 9 g/ha	28	3	4	7	1	6.5 (42)	95	688
Fenoxaprop-p-ethyl @ 100 g/ha	4	11	9	4	10	6.4 (40)	61	632
2 hand weedings	4	2	4	1	4	4.2 (17)	7	962
Weedy check	26	10	8	8	2	7.3 (53)	128	362
LSD (P=0.05)						**1.3**	**33**	**108**

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

8.1.4. Evaluation of fluazifop-p-butyl 12.5% + fomesafen 12.5% (Fusilex 25%SL) for weed control in soybean

Bioefficacy of fluazifop 12.5% + fomesafen 12.5% in soybean was studied in a field trial during rainy season 2012. Nine treatments consisted of four doses of fluazifop + fomesafen (200, 250, 313, 500 g a.i./ha), fluazifop-p-butyl and fomesafen alone, imazethapyr at 100 g a.i./ha along with weed-free and weedy checks.

Major weed species in the field were: *Echinocloa colona, Commelina benghalenesis, Dinebra retroflexa, Phyllanthus niruri, Physalis minima* and *Cyperus iria*. Post-emergence ready-mix application of fluazifop + fomasafen at all the rates reduced the population of weeds at 45 DAS. Superior yield attributing characters and effective weed control contributed to higher yields under higher doses of fluazifop + fomesafen. Application of fluazifop + fomasafen showed good control of grassy as well as broad-leaved weeds. Activity of imazethapyr against monocot (*Echinochloa colona*) and dicot weeds (*Commelina benghalensis, Phyllanthus niruri* and *Euphorbia geniculata*) was increased with increase in application rates, maximum being at 500 g/ha. Weed dry weight was significantly lower in plots treated with fluazifop + fomesafen at 250 and 313 g a.i/ha compared with other treatments. Higher seed yield of 1.1 t and 0.8 t/ha were recorded with hand weeding twice and fluazifop + fomesafen at 313 g a.i./ha, respectively, which were at par with each other (Table 4).

Table 4: Effect of different herbicidal treatments on weed population, weed dry weight and yield of soybean

Treatment (g a.i./ha)	Weed population (no./m^2)	Weed dry weight (g/m^2)	Seed yield (kg/ha)
Fluazifip-p-butyl 12.5% + fomesafen 12.5% (200)	7.4 (54)*	89	743
Fluazifop + fomesafen (250)	6.3 (40)	62	784
Fluazifop + fomesafen (313)	5.3 (28)	51	830
Fluazifop + fomesafen (500)	5.0 (25)	43	792
Fluazifop-p-butyl (125)	6.9 (47)	71	510
Fomesafen 25% SL (250)	5.7 (33)	113	476
Imazethapyr (100)	4.7 (22)	54	754
2 hand weedings	3.9 (15)	8	1110
Weedy check	7.9 (62)	133	278
LSD (P=0.05)	**0.77**	**21**	**90**

*Weed count values were subjected to $\sqrt{x+0.5}$ transformation. Values in parentheses are original

8.1.5. Evaluation of bioefficacy and phytotoxicity of AE 1887196-20% + AEF 095404- 10%-30% WG against broad-spectrum weeds in transplanted and direct-seeded upland rice, and their residues on succeeding crop

(a) *Direct-seeded rice*

An experiment was carried out during rainy season 2012 with rice variety 'Kranti'. Ten treatments, viz. premix combination of AE 1887196-20% + AEF 095404-10%=30% WG (30% premix) at 35 +17.5, 40 + 20,45 + 22.5 g a.i./ha as premix, at 45 and 22.5 g a.i./ha alone application of AE 1887196 SC 20% and AEF 095404 WG 15%, respectively, butachlor 50 EC 1250 g a.i./ha, cyhalofop-p-butyl 10 EC at 75 g a.i./ha and pyrazosulfuron-ethyl 15 g a.i./ha along with 2 hand weeding and weedy check were included. All herbicides were applied as post-emergence at 18 DAS except butachlor 50 applied as pre-emergence.

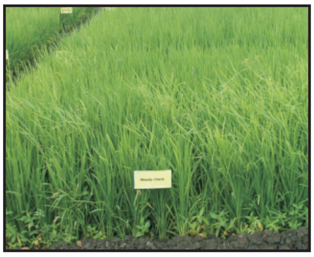
There was a significant reduction in weed count due to application of herbicides when compared to untreated control (Table 5). Application of AE 1887196-20% + AEF 095404-10% reduced the population of weeds of both mono and dicots to a greater extent as compared to AE 1887196-20% SC and AEF 095404-15% WG alone. The reduction in weed population under AE 1887196-20% + AEF 095404-10% WG premix was greater than standard checks like cyhalofop-p-butyl, butachlor and pyrazosulfuron-ethyl. Similarly, application of premix combination of AE 1887196-20% + AEF 095404-10% at 45+22.5 g/ha reduced the biomass of weeds of both mono and dicots to a greater extent than AE 1887196-20% SC and AEF 095404-15% WG alone.

The loss in grain yield due to weeds was 48%. The grain yield obtained under AE 1887196-20% + AEF 095404-10% (30% premix) 45 + 22.5 g a.i./ha was superior to AE 1887196-20% SC and AEF 095404-15% WG alone. AE 1887196-20% + AEF 095404-10% 45+22.5 g a.i./ha recorded increase in yield of rice by 46% over weedy check due to lower weed competition. AE 1887196-20% + AEF 095404-10% 45 + 22.5 g a.i./ha was also on par with AE 1887196-20% + AEF 095404-10% 40+20 g a.i./ha treated plots. Premix combination of AE 1887196-20% + AEF 095404-10% at 45+22.5 g a.i./ha was compatible with each other without any phytotoxicity effect on the rice crop. It was concluded that pre-mix combination of AE 1887196-20% + AEF 095404-10% controlled broadleaved weeds as well as grassy weeds effectively in rice. There was no residual toxicity on follow up gram crop.

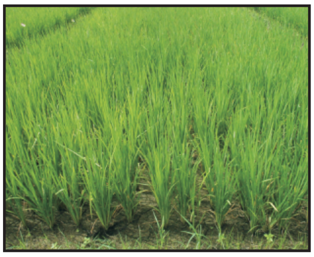
Table 5: Bio-efficacy of premix combination of AE 1887196-20% + AEF 095404-10% for controlling weeds in direct-seeded rice

Treatment	Dose (g a.i/ha)	Weed population (no./m²)	Weed dry weight (g/m²)	Rice grain yield (t/ha)
AE 1887196-20% + AEF 095404-10%	35+17.5	3.86 (15)*	23.78	3.39
AE 1887196-20% + AEF 095404-10%	40+20	3.07 (9)	21.88	3.82
AE 1887196-20% + AEF 095404-10%	45+22.5	2.63 (7)	15.36	4.16
AE 1887196-20%SC	45	3.60 (13)	19.31	3.21
AEF 095404-15%WG	22.5	3.43 (12)	29.48	3.29
Butachlor 50 EC	1250	4.10 (17)	61.61	2.54
Pyrazosulfuron-ethyl 15 WP	15	3.92 (15)	39.05	2.70
Cyhalofop-p-butyl 10 EC	75	3.90 (15)	38.20	3.34
Two hand weedings		1.82 (3)	8.77	3.67
Weedy check		5.07 (26)	91.79	1.93
LSD (P=0.05)		**0.64**	**11.03**	**0.42**

*Weed count values were subjected to $\sqrt{x+0.5}$ transformation. Values in parentheses are original



Weedy check



Treated with AE 1887196-20% + AEF 095404-10%

(b) *Transplanted rice*

In the transplanted crop, the major weed population comprised of *Echinocloa colona, Caesulia auxillaris, Phyllanthus niruri, Ludwigia* and *Cyperus iria*. There was a significant reduction in weed count due to application of herbicides when compared to untreated control. Application of AE 1887196-20% + AEF 095404-10% reduced the population of weeds of both mono and dicots to a greater extent as compared to AE 1887196-20% SC and AEF 095404-15% WG alone application.

The loss in grain yield due to weeds was 52%. The grain yield obtained under AE 1887196-20% + AEF 095404-10% 45 + 22.5 g/ha was superior to AE 1887196-20% SC and AEF 095404-15% WG alone. Application of AE 1887196-20% + AEF 095404-10% @ 45 + 22.5 g a.i./ha increased the yield of rice by 48% over weedy check due to lower weed competition (Table 6). It was concluded that premix combination of AE 1887196-20% + AEF 095404-10% WG controlled broadleaved weeds as well as grassy weeds effectively in rice. There was no residual toxicity of rice treatment on follow-up wheat crop.

Table 6: Bio-efficacy of AE 1887196-20% + AEF 095404-10%=30% WG (Premix) in transplanted rice

Treatment	Dose (g a.i/ha)	Weed population (no./m²)	Weed dry weight (g/m²)	Rice grain yield (t/ha)
AE 1887196-20% + AEF 095404 - 10%	35 + 17.5	3.38 (11)*	53.66	4.26
AE 1887196-20% + AEF 095404 - 10%	40 + 20	3.81 (14)	21.56	4.81
AE 1887196-20% + AEF 095404 - 10%	45 + 22.5	4.16 (17)	14.80	5.49
AE 1887196-20%SC	45	3.21 (10)	22.10	3.91
AEF 095404-15%WG	22.5	3.29 (11)	26.86	4.99
Butachlor 50 EC	1250	2.54 (6)	47.32	3.72
Pyrazosulfuron-ethyl 10 WP	15	2.70 (7)	36.52	4.53
Pretilachlor 50 EC	625	3.34 (11)	22.94	4.48
2 hand weedings		3.67 (13)	6.29	4.01
Weedy check		4.62 (21)	60.21	2.49
LSD (P=0.05)		**0.85**	**1.41**	**1.06**

*Weed count values are subjected to $\sqrt{x + 0.5}$ transformation.
Values in parentheses are original.

8.1.6. Weed control efficacy of K-salt glyphosate formulation against weeds of cotton and maize

This study was conducted in a non-crop situation against weeds of maize and cotton during rainy season 2012. Six treatments comprising of K-salt glyphosate (formulated dose) @ 900, 1350, 1800, 2700, 3600 ml/ha, and untreated control were tested. Major weed species were: *Echinochloa colona, Digitaria sanguinalis, Dinebra retroflexa, Eragrostis, Dactyloctenium, Eleusine indica, Cyperus iria, Cynodon dactylon, Commelina benghalensis, Amaranthus, Ageratum conyzoides, Physalis minima, Euphorbia geniculata, Portulacea oleracea, Alternanthera,* and *Chenopodium album.* All weed species were adversely affected due to application of glyphosate. The yellowing of weeds started from 4th day after spray of herbicide and burning started at 8-10th day. The yellowing and burn down was much faster with glyphosate @ 3600 ml/ha, indicating good speed of kill of the weeds. The plots treated with K-salt glyphosate @ 2700 and 3600 ml/ha recorded the highest weed control (Table 7). These treatments were on par with each other, and significantly superior to the lower dose of glyphosate @ 900-1800 ml/ha. It was concluded that effective dose of the K salt formulation of glyphosate for managing weeds of maize and cotton would be 2700-3600 ml/ha.

Table 7: Species-wise % weed control at 30 days after application of glyphosate

Treatment	*Echinochloa*	*Digitaria*	*Dinebra*	*Eragrostis*	*Dactyloctenium*	*Eleusine*	*Cyperus iria*	*Cynaodn*	*Commelina*	*Amaranthus*	*Ageratum*	*Phyalis*	*Euphorbia*	*Portulacea*	*Alternanthera*	*Chenopodium*
Glyphosate @ 900 ml/ha	24	21	25	12	22	22	17	7	35	44	21	31	7	15	68	15
Glyphosate @ 1350 ml/ha	48	30	33	19	29	23	32	20	20	66	44	60	21	31	78	27
Glyphosate @ 1800 ml/ha	56	54	52	26	44	25	47	34	29	**83**	52	63	27	22	100	30
Glyphosate @ 2700 ml/ha	73	86	76	85	100	20	59	88	40	100	75	57	21	27	100	85
Glyphosate @ 3600 ml/ha	90	100	80	100	100	28	75	83	50	100	83	92	25	31	100	100
Untreated control	0	0	0	0	0	0	0	0	0	00	0	00	00	00	00	0

8.2. Consultancy projects

8.2.1. Survey, training, release and monitoring of bioagent *Zygogramma bicolorata* for biological Control of *Parthenium* in Saoner and Kamleswar Taluka of Nagpur region

Parthenium has infested large areas in Nagpur region. It has infested all type of cropped and non-cropped areas including orange orchards. In order to reduce chemical load in the environment and public demand for its biological control, the agriculture department of Nagpur (Maharashtra) approached the Directorate to undertake a consultancy project for training, release and monitor the impact of Mexican beetle for control of *Parthenium*. Accordingly, this project was undertaken during 2012 in collaboration with agriculture department of Nagpur for release of bioagents, monitor and provide training to villagers about biological control of *Parthenium*.

About 20 lakh beetles were released under this project in different villages of Nagpur district during September 2012. Release of adult beetles was targeted on the road side, bank side of water canals, river side, wasteland and community land badly infested with *Parthenium*. After release of bioagent, observations were taken about the establishment of Mexican beetles and their impact in suppression of *Parthenium*. Survey carried out in different villages of Kamti, Mauda, Ramtek, Katol, Narkehd, Saoner, Kalmeshwar, Katol, Kuhi and Parshvani revealed establishment of beetle on large areas coupled with suppression of *Parthenium*. Heavy attack of bioagents caused up to 100% mortality of *Parthenium* at some places. This indicated that Mexican beetles established in the region and can lower down *Parthenium* intensity manifold in future. It was also observed that wherever there was complete defoliation of large plants, there was no presence of even small plants. The second flush was completely eaten by the beetle. In areas, particularly on the road side and wastelands, *Parthenium* was suppressed due to action of beetles and the vacated sites were replaced by *Cassia tora*.

(a) (b) (c)

(a) Training to farmers and release of Mexican beetles in Nagpur region, (b) A large patch of *Parthenium* was defoliated by the beetles. (c) Area replaced by other vegetation amidst defoliated *Parthenium*

8.2.2. Analysis of wheat grains for *Striga* seed infestation

This project was undertaken during June, 2012 at the instance of Food Corporation of India for testing presence of *Striga* seeds in wheat grains intended to be exported to Iran. A total of 1047 samples of wheat grains (about 1 kg each) were received from different locations, viz. Haryana (10 centres), Punjab (12 centres) and Madhya Pradesh (9 centres). These samples were analysed thoroughly for infestation of *Striga* seeds. Grain lots were homogenized, sampled and divided by Boehner divider. As per standard guidelines, 125 g of sample was taken, sieved initially through 4 mm sieve. The materials passing through first sieving was again sieved through 2 mm sieve. The material was carefully collected and examined under Stereo Binocular Microscope at varying magnification up to 164 times. The images of different weed seeds were compared and matched with standard images of *Striga* seeds taking into account shape, size and colour and surface characteristics. The analysis of all 1047 samples of wheat grains received from different centres was completed within a fortnight. All samples were found to be free from *Striga* infestation.

8.3. Service Projects

8.3.1. Supply of Mexican beetles and monitoring at released sites

Mexican beetles were mass reared in net houses of the Directorate during 2012. About 1.15 lakhs 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. About 10,000 beetles were released in three different sites of Mohanpur area in collaboration with BCKV, Mohanpur.

On the request of Principal, Engineering College at Pauri (Uttrakhand), about 18,000 beetles were released during a glittering programme where hundreds of students participated. The programme was widely covered by the local newspapers which created greater awareness among people about biological control.

Monitoring and feedback from different centers revealed the 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.

8.3.2. Vermicompost from weed and agro-waste biomass

Vermicomposting was undertaken at the experimental farm of the Directorate in big way. It was decided to use all the uprooted weed biomass for vermicomposting. 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 vermicomposting besides agro-waste of crops like soybean, rice, wheat, maize, mustard, chickpea, pigeonpea, 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 20 t vermicompost was prepared, which was twice more than last year. Chemical analysis revealed good nutrient content in the vermicompost prepared from weed biomass like *Parthenium*, *Medicago hispida* and water hyacinth (Table 8).

Table 8: Nutrient concentration in vermicompost of different weed substrates

Type of weed substrate	N (%)	P (%)	S (%)	Fe (ppm)	Cu (ppm)	Cd (ppm)	EC (dS/m)	pH (1:10)
Parthenium hysterophorus	0.74	0.22	0.95	>2144	30.9	ND	1.07	8.31
Medicago hispida	1.91	1.17	1.05	>2015	25.1	ND	0.61	7.49
Eichhornia crassipes	1.26	1.15	1.12	>2077	33.7	ND	0.83	6.61



Uprooted weedy rice being transported for making vermicompost (left); vermicompost unit (centre); soybean biomass in process of vermicomposting (right)

8.3.3. Evaluation of commercial herbicide formulations for active ingredient

Two commercial formulations of pretilachlor herbicide, viz. thor 50% and check 50% were procured from the local market and analyzed for per cent active ingredient by HPLC and GLC methods to evaluate the actual a.i. claimed by the manufacturer in their commercial products. After analysis, it was found that the active ingredient in products like Thor and Check was 31.1 and 44.6%, respectively when analyzed through HPLC.

Samples analyzed by GLC method without using internal standard revealed that 2,4-D EE 38 EC known as weedmar of Dhanuka Ltd. (37.7% analysed value), which was the same as the original value i.e. 38%. On the other hand, hunter of S.N. Crop Science was found to have 32.5% (analysed value) as against original value of 38%. In case of another herbicide i.e. pretilachlor 50 EC marketed as check by Hyderabad Chemicals was found to contain 44.3% (analysed value).

It is noted that due to increasing demand of herbicides in the market in the light of labour scarcity, the spurious herbicides have started prevailing in the market. As a result, farmers are getting cheated and crop productivity is likely to be affected besides other side effects like residue development.

8.3.4. Analysis of herbicide residues in soil and plant samples of farmers' fields

Crop, weed and soil samples were received from a farmer, Sh Tulsi Ram s/o Sh Achal Singh Rajput, Pipalkhedi, Khejda Babbar of Berasia Tehsil, Bhopal through Deputy Director, Kisan Kalyan and Krishi Vikas, Bhopal and Farm Manager, KVK, Nabibagh. It was also informed that herbicide sulfosulfuron 75% + metsulfuron-methyl 5% (Sri Ram Fit) of Shri Ram Fertilizer was purchased from the local market for the control of weeds in wheat fields. After spray, it was noted by the farmer that the wheat crop as well associated weeds especially wild oat turned pale yellow. Consequently in the same field, when soybean was sown during rainy season, there was poor germination because of sulfosulfuron residues. Accordingly, samples were analyzed for the residues of said herbicide by HPLC using standard protocols. After analysis, residues of sulfosulfuron were found as 0.119, 0.041 and 0.0082 µg/g in soil at 0-6, 6-12 and 12-16 inch, respectively. Residues in weeds like *Cyperus* (Gundla) and soybean plant were 0.0098 and 0.008 µg/g, respectively.

9. STUDENTS RESEARCH PROGRAMME

Directorate collaborated with several educational and research institutions. It has signed MOU with Jawaharlal Nehru Krishi Vishva Vidyalaya, Jabalpur in the area of research, teaching and extension. This Directorate has also been recognized by Rani Durgavati Vishva Vidyalaya, Jabalpur and other organizations as a post-graduate research centre for their students. Following post-graduate students and research scholars of those institutions did their thesis research work at the Directorate :

Name of student	Degree / subject	Title of thesis	College/ University	Chairman / co-Chairman
1. Ms. Uzama Waseem	M.Sc. Microbiology	Enhanced biodegradation of an acetolatate synthase (ALS) inhibitor pyrazosulfuron-ethyl herbicide in agricultural soil by soil fungi	Mata Gujri Woman College, RDVV, Jabalpur	Dr. Shobha Sondhia
2. Ms. Smita Rajput	M.Sc. Microbiology	Role of soil fungus in the enhanced biodegradation of penoxsulam in agriculture soil	Mata Gujri Woman College, RDVV, Jabalpur	Dr. Shobha Sondhia
3. Ms. Ruby Singh	M.Sc. Microbiology	Effect of metribuzin on physiological, nodulation and biochemical parameters of pea (*Pisum sativum*)	St. Aloysius College, RDVV, Jabalpur	Dr. Meenal Rathore
4. Ms. Hemlata Yadav	M.Sc. Biotechnology	Extraction of macromolecules and their electrophoresis	Rajiv Gandhi College, APS University, Satna	Dr. Meenal Rathore
5. Mr. Amit Dwivedi	M.Sc. Biotechnology	Antioxidant defence under elevated CO_2 condition in *Vigna radiata* L. (Wilkzek) and *Euphorbia geniculata*	Rajiv Gandhi College, APS University, Satna	Dr. Bhumesh Kumar
6. Ms. Neeti Shukla	M.Sc. Microbiology	Bio-ethanol production from water hyacinth using yeast	RDVV, Jabalpur	Dr. C. Kannan
7. Ms. Shilpa Kaurav	M.Sc. Microbiology	Exploitation of native fungal pathogens for the biological management of water hyacinth	RDVV, Jabalpur	Dr. C. Kannan
8. Mr. Little Kumar Prajapati	M.Sc. Biotechnology	Studies on the enzyme pattern of chickpea upon infection with *Cuscuta campestris*	Rajiv Gandhi College, APS University, Satna	Dr. C. Kannan
9. Ms. Urvashi Yadav	M.Sc. Microbiology	Identification of sulfosulfuron-degrading fungi and fungal degradation of the herbicide in soil and media	Govt. M.H. College of Home Science, RDVV, Jabalpur	Dr. P.P. Choudhury
10. Ms. Shivani Pare	M.Sc. Microbiology	Identification of sulfosulfuron-degrading fungi and fungal degradation of the herbicide in water	St. Aloysious College, RDVV, Jabalpur	Dr. P.P. Choudhury
11. Mr. Virendra Kakotiya	M.Sc. Soil Science	Influence of soil organic matter in the phototransformation of pretilachlor, an acetanilide herbicide	JNKVV, Jabalpur	Dr. P.P. Choudhury
12. Mr. Manish Kumar Namdeo	M.Sc. Biotechnology	Effect of indirect application of pre and post emergence herbicides on mortality and biomass of earthworm, *Eisenia foetida*	Rajiv Gandhi College, APS University, Satna	Dr. Sushil Kumar
13. Mr. Ashutosh Kumar Singh	M.Sc. Biotechnology	Effect of different weed substrates on population and biomass of earthworm, *Eisenia fetida*	Rajiv Gandhi College, APS University, Satna	Dr. Sushil Kumar
14. Mr. Mohammad Rashid Khan	M.Sc. Soil Science	Impact of weed management practices on soil health indicators in a mango orchard with and without intercropping	JNKVV, Jabalpur	Dr. K.K. Barman
15. Mr. Gopal Patel	M.Sc. Soil Science	Effect of waste water irrigation on heavy metal accumulation in soil and its removal by plants	JNKVV, Jabalpur	Dr. P.J. Khankhane

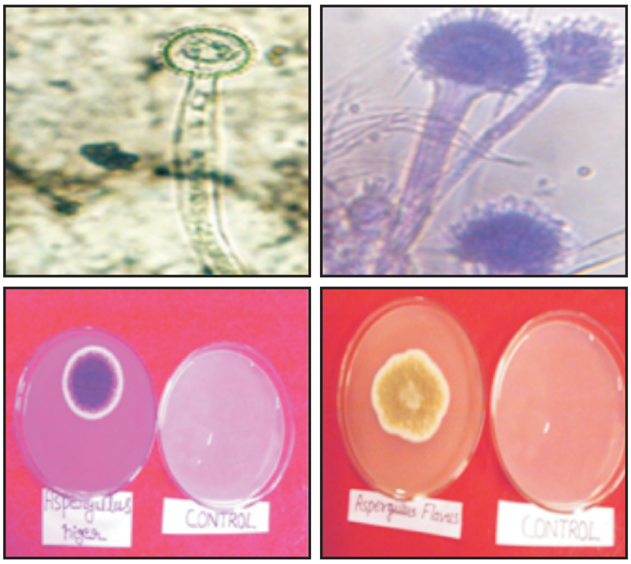
9.1. Enhanced biodegradation of an acetolatate synthase (ALS) inhibitors pyrazosulfuron-ethyl herbicide in agricultural soil by soil fungi

Rhizosphere soils from rice field were collected and isolated soil fungi capable of degradating pyrazosulfuron-ethyl. *Alternaria alternata, Aspergillus niger* and *Penicillium chrysogenum* were isolated and identified as pyrazosulfuron-ethyl degradating soil fungi. Degradation of pyrazosulfuron-ethyl in rice soil by soil fungi is reported first time. Major and minor routes of degradation of pyrazosulfuron-ethyl in agricultural soils by *A. flavus, A. niger* and *P. chrysogenum* were identified. These were found effective to degrade pyrazosulfuron-ethyl in soil by the cleavage of sulfonylurea bridge. This resulted in the formation of degradation products which further cleaved to several minor products. Degradation products were identified as ethyl-5-[(4, 6-dimethoxypyrimidin-2-ylcarbamoyl) sulfamoyl]-1-methyl pyrazole- 4-carboxylic acid; ethyl 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylate and 4, 6-dimethoxy-pyrimidin-2-amine, 1-methyl-5-sulfamyl-1H-pyazole-4-carboxylic acid.

9.2. Role of soil fungus in the enhanced biodegradation of penoxsulam in agriculture soil

Rhizospheric soils from rice field were collected and isolated soil fungi capable of degradating penoxsulam. *Aspergillus flavus* and *A. niger* were isolated and identified as penoxsulam degradating soil fungi. Five metabolites of penoxsulam were identified from soil inoculated with *Aspergillus flavus*. These were methyl 3-[[[2-(2,2-difluoroethoxy)-6-(trifluromethyl) phenyl]sulfonyl]amino]-1H-1,2,4 triazole 5-carboxylate m/z 373 (I); 5-hydroxyl, 8- methoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine (III); 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine, 5,8 dicarboxylic acid (I); 2-(2,2-difluoroethoxy) -6 (trifluromethyl) benzenesulfonamide (IV); 5,8 Dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2 amine (II) and 2-(2,2-difluoroethoxy)-*N*-1H-1,2,4 triazole 3-yl-6 (triflurometyl)benzenesulfonamide (V).

Major degradation products of penoxsulam obtained by *Aspergillus niger* in soil was isolated and characterized by LC-MS/MS. Four metabolites of penoxsulam were identified from soil inoculated by *Aspergillus niger*. They were characterized as methyl 3-[[[2-(2,2-difluoroethoxy)-6-(triflurometyl) phenyl] sulfonyl] amino]-1H-1,2,4 triazole 5-carboxylate m/z 373 (I); 5,8 Dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidin-2-amine m/z 179(II); 2-(2,2-difluoroethoxy)-6-(triflurometyl) phenyl] sulfonyl] amino]-1H-1,2,4 triazole 5-carboxylic acid m/z365 (III) and 5,8 Dimethoxy 1,2,4 triazolo-[1,5-c]pyrimidine 2 yl sulfamic acid m/z 195 (IV).



Aspergillus niger *Aspergillus flavus*

9.3. Effect of metribuzin on physiological, nodulation and biochemical parameters of pea (*Pisum sativum*) var. 'JP 885' and 'VRP 7'

A study was done to assess the effect of metribuzin on pea cultivars tolerant ('JP 885') and susceptible ('VRP-7') to metribuzin. Exposure to metribuzin at 125 g a.i./ha and above had a negative effect on plant growth and development, total plant dry weight and root : shoot dry weight ratio in both the cultivars. Stomatal conductance, transpiration, transpirational cooling also decreased with metribuzin treatment. Activity of antioxidant enzymes increased at 8 DAT, suggesting active defence mechanism in response to herbicide application. A 54 kDa protein peptide expressed in JP 885 with metribuzin exposure at all doses but the same expressed in VRP-7 only at exposure to 125 g a.i./ha. The non-treated plants did not express the peptide band. Metribuzin application reduced number of nodules per plant and *Rhizobium* population isolated from nodules. The numbers decreased with increasing dose of metribuzin.

9.4. Extraction of macromolecules and their electrophoresis

A comparative assessment of DNA quality and yield using three DNA extraction protocols was made using leaf and seeds of rice. Leaves yielded relatively higher DNA. Total protein was extracted from plants of *Echinochloa crusgalli* and *E. colona* exposed to salinity and water stress, respectively. Salinity stress invoked expression of new proteins in *E.crusgalli*, while water stress caused loss in protein expression in *E. colona.*

9.5. Antioxidant defence under elevated CO_2 condition in *Vigna radiata* L. (Wilkzek) and *Euphorbia geniculata*

Elevated atmospheric CO_2 had a positive effect on overall growth of mungbean plants as well as weed species (*Euphorbia geniculata*). Promotion in growth at elevated CO_2 can be attributed to the higher dry matter accumulation. Exposure of plants to high CO_2 led to increase in rate of photosynthesis, while decrease in stomatal conductance and rate of transpiration in mungbean. Conversely, an increase in photosynthesis in *E. geniculata* was associated with parallel increase in stomatal conductance and rate of transpiration. Species specific differences in protein profiles were observed in response to elevated CO_2. In addition, it was also observed that rise in CO_2 concentration influenced the defence mechanism of plants as can be seen in differential regulation of enzymes at activity level.

9.6. Bio-ethanol production from water hyacinth using yeast

This study was conducted to find out the suitable cellulosic biomass for bioethanol production from the water hyacinth and yeast isolates from the water bodies and its characterization and use for fermentation to produce biofuels. Results showed that water hyacinth has a potential, renewable and low-cost biomass for alcohol production on a commercial scale. The two methodologies for the bioconversion of water hyacinth into ethanol were compared for their efficiency in bio conversion. Further, the yeast isolates isolated from the ponds with water hyacinth under local conditions were compared with the standard yeast culture *Pistia strateotis* obtained from the IMTECH, Chandigarh. It was observed that isolate 2 was found to be more efficient when compared with other isolates and also the standard yeast.

9.7. Exploitation of native fungal pathogens for the biological management of water hyacinth

A survey was conducted to isolate the native fungal pathogens on water hyacinth in and around Jabalpur. Accordingly, five different fungal species, viz. *Fusarium* spp., *Alternaria* spp., *Trichoderma* spp., *Mucor* spp., *Aspergillus* spp. were isolated. Among the different species isolated, only *Alternaria* spp. and *Fusarium* spp. were pathogenic to water hyacinth and thus used for further studies. *Alternaria alternata* obtained from DWSR was reported to have high infection potential to cause disease on water hyacinth. It can be easily cultured in potato dextrose agar medium and also mass produced. During the study, it is found that this fungus is host specific. Potato dextrose agar medium was found to be a better medium for the growth of *A. alternata*, maximum growth was recorded at pH 7 and the radial growth was minimum at 40°C for all the pathogens.

9.8. Studies on enzyme pattern of chickpea upon infection with *Cuscuta campestris*

This study was conducted to find out the effect of plant growth promoting bioagents *Pseudomonas fluorescence* and *Trichoderma viride* on inducing resistance against *Cuscuta* on chickpea. The plants were treated with the bioagents and the synthetic stimulant salicylic acid (0.1ppm) and thiobendazole (Bion @ 50% a.i.). The treatments led to increase in soluble protein content of leaves in chickpea and cuscuta. Soluble proteins of leaves were also resolved on 10% SDS-PAGE and it was found that application of bion induced least number of high molecular weight proteins in chickpea. Bion also caused severe growth suppression in chickpea. Upregulation of several proteins of size 209 kDa and 118 kDa were noticed in response to the treatment of the bioagents and salicylic acid. It was also observed that the defense enzymes were induced upon the application of the above treatments.

9.9. Identification of sulfosulfuron-degrading fungi and fungal degradation of the herbicide in soil and media

An experiment was conducted to investigate the fate of sulfosulfuron in soil to isolate sulfosulfuron-degrading fungi from agricultural soil and to study degradation of sulfosulfuron by the screened microorganism. *Trichoderma viride* and *Cladosporium herbarum* were identified as sulfosulfuron-degrading fungi from soil. The degradation products from media and soil were: 2-amino-4,6-dimethoxypyrimidine, 2-ethylsulfonyl imidazo{1,2-a}pyridine-3-sulfonamide, *N*-(4,6-dimethoxypyrimidin-2-yl)urea, *N*-(4,6-dimethoxypyrimidin-2-yl)-*N*'-hydroxyurea and *N*, *N*'-bis(4,6-dimethoxypyrimidin-2-yl)urea. The enzymes involved in these transformations may be evaluated to decontaminate soil and water from sulfosulfuron contamination.

9.10. Identification of sulfosulfuron-degrading fungi and fungal degradation of the herbicide in water

This investigation was taken up to find out the extent of fungal degradation of persistent sulfosulfuron which is a potentially hazardous compound to contaminate ground water. *Mucor piriformis* and *Aspergillus flavus* were identified as sulfosulfuron-degrading fungi from irrigation water and the degradation products from media and irrigation water were: 2-amino-4,6-dimethoxypyrimidine, 2-ethylsulfonyl imidazo{1,2-a}pyridine-3-sulfonamide, *N*-(4,6-dimethoxypyrimidin-2-yl)urea, *N*-(4,6-dimethoxypyrimidin-2-yl)-*N*'-hydroxyurea, *N*, *N*'-bis(4,6-dimethoxypyrimidin-2-yl)urea and *N*-(4,6-dimethoxypyrimidin)- *N*'-(4-hydroxy-6-methoxypyrimidin-2-yl)urea.

9.11. Influence of soil organic matter in the phototransformation of pretilachlor, an acetanilide herbicide

To assess the role of humic acid on the phototransformation of pretilachlor, experiments were conducted under sunlight and UV-light condition. The presence of humic acid slowed down the photolysis of pretilachlor on solid surface. The photolytic half-lives of pretilachlor found on different surfaces, viz. glass, humic acid coated glass, black soil, organic matter free black soil, and humic acid coated organic matter free black soil were 5.4, 18.8, 43.0, 18.8 and 40.13 min under UV-light, and 12.04, 18.8, 47.03, 27.3, and 60.20 hr under sunlight, respectively. Thus, humic acid imparts quenching effect to protect pretilachlor from sunlight. Pretilachlor itself can absorb UV-fraction of sunlight undergoing photo transformation. But the polymers of humic acid in its vicinity act as sunscreen for pretilachlor. Two major routes of degradation have been proposed. The first route of degradation pertains to deacylation at amide linkage. The other route involves the cleavage of ether linkage.

9.12. Effect of indirect application of pre- and post-emergence herbicides on mortality and biomass of earthworm, *Eisenia foetida*

This study aimed at studying the effects of indirect application of pre- and post-emergence herbicides on growth and reproductive parameters of the earthworm species *Eisenia foitida*. The recommended doses of three pre-emergence (butachlor, anilophos, metribuzin) and three post-emergence herbicide (clodinafop-propargil, metsulfuron methyl, glyphosate) were tested on the earthworm, *Eisenia foetida*.

Weight gained in control treatment after 60 days was significantly higher than the pre-emergence herbicide treated pots. Contrary to pre-emergence herbicides, there was significant reduction in weight of earthworm after 60 days in all the herbicide treated pots which was regained by 90 days in metsulfuron-methyl and clodinafop treated pots but weight was still lower in glyphosate treated pots. In control, weight was significantly higher than the herbicide treated pots. The average total mortality of earthworms from initial 50 numbers ranged from 5.2-7.0 in pots treated with pre-emergence herbicides and was significantly higher than the control. There was least mortality of earthworm in the control than treated pots. Significantly higher number of juveniles produced in control than herbicide-treated pots indicated effect on reproduction capabilities of earthworm.

9.13. Effect of different weed substrates on population and biomass of earthworm *Eisenia foetida*

A study was initiated to find out the suitability of three species of weeds (*Parthenium hysteroshorus*, *Eichhornia crassipes* and *Medicago hispida*) as substratum for the earthworm *Eisenia fetida* and the nutrient status in the vermicompost prepared from these weeds. Results showed that good quality vermi-compost can be prepared from all the three weed species. The highest growth of initially released earthworms was recorded in the *Medicago hispida* substrate followed by *Parthenium* and water hyacinth. *Medicago hispida* substrate was found most preferred, which was evidenced by the fact that it was converted fully in 80 days while other two substrates were converted in 100 days. However, in spite of substrate preference for *M. hispida* and high growth and offspring production, the yield of vermicompost was high in case of *Parthenium*. It was also established that *Parthenium* seeds may be engulfed by the earthworms due to its tiny size and the seeds are not killed while passing through the gut.

Good quantity of macro- and micronutrients were found in all type of vermicompost prepared from different substrates. But high N content was found in *M. hispida,* which may also be correlated with high growth and fast reproduction in earthworms.

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

Soil health indicators were studied in a newly-established mango orchard of DWSR research farm receiving various weed control measures for last five years. There were 8 floor management treatments consisting of two cultural practices, viz. growing intercrops during rainy, winter and summer seasons by following cowpea-pea-cowpea and blackgram-pea-green gram sequences, two integrated weed management practices, viz. growing the above-mentioned intercrops in combination with the application of fluchloralin (1.0 kg/ha PPI) /pendimethalin (1.0 kg/ha PE) in each season, two chemical weed control measures, viz. application of metribuzin (0.5 kg/ha PE) and glyphosate (2 kg/ha Post) in each season, operating tractor drawn rotavator twice in each season as a mechanical weed control measure, and a weedy check as control.

Results showed that managing weeds in the newly-established mango 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. 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. Chemical treatments also hampered the development of soil biological health in terms of soil microbial biomass carbon. Growing legumes with recommended doses of N and P as intercrops 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 C, and improved soil available P status. Application of pendimethalin adversely affected the soil microbial biomass carbon. Growing leguminous intercrops with recommended N and P was relatively better than other treatments in terms of soil health, but showed a slight decline in available K. Hence, it is suggested to include fertilizer K in these treatments for making them much better option of managing weeds in the orchard in view of the soil health. It was concluded that the intercropping treatments were better than the sole mechanical and chemical treatments in terms of overall soil health.

9.15. Effect of waste water irrigation on heavy metal accumulation in soil and its removal by plants

An experiment was carried out to find out effect of waste water application on metal accumulation in soil and to evaluate weedy plants for removal of lead from contaminated medium. It was observed that untreated drain water enhanced fresh weight of spinach as compared to tube-well water application. Spinach in plots irrigated with waste water indicated increased concentration of Cu, Cd, Pb, Mn and Fe as compared to tube well water irrigation. Among the weedy plants, 2-3 times higher amount of lead was accumulated in *Arundo donax* grown in contaminated medium.

10. TRANSFER OF TECHNOLOGY

10.1. Knowledge Management Service

Directorate started Knowledge Management Service (KMS) through SMS for disseminating weed management technologies to the farmers of the country. The facility was inaugurated on 20 Ocotober, 2013 by Dr. R.P. Singh, Former Director, PDFSR, and Secretary General, IAUA. Dr. A.R. Sharma, the Director of DWSR explained its need to disseminate the knowledge-based information on weed management to all stakeholders in agriculture in no time.

Kisan Mobile Advisory Service (KMAS) is one such initiative of information and communication technologies which provides location–specific and crop-specific farm advisory services and facilities to a large section of the farming community. The Kisan mobile sandesh delivers real time agricultural information and customized knowledge to improve farmer's decision making ability so that they may make a strategy to manage weeds to increase their production and productivity.

DWSR is providing weed management advisory service to all registered farmers/ SMS/ stakeholders. So far 400 registered stakeholders are availing this facility. Registration is free for all interested stakeholders of the country and can be done by sending an e-mail to : dirdwsr@icar.org.in

10.2. Farmers' visits

Farmers from different parts of the country visited this Directorate to familiarize themselves with latest technologies on weed management (Table 1). Scientists interacted with them to solve their on-spot queries with regard to weed problems. During the visits, a meeting with scientific staff was organized in the conference hall of the Directorate and lectures were delivered on the theme of their interest. During Kisan Mela, Krishak Sangoshthi was organized on 19 February, 2013 in which about 5000 farmers participated.

Table 1: Details of agricultural officials / farmers visiting the Directorate during 2012-13

States/ Districts	Number of farmers/ AOs	Date	States/ districts	Number of farmers/ AOs	Date
Narshingpur (M.P.)	35	20 January, 2012	Seoni (M.P.)	30 woman farmers	5 February, 2012
Mandala (M.P.)	27	18 February, 2012	Damoh (M.P)	32	13 March, 2012
Alwar (Rajasthan)	40	17 March, 2012	Katni (M.P.)	45	23 March, 2012
Lalitpur (U.P.)	60	24 March, 2012	Hoshangabad (M.P.)	20	8 April, 2012
Bharatpur (Rajasthan)	38	23 April, 2012	Seoni (M.P.)	30	8 October, 2012
Tikamgarh (M.P.)	42	23 November, 2012	Sagar (M.P.)	25	15 December, 2012
Narsingpur (M.P.)	13	5 January, 2013	Seoni (M.P.)	25	10 January, 2013
Damoh (M.P.)	40	17 January, 2013	Bharatpur (Rajasthan)	50	24 January, 2013
Chhindwara (M.P.)	50	31 January, 2013	Sagar (M.P.)	35	18 February, 2013
Chhattisgarh	56	20 February, 2013	Jhansi (U.P.)	49	21 February, 2013
Betul (M.P.)	30	4 March, 2013	Damoh (M.P.)	35	4 March, 2013
Balaghat (M.P.)	30	13 March, 2013	Rewa (M.P.)	35	16 March, 2013
Lalitpur (U.P.)	35	18 March, 2013	Umariya (M.P.)	30	20 March, 2013
Jhunjunu (Rajasthan)	70	26 March, 2013			




10.3. Village adoption

Directorate adopted 6 localities, about 50-100 km from Jabalpur under On-Farm Research programme (Table 2). A multi-disciplinary team of 3 scientists along with technical staff visited each of these localities on a specified day of the week for better adoption of weed management technologies. In addition, these teams identified the specific weed problems and suggested solutions.

Table 2: Localities/villages adopted under On-Farm Research programme

Localities	Villages	Major cropping system
Locality 1 (Majholi)	Pola, Hinota, Gathora	Soybean-based cropping system
Locality 2 (Bankhedi)	Amna	Direct-seeded rice based cropping system
Locality 3 (Panagar)	Mahagawa, Kariwah	Rice-based cropping system
Locality 4 (Shahpura)	Bhamki, Kisrod	Direct-seeded rice based cropping system
Locality 5 (Gosalpur)	Podi/Hindora	Rice-based cropping system
Locality 6 (Kundam)	Khukham, Padariya, Ranipur	Maize- and rice-based cropping system

10.4. Awareness campaigns

Awareness campaigns were organized against problem / invasive weeds. *Parthenium* Awareness Week was organized from 16-22 August, 2012 simultaneously throughout the country involving state agricultural universities, ICAR institutes, KVKs, NGOs, colleges, schools and other educational institutions. The objective was to create public awareness about the ill effects and management of *Parthenium*. The Directorate has been coordinating this programme since 2002 and distributing necessary literature through posters, leaflets, CDs, etc. An awareness week on management of *Parthenium* was arranged in nearby villages of Jabalpur, namely Sonpur, Bharda Padaria and Sarsawa Jetwa etc. involving farmers, residents, school children, teachers, NGOs, KVKs and media of Jabalpur (Table 3). A scientists-farmers' interface meeting/ training-cum-workshop was also organised on the occasion.

Table 3: Programmes organized during the *Parthenium* Awareness Week at the Directorate

Date	Village	Activity
16 August, 2012	Padaria, Panagar	Kisan Gosthi, students rally, uprooting of *Parthenium*, release of Mexican beetles
17 August, 2012	Sarsawa, Panagar Block, Jabalpur	-do-
18 August, 2012	Virner (Sonpur), Jabalpur	-do-
19 August, 2012	DWSR, Jabalpur	One-day training for farmers and colony residents
20 August, 2012	Priyadarshni Colony, and Gadheria village, Jabalpur	Training, exhibition, release of bioagents, uprooting of *Parthenium*
21 August, 2012	Mahakaushal College, Jabalpur	Lecture on ill-effects of *Parthenium* and its management, uprooting of *Parthenium*, students rally
22 August, 2012	DWSR, Jabalpur	Film show, exhibition and quiz competition for school children





10.5. Kisan Mela

A Kisan Mela was organized on 19 February, 2013. The mela was inaugurated by Shri Prabhat Sahu, Mayor of Jabalpur. Around 5000 farmers from Jabalpur and adjoining districts participated in this programme. During the programme, 20 progressive farmers of the area were honoured. Kisan Sangosthi and field visits were also arranged. During the event, 45 stalls of various organizations demonstrated their latest technologies and products. Technical calendar on weed management, extension folders and related materials were distributed to the farmers, stake holders and other visitors. Farmers showed keen interest in conservation agriculture technologies and were impressed with the performance of zero-till sown crops of wheat, maize, chickpea and mustard at the experimental farm of the Directorate.

10.6. Participation in Pusa Krishi Vigyan Mela

Directorate took part in Pusa Krishi Vigyan Mela on 6-8 March, 2013 held at IARI, New Delhi and displayed various weed management technologies. The stall of the Directorate became a star attraction for dignitaries, scientists, students and farmers. Weed identification E-modules and other literature of the Directorate became very popular among the stakeholders.


10.7. Television and radio talks

Talks on various aspects of weed management were delivered by the scientists of the Directorate. Dr. A.R. Sharma presented a programme on *Parthenium* management, which was broadcasted by Doordarshan (National Channel) on 28 August, 2012. Dr. P.K. Singh delivered following radio talks from Jabalpur station of AIR: (i) *Kaans, doob and motha ka gair fasliya chhetron me niyantran* (27 April, 2012), (ii) *Soybean me kharpatwar prabandhan* (14 August, 2012), and (iii) *Ganne ki fasal me kharpatwar prabandhan* (22 February, 2013).

11. EDUCATION AND TRAINING

11.1. 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.

Table 1 : Participation of scientists in training programmes

Name of participants	Training attended	Institution	Dates
1. A.R. Sharma	Entrepreneurship development programme	NAARM, Hyderabad	4-8 June, 2012
2. V.P. Singh	Consultancy projects management	NAARM, Hyderabad	7-14 August, 2012
3. Anil Dixit	Pre-RMP training programme on management development programme on leadership development	NAARM, Hyderabad	8-19 October, 2012
4. Bhumesh Kumar	Plant adaptation responses towards abiotic stress	ICGEB, New Delhi	21 November - 2 December, 2011
	Quarantine pests detection and identification	NIPHM, Hyderabad	4-24 September, 2012
5. P.P. Choudhury	Application of nanotechnology in soil science and plant nutrition research	IISS, Bhopal	18-27 September, 2012
6. Raghwendra Singh	Analysis of experimental data using SAS	NAARM, Hyderabad	2-8 November, 2012
	Refresher course on agricultural research management	NAARM, Hyderabad	7-19 January, 2013
7. Meenal Rathore	Refresher course on agricultural research management	NAARM, Hyderabad	7-19 January, 2013
8. Yogita Gharde	Forecast modeling in crops using weather and geo-informatics	IASRI, New Delhi	22 August – 4 September, 2012
9. Dibakar Ghosh	Professional attachment training programme	CRRI, Cuttack	8 February - 7 May, 2012
	Advances in weed management	DWSR, Jabalpur	31 October - 9 November, 2012
10. K.K. Tiwari	9th Advanced level training in soil testing, plant analysis and water quality assessment	IARI, New Delhi	4-24 September, 2012

11.2. Organization of training programmes

Several training programmes were organized by the Directorate during the year (Table 2). Four major training programmes were organized for the scientists and teachers of ICAR Institutes and state agricultural universities, officials of the state department of agriculture and progressive farmers.

Table 2 : Training programmes organised at the Directorate

Training programme	Sponsored by	Dates	No. of participants	Coordinator	Coordinators
1. Training on advancement in weed management techniques	Department of Agricul ture, U.P.	16-20 October, 2012	25	P.K. Singh	V.P. Singh and Dibakar Ghosh
2. National training on advances in weed management	ICAR, New Delhi	31 October - 9 November, 2012	22	P.K. Singh	Anil Dixit and Shobha Sondhia
3. Model training course on weed management for sustainable oilseeds and pulse production	Ministry of Agriculture, GOI	13-20 December, 2012	25	P.K. Singh	Sushil Kumar and K.K. Barman
4. Weed management and chemical weed control	Project Directorate ATMA, Parbhani, Maharashtra	12-14 March, 2013	24	P.K. Singh	Anil Dixit and Bhumesh Kumar

11.3. 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 3 : Lectures delivered by scientists in other institutions

Speaker	Topic	Institute / Training	Date
A.R. Sharma	Weed management in perennial crops	AICRP on Agroforestry workshop at JNKVV, Jabalpur	19 May, 2012
	Emerging issues in weed management	KVK Workshop at ZPD, Jabalpur	28 June, 2012
	Weed management in conservation agriculture system	Summer School at PDKV, Akola	10 September, 2012
	Conservation agriculture and weed management: problems and prospects	Winter School at PDFSR, Modipuram	22 October, 2012
	Conservation agriculture and weed management: problems and prospects	CAFT, JNKVV, Jabalpur	26 October, 2012
	New approaches for crop establishment and weed management in rice-wheat cropping system	CRRI, Cuttack	3 March, 2013
P.K. Singh	Role of weed management in crop production	CAFT, JNKVV, Jabalpur	21 October, 2012
	Weed management scenario in KVKs	XIX Zonal Workshop of KVKs of Zone - VII Bastar, Chhattisgarh	4-6 May, 2012
	Importance of weed management	Training-cum-Workshop on weed management at ZPD, Jabalpur	28-29 June, 2012
Sushil Kumar	Biological control of worst weeds - *Parthenium* and water hyacinth	CAFT, JNKVV, Jabalpur	21 October, 2012
V.P. Singh	Weed management strategies in relation to conservation agriculture	Summer School at CRIDA, Hyderabad	26 September, 2012
	Weed management in rice-based cropping system	Summer School at DRR, Hyderabad	25 September, 2012
	Soil solarization - a novel technique for managing weeds and soil-borne diseases	CAFT, JNKVV, Jabalpur	21-22 October, 2012
Anil Dixit	Advances in weed management in mustard	AICRP on Rapeseed-Mustard workshop at BAU, Ranchi	3-5 August, 2012
	Herbicidal options for weed management in sustainable agriculture	CAFT, JNKVV, Jabalpur	22 October, 2012
K.K. Barman	Impact of herbicides on soil microbial processes	CAFT, JNKVV, Jabalpur	21October, 2012
Shobha Sondhia	Phytochemicals as alternative source for sustainable weed management	CAFT, JNKVV, Jabalpur	21October, 2012
	Extraction and isolation procedure of bioactive molecule from plants	Institute of Technology, Khamaria, Jabalpur	23 March, 2013
Bhumesh Kumar	Climate change and weed management: challenges and strategies	CAFT, JNKVV, Jabalpur	21 October, 2012
P.P. Choudhury	Environmental fate of herbicides	CAFT, JNKVV, Jabalpur	21 October, 2012
C. Kannan	Systemic induced resistance in the management of parasitic weeds	St. Aloysius College, Jabalpur	18 February, 2013
Yogita Gharde	Statistics: An interdisciplinary approach in life sciences	St. Aloysius College, Jabalpur	8 February, 2013

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, 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 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 (Table 1).

Table 1 : Visits by the Director and Nodal Officers to different AICRP–WC centres

Date	Visits by Director	Visits by Nodal officers
5 April, 2012	OUAT, Bhubaneswar	
2-6 August, 2012		BAU, Ranchi
3-4 September, 2012		GBPUAT, Pantnagar
10-11 September, 2012	DPDKV, Akola	
11 September, 2012		ANGRAU, Hyderabad
11-12 September, 2012	MAU, Parbhani	
22-23 September, 2012		IGKV, Raipur
27-28 September, 2012	ANGRAU, Hyderabad	
9 October, 2012	IGKV, Raipur	
22 October, 2012	SVBPUAT, Meerut	
11November, 2012	UAS, Dharwad	
12 November, 2012	UAS, Bengaluru	
5 November, 2012		BAU, Ranchi
2 December, 2012	CSKHPKV, Palampur	
18 December, 2012		UAS, Bengaluru
21-23 December, 2012	PAU, Ludhiana	
7-10 January, 2013		CCSHAU, Hisar
11-12 January, 2013		RVSKVV, Gwalior
3 March, 2013	OUAT, Bhubaneswar	
5 March, 2013	VB, Sriniketan	

12.2. Crop and horticultural institutes of ICAR

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. They visited the following institutes during the year: VPKAS, Almora; IARI, New Delhi; NBPGR, New Delhi; DMR, New Delhi; IARI, New Delhi; CRIDA, Hyderabad; DOR, Hyderabad; DRR, Hyderabad; DSR, Hyderabad; SFRI, Raipur; IINRG, Ranchi; and CIAE, Bhopal.

12.3. Collaboration with KVKs

Two scientists of the Directorate participated in the XIX Zonal Workshop of KVKs of Zone-VII involving the states of Madhya Pradesh, Odisha and Chhattisgarh organized at Bastar from 4-6 May, 2012. Further, six scientists participated in the training-cum workshop on weed management for the programme coordinators of 65 KVKs of these states held at Zonal Project Directorate, Jabalpur on 28-29 June, 2012. Technologies related to weed management for different crops like rice, wheat, chickpea, greengram, soybean, tomato and groundnut under various farming situations were discussed. In this workshop, technical programme of KVKs on weed management was finalized.

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 for better collaboration in the area of research, teaching and extension. This Directorate has also been recognized by Rani Durgavati Vishva Vidyalaya, Jabalpur, as a post-graduate research centre for their students. Many post-graduate students and research scholars of these institutions are doing their research work at the Directorate. Details of research work done by the students are given in Chapter 9.

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.

13. हिन्दी राजभाषा कार्यान्वयन

निदेशालय की राजभाषा कार्यान्वयन समिति द्वारा वर्ष भर निदेशालय में हिन्दी राजभाषा की उपयोगिता बढ़ाने एवं निरंतर प्रगति हेतु अनेक उपाय किये गये। समिति अपने सीमित साधनों के बावजूद दायित्व को पूरा करने के लिए सतत् प्रयत्नशील है। समिति के प्रयासों के परिणामस्वरूप ही संस्थान के विभागों/अनुभागों में हिन्दी में कार्य करने के लिए जो उत्साह पैदा हुआ है वह निःसंदेह गौरव एवं स्वाभिमान का विषय है।

वर्ष 2012–13 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 2012 तिमाही की बैठक दिनांक 30 जून 2012 को निदेशालय के सभागार में आयोजित की गई। जुलाई से सितम्बर 2012 की तिमाही बैठक का आयोजन दिनांक 28 सितम्बर 2012 को किया गया। अक्टूबर से दिसम्बर 2012 तिमाही की बैठक दिनांक 29 दिसम्बर 2012 को आयोजित की गई। जनवरी से मार्च 2013 को समाप्त तिमाही की बैठक 26 मार्च 2013 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 बिन्दुओं पर विचार किया गया एवं पिछली बैठक के कार्यवृत्त को चर्चा उपरान्त पारित किया गया। राजभाषा कार्यान्वयन समिति के सचिव श्री जी. आर. डोंगरे 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 अतंर्गत जारी त्रैमासिक प्रतिवेदनों, कागजातों, मांगपत्रों एवं जांच बिन्दुओं इत्यादि से संबंधित चर्चायें की गई, साथ ही ऐसे अनुभागों को चयनित किया गया जिनसे अंग्रेजी में सर्वाधिक पत्राचार होता है उन्हें उचित कार्यवाही करने हेतु पत्र भी जारी किया गया जिससे कि वे अपना पत्राचार अंग्रेजी में कम करके हिन्दी में बढ़ानें का प्रयास करें।

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 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 2012–13 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 सुनिश्चित करने का अनुरोध किया गया।

13.4. हिन्दी पखवाड़े का आयोजन

निदेशालय में राजभाषा कार्यान्वयन समिति द्वारा दिनांक 14 सितम्बर 2012 को हिन्दी दिवस तथा दिनांक 07 सितम्बर 2012 से 22 सितम्बर 2012 तक हिन्दी पखवाड़े का आयोजन किया गया। जिसमें कार्यालय के समस्त अधिकारियों/कर्मचारियों ने भाग लिया।

पखवाड़े के दौरान निदेशालय में आलेखन एवं टिप्पण प्रतियोगिता, शुद्धलेखन प्रतियोगिता, कविता पाठ प्रतियोगिता, वाद–विवाद प्रतियोगिता, क्विज कांटेस्ट प्रतियोगिताओं का आयोजन किया गया। जिसमें निदेशालय के कर्मचारियों/अधिकारियों ने बढ़–चढ़कर हिस्सा लिया।

दिनॉक 22 सितम्बर, 2012 को निदेशालय के सभागार में हिन्दी पखवाड़ा समापन एवं पुरस्कार वितरण समारोह का आयोजन किया गया। कार्यक्रम का उदघाटन भा.कृ.अनु.परिषद के महिमा वंदन गीत के साथ एवं निदेशक महोदय डॉ अजीत राम शर्मा एवं मुख्य अतिथि श्री नरेन्द्र कुमार शर्मा, हास्य एवं व्यंगकवि द्वारा मां सरस्वती जी की फोटो को माल्यार्पण एवं पूजन कर किया गया। समापन समारोह के दिन क्विज कांटेस्ट प्रतियोगिता एवं वाद–विवाद प्रतियोगिता का आयोजन भी किया गया। इस अवसर पर कार्यान्वयन समिति के अध्यक्ष ने कार्यक्रम के मुख्य अतिथि का सभी को परिचय देते हुये अपना स्वागत भाषण दिया।

इस अवसर पर कार्यक्रम के मुख्य अतिथि श्री नरेंद्र कुमार शर्मा ने अपने उद्‌बोधन में कहा कि आज भी हिन्दी को वह स्थान नही मिला जिसकी वह अधिकारी है हमें सहृदय होकर देश की जनभाषा, हमारी अपनी राजभाषा को अपने निजी कार्यों से लेकर कार्यालय के कामकाज में लाने का संकल्प लेना होगा, उन्होंने इस अवसर पर अपनी हास्य व्यंग कविताओं से सभी को मंत्रमुग्ध कर दिया ।

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

1.	आलेखन एवं टिप्पण प्रतियोगिता	
''अ''	ओ.एन. तिवारी	प्रथम पुरस्कार
	एस.के. पारे	द्वितीय पुरस्कार

2.	शुद्ध लेखन प्रतियोगिता	
''अ''	ओ.एन. तिवारी	प्रथम पुरस्कार
	आर.पी. दुबे	द्वितीय पुरस्कार
	अनिल दीक्षित	तृतीय पुरस्कार
	शोभा सौंधिया	तृतीय पुरस्कार
''ब''	मोहन लाल दुबे	प्रथम पुरस्कार

3.	कविता पाठ प्रतियोगिता	
1.	शोभा सौंधिया	प्रथम पुरस्कार
2.	एम.के. भट्ट	द्वितीय पुरस्कार
3	ओ.एन. तिवारी	तृतीय पुरस्कार

4.	वाद विवाद प्रतियोगिता –	
1.	राघवेन्द्र सिंह	प्रथम पुरस्कार
2.	शोभा सौंधिया	द्वितीय पुरस्कार
3	बसंत मिश्रा	तृतीय पुरस्कार

5. क्विज कांटेस्ट प्रतियोगिता

समूह	नाम	स्थान	समूह	नाम	स्थान
1	आर.पी. दुबे	प्रथम	1	एच.एस. बिसेन	द्वितीय
2	सी. कन्नन		2	पी.जे. खनखने	
3	ओ.एन. तिवारी		3	एस.के. पारे	
4	पंकज शुक्ला		4	अजय पाल सिंह	
5	आर. हाड़गे		5	बी.पी. उरिया	

6. नगद पुरस्कार हेतु चयनित अधिकारी / कर्मचारी

क्र.	अधि. / कर्म. का नाम	स्थान	राशि रू.
1.	बी.पी. उरिया, सहायक	प्रथम पुरस्कार	800
2.	घनश्याम विश्वकर्मा, प्रक्षेत्र सहायक	द्वितीय पुरस्कार	600
3.	टी. लखेरा, सहायक	द्वितीय पुरस्कार	600
4.	एम.एस. रघुवंशी, वरिष्ठ तक. अधि.	तृतीय पुरस्कार	400
5.	एम.पी. तिवारी, तक. अधि.	तृतीय पुरस्कार	400
6.	अश्विनी तिवारी, डिस्पेचर	तृतीय पुरस्कार	400

7. वर्षभर हिन्दी में सर्वाधिक काम करने वाले निम्न अनुभागों को चलित शील्ड प्रदान की गई

1. क्रय एवं भण्डार अनुभाग – प्रथम पुरस्कार
2. कृषि अभियांत्रिकी अनुभाग – द्वितीय पुरस्कार
3. प्रक्षेत्र अनुभाग – तृतीय पुरस्कार

8. प्रोत्साहन पुरस्कार

1. एम. के. भट्ट

13.5. हिन्दी कार्यशालाओं का आयोजन

राजभाषा कार्यान्वयन समिति द्वारा वित्तीय वर्ष 2012–13 के दौरान चार कार्यशालाओं का आयोजन किया गया, जिनका विवरण निम्नानुसार है –

क्र.	तिमाही	दिनांक	कार्यशाला का विषय	व्याख्याता
1.	अप्रैल से जून 2012	13 जून 2012	खरपतवारों का परिचय एवं उनके नियंत्रण में शाकनाशी का उपयोग	वी.पी. सिंह प्रधान वैज्ञानिक
2.	जुलाई से सितम्बर 2012	12 सितम्बर 2012	इंटरानेट द्वारा अवकाश प्रबंधन	संदीप धगट तकनीकी अधिकारी
3.	अक्टूबर से दिसम्बर 2012	22 दिसम्बर 2012	प्रायोगिक अभिकल्पनाओं का परिचय	योगिता घरडे वैज्ञानिक
4.	जनवरी से मार्च 2013	19 मार्च 2013	संस्थान में वित्त प्रबंधन	अनिल दीक्षित प्रधान वैज्ञानिक

13.6. राजभाषा पत्रिका के अष्टम् अंक का प्रकाशन

तृण संदेश पत्रिका के अष्टम् अंक 2012 का प्रकाशन किया गया जिसमें चार खण्डों में प्रथम खण्ड में अनुसंधान उपलब्धियां, द्वितीय खण्ड में खरपतवार प्रबंधन से संबंधित लेख, तृतीय खण्ड में सामान्य खेती से संबंधित जन उपयोगी लेख एवं चतुर्थ खण्ड में सामाजिक एवं साहित्यिक गतिविधियों को स्थान दिया गया है। पत्रिका को स्लोगन एवं महापुरूषों के वचन इत्यादि से प्रभावशाली बनाया गया।

13.7. वचनामृत एवं शब्द लेखन

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

निदेशालय द्वारा 2012–13 में प्रकाशित हिन्दी प्रकाशनों की सूची निम्नानुसार है :

क्रम	प्रकाशन	प्रतिरूप	संख्या
1.	तृण संदेश अष्टम् अंक	पुस्तक	200
2.	गाजरघास से कम्पोस्ट बनाये एक साथ दो लाभ कमाये	फोल्डर	3000
3.	पर्यावरण मित्र जैविकीय विधि से गाजरघास नियंत्रण	फोल्डर	3000
4.	पुरस्कार (सिर्फ मारने पर)	पोस्टर	2000
5.	गाजर घास–जागरूकता	पोस्टर	2000
6.	किसान मेला संगोष्ठी	पोस्टर	3000
7.	खरपतवार प्रबंधन पर तकनीकी कैलेण्डर	कैलेण्डर	3000

13.8. संसदीय राजभाषा समिति द्वारा निरीक्षण

संसदीय राजभाषा समिति द्वारा खरपतवार विज्ञान अनुसंधान निदेशालय, जबलपुर में राजभाषा के प्रगति का अवलोकन करने हेतु 7 फरवरी, 2013 को निरीक्षण किया गया। समिति के सदस्य, माननीय श्री रघुनंदन शर्मा, संसद सदस्य (राज्यसभा), माननीय डॉ. (श्रीमति) बोच्चा झांसी लक्ष्मी, संसद सदस्य (लोकसभा) एवं श्री श्याम सुंदर, सचिव द्वारा निदेशालय की हिन्दी कार्यों की प्रगति का अवलोकन कर हिन्दी कार्य की सराहना की। इस दौरान निदेशालय द्वारा हिन्दी कार्यान्वयन में की गई प्रगति की प्रदर्शनी भी लगाई गई जिसे माननीय श्री रघुनंदन शर्मा, संसद सदस्य (राज्यसभा) ने काफी सराहा एवं निर्देशित किया कि भविष्य में हिन्दी कार्यों में और बढ़ोत्तरी जरूरी है।

13. हिन्दी राजभाषा कार्यान्वयन

निदेशालय की राजभाषा कार्यान्वयन समिति द्वारा वर्ष भर निदेशालय में हिन्दी राजभाषा की उपयोगिता बढ़ाने एवं निरंतर प्रगति हेतु अनेक उपाय किये गये। समिति अपने सीमित साधनों के बावजूद दायित्व को पूरा करने के लिए सतत् प्रयत्नशील है। समिति के प्रयासों के परिणामस्वरूप ही संस्थान के विभागों/अनुभागों में हिन्दी में कार्य करने के लिए जो उत्साह पैदा हुआ है वह निःसंदेह गौरव एवं स्वाभिमान का विषय है।

वर्ष 2012–13 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 2012 तिमाही की बैठक दिनांक 30 जून 2012 को निदेशालय के सभागार में आयोजित की गई। जुलाई से सितम्बर 2012 की तिमाही बैठक का आयोजन दिनांक 28 सितम्बर 2012 को किया गया। अक्टूबर से दिसम्बर 2012 तिमाही की बैठक दिनांक 29 दिसम्बर 2012 को आयोजित की गई। जनवरी से मार्च 2013 को समाप्त तिमाही की बैठक 26 मार्च 2013 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 बिन्दुओं पर विचार किया गया एवं पिछली बैठक के कार्यवृत्त को चर्चा उपरान्त पारित किया गया। राजभाषा कार्यान्वयन समिति के सचिव श्री जी. आर. डोंगरे 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 अतंर्गत जारी त्रैमासिक प्रतिवेदनों, कागजातों, मांगपत्रों एवं जांच बिन्दुओं इत्यादि से संबंधित चर्चायें की गई, साथ ही ऐसे अनुभागों को चयनित किया गया जिनसे अंग्रेजी में सर्वाधिक पत्राचार होता है उन्हें उचित कार्यवाही करने हेतु पत्र भी जारी किया गया जिससे कि वे अपना पत्राचार अंग्रेजी में कम करके हिन्दी में बढ़ानें का प्रयास करें।

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 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 2012–13 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 सुनिश्चित करने का अनुरोध किया गया।

13.4. हिन्दी पखवाड़े का आयोजन

निदेशालय में राजभाषा कार्यान्वयन समिति द्वारा दिनांक 14 सितम्बर 2012 को हिन्दी दिवस तथा दिनांक 07 सितम्बर 2012 से 22 सितम्बर 2012 तक हिन्दी पखवाड़े का आयोजन किया गया। जिसमें कार्यालय के समस्त अधिकारियों/कर्मचारियों ने भाग लिया।

पखवाड़े के दौरान निदेशालय में आलेखन एवं टिप्पण प्रतियोगिता, शुद्धलेखन प्रतियोगिता, कविता पाठ प्रतियोगिता, वाद–विवाद प्रतियोगिता, क्विज कांटेस्ट प्रतियोगिताओं का आयोजन किया गया। जिसमें निदेशालय के कर्मचारियों/अधिकारियों ने बढ़–चढ़कर हिस्सा लिया।

दिनॉक 22 सितम्बर, 2012 को निदेशालय के सभागार में हिन्दी पखवाड़ा समापन एवं पुरस्कार वितरण समारोह का आयोजन किया गया। कार्यक्रम का उदघाटन भा.कृ.अनु.परिषद के महिमा वंदन गीत के साथ एवं निदेशक महोदय डॉ अजीत राम शर्मा एवं मुख्य अतिथि श्री नरेन्द्र कुमार शर्मा, हास्य एवं व्यंगकवि द्वारा मां सरस्वती जी की फोटो को माल्यार्पण एवं पूजन कर किया गया। समापन समारोह के दिन क्विज कांटेस्ट प्रतियोगिता एवं वाद–विवाद प्रतियोगिता का आयोजन भी किया गया। इस अवसर पर कार्यान्वयन समिति के अध्यक्ष ने कार्यक्रम के मुख्य अतिथि का सभी को परिचय देते हुये अपना स्वागत भाषण दिया।

इस अवसर पर कार्यक्रम के मुख्य अतिथि श्री नरेंद्र कुमार शर्मा ने अपने उद्बोधन में कहा कि आज भी हिन्दी को वह स्थान नही मिला जिसकी वह अधिकारी है हमें सहृदय होकर देश की जनभाषा, हमारी अपनी राजभाषा को अपने निजी कार्यों से लेकर कार्यालय के कामकाज में लाने का संकल्प लेना होगा, उन्होंने इस अवसर पर अपनी हास्य व्यंग कविताओं से सभी को मंत्रमुग्ध कर दिया ।

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

1.	आलेखन एवं टिप्पण प्रतियोगिता	
"अ"	ओ.एन. तिवारी	प्रथम पुरस्कार
	एस.के. पारे	द्वितीय पुरस्कार

2.	शुद्ध लेखन प्रतियोगिता	
"अ"	ओ.एन. तिवारी	प्रथम पुरस्कार
	आर.पी. दुबे	द्वितीय पुरस्कार
	अनिल दीक्षित	तृतीय पुरस्कार
	शोभा सौंधिया	तृतीय पुरस्कार
"ब"	मोहन लाल दुबे	प्रथम पुरस्कार

3.	कविता पाठ प्रतियोगिता	
1.	शोभा सौंधिया	प्रथम पुरस्कार
2.	एम.के. भट्ट	द्वितीय पुरस्कार
3	ओ.एन. तिवारी	तृतीय पुरस्कार

4.	वाद विवाद प्रतियोगिता –	
1.	राघवेन्द्र सिंह	प्रथम पुरस्कार
2.	शोभा सौंधिया	द्वितीय पुरस्कार
3	बसंत मिश्रा	तृतीय पुरस्कार

5. क्विज कांटेस्ट प्रतियोगिता

समूह	नाम	स्थान	समूह	नाम	स्थान
1	आर.पी. दुबे	प्रथम	1	एच.एस. बिसेन	द्वितीय
2	सी. कन्नन		2	पी.जे. खनखने	
3	ओ.एन. तिवारी		3	एस.के. पारे	
4	पंकज शुक्ला		4	अजय पाल सिंह	
5	आर. हाड़गे		5	बी.पी. उरिया	

6. नगद पुरस्कार हेतु चयनित अधिकारी/कर्मचारी

क्र.	अधि./कर्म. का नाम	स्थान	राशि रू.
1.	बी.पी. उरिया, सहायक	प्रथम पुरस्कार	800
2.	घनश्याम विश्वकर्मा, प्रक्षेत्र सहायक	द्वितीय पुरस्कार	600
3.	टी. लखेरा, सहायक	द्वितीय पुरस्कार	600
4.	एम.एस. रघुवंशी, वरिष्ठ तक. अधि.	तृतीय पुरस्कार	400
5.	एम.पी. तिवारी, तक. अधि.	तृतीय पुरस्कार	400
6.	अश्विनी तिवारी, डिस्पेचर	तृतीय पुरस्कार	400

7. वर्षभर हिन्दी में सर्वाधिक काम करने वाले निम्न अनुभागों को चलित शील्ड प्रदान की गई

1. क्रय एवं भण्डार अनुभाग – प्रथम पुरस्कार
2. कृषि अभियांत्रिकी अनुभाग – द्वितीय पुरस्कार
3. प्रक्षेत्र अनुभाग – तृतीय पुरस्कार

8. प्रोत्साहन पुरस्कार

1. एम. के. भट्ट

13.5. हिन्दी कार्यशालाओं का आयोजन

राजभाषा कार्यान्वयन समिति द्वारा वित्तीय वर्ष 2012–13 के दौरान चार कार्यशालाओं का आयोजन किया गया, जिनका विवरण निम्नानुसार है –

क्र.	तिमाही	दिनांक	कार्यशाला का विषय	व्याख्याता
1.	अप्रैल से जून 2012	13 जून 2012	खरपतवारों का परिचय एवं उनके नियंत्रण में शाकनाशी का उपयोग	वी.पी. सिंह प्रधान वैज्ञानिक
2.	जुलाई से सितम्बर 2012	12 सितम्बर 2012	इंटरनेट द्वारा अवकाश प्रबंधन	संदीप धगट तकनीकी अधिकारी
3.	अक्टूबर से दिसम्बर 2012	22 दिसम्बर 2012	प्रायोगिक अभिकल्पनाओं का परिचय	योगिता घरडे वैज्ञानिक
4.	जनवरी से मार्च 2013	19 मार्च 2013	संस्थान में वित्त प्रबंधन	अनिल दीक्षित प्रधान वैज्ञानिक

13.6. राजभाषा पत्रिका के अष्टम् अंक का प्रकाशन

तृण संदेश पत्रिका के अष्टम् अंक 2012 का प्रकाशन किया गया जिसमें चार खण्डों में प्रथम खण्ड में अनुसंधान उपलब्धियां, द्वितीय खण्ड में खरपतवार प्रबंधन से संबंधित लेख, तृतीय खण्ड में सामान्य खेती से संबंधित जन उपयोगी लेख एवं चतुर्थ खण्ड में सामाजिक एवं साहित्यिक गतिविधियों को स्थान दिया गया है। पत्रिका को स्लोगन एवं महापुरूषों के वचन इत्यादि से प्रभावशाली बनाया गया।

13.7. वचनामृत एवं शब्द लेखन

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

निदेशालय द्वारा 2012–13 में प्रकाशित हिन्दी प्रकाशनों की सूची निम्नानुसार है :

क्रम	प्रकाशन	प्रतिरूप	संख्या
1.	तृण संदेश अष्टम् अंक	पुस्तक	200
2.	गाजरघास से कम्पोस्ट बनाये एक साथ दो लाभ कमाये	फोल्डर	3000
3.	पर्यावरण मित्र जैविकीय विधि से गाजरघास नियंत्रण	फोल्डर	3000
4.	पुरस्कार (सिर्फ मारने पर)	पोस्टर	2000
5.	गाजर घास–जागरूकता	पोस्टर	2000
6.	किसान मेला संगोष्ठी	पोस्टर	3000
7.	खरपतवार प्रबंधन पर तकनीकी कैलेण्डर	कैलेण्डर	3000

13.8. संसदीय राजभाषा समिति द्वारा निरीक्षण

संसदीय राजभाषा समिति द्वारा खरपतवार विज्ञान अनुसंधान निदेशालय, जबलपुर में राजभाषा के प्रगति का अवलोकन करने हेतु 7 फरवरी, 2013 को निरीक्षण किया गया। समिति के सदस्य, माननीय श्री रघुनंदन शर्मा, संसद सदस्य (राज्यसभा), माननीय डॉ. (श्रीमति) बोच्चा झांसी लक्ष्मी, संसद सदस्य (लोकसभा) एवं श्री श्याम सुंदर, सचिव द्वारा निदेशालय की हिन्दी कार्यों की प्रगति का अवलोकन कर हिन्दी कार्य की सराहना की। इस दौरान निदेशालय द्वारा हिन्दी कार्यान्वयन में की गई प्रगति की प्रदर्शनी भी लगाई गई जिसे माननीय श्री रघुनंदन शर्मा, संसद सदस्य (राज्यसभा) ने काफी सराहा एवं निर्देशित किया कि भविष्य में हिन्दी कार्यों में और बढ़ोत्तरी जरूरी है।

14. AWARDS AND RECOGNITIONS

14.1. Awards

Dr. Sushil Kumar, Principal Scientist (Entomology) was awarded the prestigious 'Swami Sahajanand Saraswati Outstanding Extension Scientist Award 2011' on the 84th Foundation Day of ICAR. Dr. Sushil Kumar carried out research and extension work in the field of biological control of *Parthenium*. He developed cost effective and sustainable techniques for the mass multiplication of bioagent *Zygogramma bicolorata* and distributed the live-bioagent throughout the country. The biological control helped in suppression of *Parthenium* and helped other vegetation to restore in the large area on sustainable basis.

Dr. Sushil Kumar, Principal Scientist (Entomology) was awarded Late Shri PP Singhal Memorial Award 2013 by Society of Plant Protection Sciences, New Delhi for his outstanding work on biological control of weeds.

Dr. R.P. Dubey, Principal Scientist (Agronomy) was awarded Fellow (2011) of Indian Society of Weed Science during the Biennial Conference held at KAU, Thrissur from 19-20 April, 2012.

Dr. P.P. Choudhury, Senior Scientist (Organic Chemistry) received 'Third Best Poster Presentation Award' during the Biennial Conference of ISWS held during April 19-20, 2012 at KAU, Thrissur.

Dr. Meenal Rathore, Senior Scientist (Biotechnology) received 2nd Best Poster Award under the theme 'Management of biotic stress' at the ARRW Golden Jubilee International Symposium held on 2-5 March, 2013 at CRRI, Cuttack.

Dr. P.P. Choudhury, Senior Scientist (Organic Chemistry) received 'Best Trainee Award' in the ICAR sponsored short course on Application of nanotechnology in soil science and plant nutrition research held from 18-27 September, 2012 at IISS Bhopal.

Sh. Veer Singh, SSS and **Sh. S.K. Bose,** T-4 became champions in carom and chess events, respectively at the annual sports meet of ICAR-Central Zone held at IARI, New Delhi from 26-20 September, 2012.

Dr. Bhumesh Kumar, Senior Scientist and **Sh. Nemi Chand, SSS** secured third position in shot put and 100 m sprint, respectively.

Sh. Mohan Dubey, SSS secured third in two track events, 400 m and 1500 m.

Dr. A.R. Sharma, Director, DWSR was awarded Fellow (2009) of the Indian Society of Agronomy during the Third International Agronomy Congress held at New Delhi from 26-30 November, 2012.

Dr. A.R. Sharma, Director was awarded Fellow (2010), Indian Association of Soil and Water Conservationists during the National Conference (LESCRA-2013) held at OUAT, Bhubaneshwar from 4-6 April, 2012.

Dr. A.R. Sharma, Director received the 'Award of Honour' for his outstanding contributions to agricultural research and development at the Golden Jubilee Alumni Meet of the PAU, Ludhiana from 20-21 December, 2012.

DWSR, Jabalpur has been awarded Best Stall prize during the Third International Agronomy Congress held at IARI, New Delhi from 26-30 November, 2012.

14.2. Recognitions

Dr. Anil Dixit, Principal Scientist (Agronomy) was nominated as member of Editorial Board of Journal of Krishi Vigyan published by PAU, Ludhiana.

Dr. Shobha Sondhia, Senior Scientist (Residue Chemistry) was elected as Treasurer, Indian Society of Weed Science for the biennium 2013-14.

Dr. Sushil Kumar, Principal Scientist (Entomology) was elected as Chief Editor, Indian Journal of Weed Science for the biennium 2013-14.

Dr. A.R. Sharma, Director was elected as Secretary, Indian Society of Weed Science for the biennium 2013-14.

Dr. A.R. Sharma, Director was nominated as Associate Editor-in-Chief of the Indian Journal of Agronomy for the biennium 2013-14.

Dr. A.R. Sharma, Director was nominated as Member, Research Advisory Committee of National Centre for Integrated Pest Management, New Delhi for the triennium 2013-15.

15. PUBLICATIONS

15.1. Research articles

1. Choudhury, P.P., Barman, K.K. and Dureja, P. 2012. Influence of some organic molecules on the rate and pattern of photolysis of chlorimuron-ethyl. *Agricultural Science Research Journal* **2**(12): 633-638.
2. Gharde, Yogita, Rai, Anil and Chandra, Hukum. 2012. Hierarchical bayes small area approach for spatial data. *Journal of Indian Society of Agricultural Statistics* **66**(2): 259-268.
3. Kannan, C. 2012. A report on the natural incidence of *Puccinia noccae* on the exotic weed *Lagasea mollis* in India. *Journal of Biological Control* **26**(3): 285-287.
4. Khankhane, P.J. and Varshney, Jay G. 2011. Lead and manganese by weeds at metal contaminated sites in Jabalpur. *Indian Journal of Weed Science* **43**(3&4): 224-225.
5. Kubiak, J., Khankhane, P.P., Kleingeld, Pieter J. and Lima, Ana T. 2012. An attempt to electrically enhance phytoremediation of arsenic contaminated water. *Chemosphere* **87**: 259-264.
6. Pancheshwar, D.K., Varma, R.K., Gupta, P.K. and Gharde, Y. 2012. Molecular variability of *Rhizoctonia bataticola* causing charcoal rot of soybean using RAPD marker. *Annals of Plant Protection Sciences* **20**(1): 148-153.
7. Sharma A.R., Jat M.L., Sahrawat Y.S., Singh V.P. and Singh, Raghwendra. 2012. Conservation agriculture for improving productivity and resource-use efficiency: Prospects and research needs in Indian context. *Indian Journal of Agronomy* **57**(special issue): 131-140.
8. Sharma, S., Banerjee, K. and Choudhury, P.P. 2012. Degradation of chlorimuron-ethyl by *Aspergillus niger* isolated from rice rhizospheric soil. *FEMS Microbiology Letters* **337**(1): 18-24.
9. Singh, D.K., Sharma, D.P., Abraham, G. Annee and Singh, P.K. 2012. Information delivery system through kisan mobile advisory services. *Indian Journal of Extension Education* **47**(3&4): 141-145
10. Singh, P.K. and Barman, K.K. 2011. Impact of weed management technologies in changing economic scenario of farmers. *Indian Journal of Extension Education* **47**(3&4): 6-9.
11. Singh, P.K., Barman, K.K. and Singh, D.K. 2011. Adoption of rice production technologies by tribal farmers of Mandla District of M.P. *Indian Journal of Extension Education* **47**(3&4): 124-127.
12. Sondhia, S. 2012. Dissipation of pendimethalin in soil and its residues in chickpea (*Cicer arietinum* L.) under field conditions. *Bulletin of Environmental Contamination and Toxicology* **89**(5): 1032-1036.
13. Sondhia, S. and Dixit, Anil. 2012. Bioefficacy and persistence of ethoxysulfuron in rice. *Oryza* **49**(3): 179-183.
14. Sondhia, S., Duke, S.O., Solomon, Green, Nadezhda, G., Gemejiyeva, Mamonov L.K. and Cantrell, C.L. 2012. Phytotoxic furano-coumarins from the shoots of *Semenovia transiliensis* Regel & Herder. *Natural Product Communications* **10**: 1327-1330.
15. Sushilkumar. 2011. Aquatic weed problems and management in India. *Indian Journal of Weed Science* **43** (3&4): 118-138.
16. Sushilkumar. 2011. Biological based chemical integration for early control of water hyacinth. *Indian Journal of Weed Science* **43**(3&4): 211-214.

15.2. Papers presented

1. Abraham, C.T., Jose, Nimmy and Rathore, Meenal. 2012. Current status of weedy rice in India and strategies for its management, pp. 8. Invited paper presented at the Biennial Conference of Indian Society of Weed Science on '*Weed threat to Agriculture, Biodiversity and Environment*' held at Kerala Agricultural University, Thrissur during 19-20 April, 2012.
2. Barman, K.K. 2012. Effect of alternate wetting-drying of soil on efficacy and dissipation of butachlor, pretilachlor and pendimethalin, pp. 55. Paper presented at the Biennial Conference of Indian Society of Weed Science on '*Weed threat to Agriculture, Biodiversity and*

Environment' held at Kerala Agricultural University, Thrissur during 19-20 April, 2012.

3. Chandra, H., Gharde, Y. and Jain, V. K. 2012. Small area prediction under unit level model using estimated auxiliary data. Invited talk delivered in the session on '*Small Area Estimation*' at the 66th Annual Conference of Indian Society of Agricultural Statistics held at New Delhi during 18-20 December, 2012.

4. Chandra, N., Jain, N.K., Sondhia, S. and Srivastava, A.B. 2012. Deltamethrin induced toxicity and ameliorative effect of alpha-tocopherol in broiler. Paper presented at the National Seminar on '*Emerging Trends in Diagnosis and Control of Poultry Diseases*' held at Hisar during 5-7 November, 2012.

5. Chandra, N., Jain, N.K., Sondhia, S. and Srivastava, A.B. 2013. Determination of deltamethrin residues in muscles of chickens by HPLC. Paper presented at the 1st International Conference on '*New Horizons in Pharmaceutical and Biomedical Sciences*' (NHPBMS-2013) in association with International Journal of Pharmaceutical Sciences and Research (IJPSR) held at Dehradun during 12-13 January, 2013.

6. Dixit, Anil, Raghuvanshi, M.S. and Sushilkumar. 2012. Biosafety assessment of transgenic staked corn hybrids, pp. 56. Poster paper presented at the Biennial Conference of Indian Society of Weed Science on '*Weed threat to Agriculture, Biodiversity and Environment*' held at Kerala Agricultural University, Thrissur during 19-20 April, 2012.

7. Dixit, Anil. 2012. New molecules in weed management, pp 31. Poster paper presented at the Biennial Conference of Indian Society of Weed Science on '*Weed threat to Agriculture, Biodiversity and Environment*' held at Kerala Agricultural University, Thrissur during 19-20 April, 2012.

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2. धगट, संदीप एवं धगट, मोनिका 2012. टिकाऊ खेती के लिए भूमि में गुणवत्ता (स्वास्थ्य मृदा) होना आवश्यक । तृण सन्देश **8**: 47

3. दीक्षित, अनिल 2012 फसलों में शाकनाशी रसायनों के प्रयोग। तृण सन्देश **8**: 12

4. दीक्षित, अनिल 2012 प्लास्टिक मल्चिंग खरपतवार नियंत्रण का तंत्र। तृण सन्देश **8**: 25

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6. डोंगरे, जी.आर. 2012. नीदा करो नियंत्रण (कविता)। तृण सन्देश **8**: 52

7. डोंगरे, जी.आर. 2012. औषधीय गुणों से भरपुर फलों का राजा आम। तृण सन्देश **8**: 64

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11. मीणा, एम.के. 2012. गुलाब की खेती । तृण सन्देश **8**: 62

12. रघुवंशी, एम.एस., बर्मन, के.के. एवं डोंगरे, जी.आर. 2012. जैविक खेतीः आधुनिक भारतीय कृषि का प्राचीन स्वरुप । तृण सन्देश **8**: 38

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15. सिंह, पी.के. एवं पारे, एस.के. 2012. खरपतवार प्रबन्धन तकनीक का क्षेत्र प्रदर्शन। तृण सन्देश 8: 18

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17. सिंह, पी.के. एंव बर्मन, के.के. 2012. मृदा को प्रदूषित करने वाले प्रमुख कारक। तृण सन्देश 8: 60–61

18. सिंह, पी.के. एवं बर्मन, के.के. 2012. मृदा का प्रदूषित करने वाले प्रमुख कारक । तृण सन्देश 8: 60

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21. सिंह, वी.पी., मीणा, आर.के. एवं कौरव, पवन 2012 लघु एवं सीमांत कृषकों के लिए सर्वोत्तम विधि : श्री धान पद्धति। तृण सन्देश 8: 27

22. सुशीलकुमार एवं सौंधिया शोभा 2012 एलीगेटर वीड या घड़ियाली खरपतवार की भारत में बढ़ती समस्या। तृण सन्देश 8: 31

23. तिवारी, सुरेश एवं विश्वकर्मा, घनश्याम 2012. खरपतवार क्या है? एवं खरपतवार से फसलों का बचाव कैसे करें। तृण सन्देश 8: 33

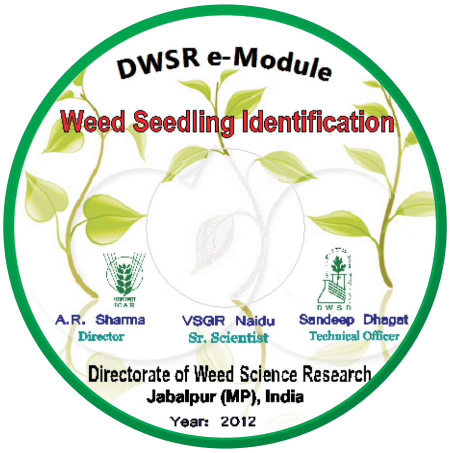
24. उपाध्याय, आर.एस. 2012. कृषि में समुचित विकास की आवश्यकता । तृण सन्देश 8: 59

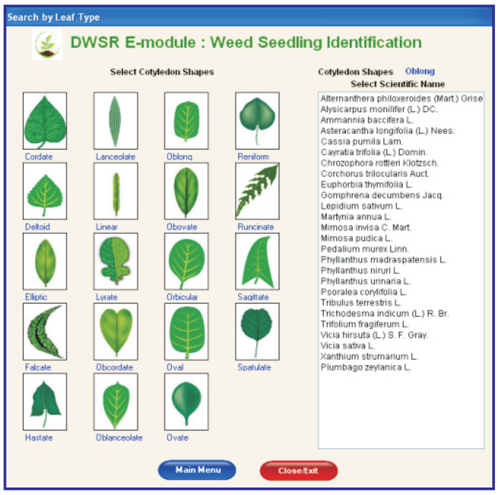
25. विश्वकर्मा, घनश्याम एवं तिवारी एस. के 2012. प्याज की उन्नत खेती। तृण सन्देश 8: 55

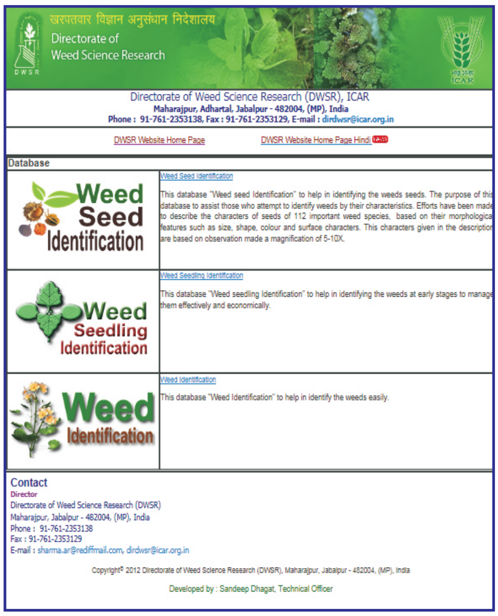
26. विश्वकर्मा, घनश्याम एवं सिंह, वी.पी. 2012. जीरो टिलेज से गेहूं का सफल उत्पादन । तृण सन्देश 8: 45

15.6. e-Module on Weed Seedling Identification

An e-module on 'Weed seedling Identification' was published by the Directorate to help in identifying the weeds at early stages to manage them effectively and economically. In this e-module, the user can identify a weed using search/query with the scientific name of the weed, or by viewing the cotyledon shape thumbnail. User can select the image or name of weed seedling to retrieve the data of that species with all identification characters. The weed seedling information would appear as follows:







16. MONITORING AND REVIEW OF RESEARCH PROGRAMMES

Research programmes of the Directorate have been reviewed by different committees as per the provisions of the Council. Recommendations made by these committees have been implemented for strengthening the research programmes.

The following meetings of various committees were held during the year:

16.1. Quinquennial Review Team meeting

Quinquennial Review Team reviewed the research, teaching, training and extension programmes of the Directorate including AICRP on Weed Control for the period from 2006 to March 2012. Duirng the year 2012, two meetings of QRT was held on 1-3 May, 2012 at DWSR, Jabalpur; and 16-17 May 2012 at NRCPB, New Delhi. Dr. S.C. Modgal, Chairman, and other members, Dr. B.S. Parmar, Dr. B.L. Jalali, Dr. R.S. Malik and Dr. P. Ananda Kumar participated in these meetings. QRT has made exhanstive recommendations for revamping the research programmes of the Directorate and strengthening AICRP network programmes. The final report of QRT of this Directorate for period from 2006 to March 2012 has been submitted to the Council.

16.2. Institute Research Council meeting

Meetings of IRC were conducted under the Chairmanship of Dr. A.R. Sharma, Director, DWSR on 14 and 16 June, 2012. Dr. A.K. Pandey, Chairman, M.P. Private Universities Regulatory Commission, Bhopal, and Dr. R.S. Tripathi, Former Director of Research IGKV, Raipur were invited to act as resource persons. Dr. A.R. Sharma presented brief information about the Directorate, mandate / objectives, infrastructure, staff strength, and research projects undertaken during 2011-12. Dr. A.K. Pandey stressed on the importance of bioherbicide development and biocontrol measures for managing weeds. He emphasized on integration of bioherbicides with other weed management technologies. He insisted to survey for indigenous bioagents and to explore their potential for management of problem weeds. Dr. R.S. Tripathi stressed that although the weeds are harmful, yet they are equally useful and hence should be treated as such. Attention should be given to management practices established using reduced herbicide use and mechanical weeding needs to be promoted. The research work carried out by the scientists during 2011-12 was reviewed in the meeting, and new programmes for 2012-13 were decided.

16.3. Research Advisory Committee meeting

XVI Research Advisory Committee meeting of the Directorate was held on 22-23 February, 2013 under the Chairmanship of Dr. R.K. Malik. Other memebrs, Dr. R.S. Balyan, Dr. B.L. Jajali and Dr. B.S.

Parmar were also present. Director, DWSR made a brief presentation on research programnmes and other activities undertaken during 2011-12. He covered the aspects related to (i) historical background of DWSR, (ii) facilities available at DWSR, (iii) staff strength, (iv) discipline-wise scientific strength, (v) research programmes, and (vi) meetings of last RACs, QRTs, IMCs and IRCs. The committee reviewed the ongoing research programmes of the Directorate, and made useful recommendations. The members had intensive discussions with the scientists and visited the experimental farm and laboratories of the Directorate.

16.4. Institute Management Committee meeting

XXI Meeting of IMC was held on June 30, 2012 at the Directorate. It was the first meeting of the newly-constituted IMC. Dr. A.R. Sharma, Director, DWSR and Chairman, IMC made a brief presentation on the DWSR - historical background, mandate, infrastructure, staff strength, research projects undertaken, and new research programmes. Dr. S.C. Modgal, the Chairman, QRT presented the QRT report, which, after thorough discussion, was adopted by the IMC. Five programme leaders presented the salient research achievements of 2011-12, and the newly-identified major research programmes. Administrative and financial issues were discussed in the meeting.

16.5. Project Monitoring and Evaluation Committee meeting

Meetings of the PMC Committee were held on 26 June, 2012; 22 November, 2012 and 21 January, 2013 under the chairmanship of Dr. A.R. Sharma, Director. The other members included Dr. V.P. Singh, Incharge, PME Cell; Dr. K.K. Barman, Incharge RFD Cell; Dr. R.P. Dubey, Incharge, AICRP on Weed Control; and Principal Investigators of research programmes, Dr. D.K. Pandey, Dr. Shobha Sondhia, Dr. P.K. Singh and Dr. Sushil Kumar. Besides, Dr. Anil Dixit, Er. H.S. Bisen and Dr. M.S. Raghuvanshi also participated as special invitees. The issues discussed in these meetings related to prioritization and evaluation of projects, submission of RPFs, RPPs of new research programmes, contract and consultancy research projects, SFC and Vision 2050 document, annual report etc.

17. EVENTS ORGANISED

17.1. Biennial Workshop of AICRP on Weed Control

Biennial workshop of All India Coordinated Research Project on Weed Control was organized at KAU, Thrissur, Kerala on 17-18 April, 2012. Dr. C.T. Abraham, Associate Dean, KAU, Thrissur and Principal Investigator, AICRP Weed Control at Thrissur centre welcomed the dignitaries and participants to the biennial workshop. Dr. P.V. Balachandran, Director of Extension, KAU in his presidential address highlighted the problems posed by aquatic weeds and weedy rice in the lowlands of Kerala state. He informed that the state of Kerala is proposed to be declared as an "organic state". Herbicide should be used in aquatic bodies with caution as these may harm the ecosystem if used indiscriminately. Top priority should be given for strengthening the research on pesticide residues. Dr. A.R. Sharma, Director, DWSR presented an outline of the areas of importance in weed management research in the light of several discussions held at the top level in ICAR. Later, he presented the research highlights of AICRP-WC during 2011-12. All scientists from 22 Coordinating Centres and 9 volunteer centres attended the meeting and presented the achievements made during the year. Technical programme for the next two years was finalized in the meeting.

17.2. Biennial Conference of Indian Society of Weed Science

Indian Society of Weed Science in collaboration with Kerala Agricultural University, Thrissur and Directorate of Weed Science Research, Jabalpur organized two days biennial conference on the theme 'Weed threat to Agriculture, Biodiversity and Environment' at KAU Thrissur, Kerala on 19-20 April, 2012. About 200 weed scientists from different parts of the country participated. Lead papers on different aspects of weed management were presented by the invited speakers. Dr. R.D. Gautam, Principal Scientist, IARI, New Delhi delivered the first 'Prof. Mahesh K. Upadhyay Lecture' on non-chemical weed management with special reference to *Parthenium hysterophorus*. General Body Meeting of the ISWS was held on 19 April, 2012, in which decision for unification of the two factions and conducting elections for the new Executive Council was taken.

17.3. *Parthenium* Awareness Week

Parthenium Awareness Week was organized from 16-22 August, 2012 throughout the country under the guidance and supervision of the Directorate. Technical knowhow and published material in the form of charts, posters, leaflets, banners, display boards etc. was provided to all 22 centres of AICRP-Weed Control, ICAR institutes, SAUs, KVKs, and NGOs. During this period, DWSR organized three scientists-farmers interface meetings from 16-18 August, 2012 at Padaria, Saraswa and Virner villages. One-day training programme for the farmers was also organized on 19 August, 2012. For creating awareness amongst school children, a quiz contest was also organized on 21 August, 2012.

17.4. Trainings organized

Directorate organized the following trainings:

- Training on 'Advancement in Weed Management Techniques' for officers of State department of Uttar Pradesh and progressive farmers (16-20 October, 2012)
- National Training on 'Advances in Weed Management' for the scientists of ICAR institutes and SAUs (31 October - 9 November, 2012)
- Model Training Course on 'Weed management for sustainable oilseeds and pulse production' for subject matter specialists (SMS) of different states (13-20 December, 2012)
- Training on 'Weed Management and Chemical Weed Control' for the progressive farmers under Project Directorate ATMA, Parbhani, Maharashtra (12-14 March, 2013)

17.5. Agriculture Education Day

Agriculture Education Day was celebrated for the first time on 20 November, 2012 at the Directorate for promoting the spirit of agricultural science among the school children of the rural areas of Jabalpur. Thirty students from 6 government schools belonging to classes from IX to XII participated in this programme. The students were enlightened on the topics, such as `Developments in agriculture – an historical perspective', `Challenges to agriculture vis-à-vis climate change', and `Environmental pollution – human concerns and solutions' using easily understandable Power Point Presentations.

17.6. Participation in 3rd International Agronomy Congress

Directorate participated in 3rd International Agronomy Congress held at IARI, New Delhi from 26-30 November, 2012. The stall of the Directorate displaying weed management technologies was adjudged the best stall of the Congress. A number of dignitaries and scientists from the country and abroad visited and appreciated the efforts made by DWSR and also attracted many students for publications and E-module on weed identification.

17.7. Vigilance Awareness Week

Directorate observed Vigilance Awareness Week from 19-25 November, 2012. 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.

17.8. Celebration of Independence and Republic Day

Directorate celebrated the Independence Day on 15 August, 2012 and Republic Day on 26 January, 2013 with great enthusiasm. Director greeted the members of the staff on the occasion. He listed the achievements made during the past year and the initiatives taken 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 activities were organized on this occasion.

17.9. ISWS Executive Council meeting

Elections of the members of the Executive Council of the unified Indian Society of Weed Science were conducted during the year. Dr. N.T. Yaduraju was elected unanimously as President, besides Dr. A.R. Sharma as Secretary and Dr. Shobha Sondhia as Treasurer from the headquarters. The first meeting of the newly-constituted Executive Council was held on 20 February, 2013 at DWSR Jabalpur.

18. PARTICIPATION IN SEMINARS AND WORKSHOPS

18.1. Participation in national / international seminars

A.R. Sharma

- Conference on Livelihood and Environmental Security through Resource Conservation in Eastern Region of India (LESRC-2012) organized by IASWC at Orissa University of Agriculture and Technology, Bhubaneswar from 4-6 April, 2012
- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- Training-cum-Workshop on Weed Management for states of Madhya Pradesh, Chhattisgarh and Odisha at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012
- Golden Jubilee Alumni Meet of the PAU, Ludhiana from 20-21 December, 2012
- ARRW Golden Jubilee International Symposium-2013 at CRRI, Cuttack from 2-5 March, 2013

H.S. Bisen

- Training-cum-Workshop on Weed Management for KVKs, PCs and scientists of Madhya Pradesh, Chhatisgarh and Odisha held at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- Interaction Meet of Stakeholders in Agriculture Sector for the State of MP at CIAE, Bhopal from 29-30 November, 2012

P.K. Singh

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- XIX Zonal Workshop of KVKs of Zone-VII, ICAR at Baster, Chhatisgarh from 4-6 May, 2012
- Training-cum-Workshop on Weed Management for states of Madhya Pradesh, Chhattisgarh and Odisha at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012

V.P. Singh

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- Training-cum-Workshop on Weed Management for states of Madhya Pradesh, Chhatisgarh and Odisha at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- All India Coordinated Research Project on Chickpea at GBPUAT, Pantnagar from 1-3 September, 2012
- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012

Sushil Kumar

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- XXI AICRP Workshop on Biological Control held at ANGRAU, Hyderabad from 22-23 May, 2012.
- Training-cum-Workshop on Weed Management for states of Madhya Pradesh, Chhatisgarh and Odisha at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- Interaction Meet of Stakeholders in Agriculture Sector for the State of MP at CIAE, Bhopal from 29-30 November, 2012
- Workshop-cum-Training Programme on *Ambrosia psilostachya* at UAS, Bangaluru from 19-20 December, 2012

- X National Symposium on Biotechnological Approaches for Plant Protection: Constraints and Opportunities at ICAR Research Complex for Goa from 27-29 January, 2013

Anil Dixit

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- XIX Zonal Workshop of KVKs of Zone-VII, ICAR at Baster, Chhatisgarh from 4-6 May, 2012.
- Training-cum-Workshop on Weed Management for states of Madhya Pradesh, Chhatisgarh and Odisha at ZPD, JNKVV, Jabalpur from 28-29 June, 2012
- XIX Annual group meeting on rapeseed-mustard held at BAU, Ranchi from 3-5 August, 2012
- VI Consortium Implementation Committee (CIC) and Consortium Advisory Committee (CAC) of NAIP held at CIAE, Bhopal on 19 November, 2012
- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012
- Zonal workshop for finance and account officers held at CIFE, Mumbai on 21 January, 2013

K.K. Barman

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012

R.P. Dubey

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012

D.K. Pandey

- AICRP-WC Workshop held at KAU, Thrichur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrichur from 19-20 April, 2012
- National symposium on climate change at BAU, Ranchi from 3-5 November, 2012
- ARRW Golden Jubilee International Symposium-2013 at CRRI, Cuttack from 2-5 March, 2013.

P.J. Khankhane

- Biennial Conference of ISWS at KAU, Thrichur from 19-20 April, 2012

Shobha Sondhia

- Workshop of All India Network Project on Pesticide residues at ANGRAU, Hyderabad from 12 May, 2012.
- Monitoring of Pesticide Residues at National level at ANGRAU, Hyderabad from 13 May, 2012
- Second International Science Congress, Vrindavan, Mathura from 8-9 December, 2012
- ICAR Chemists' Conclave at IARI, New Delhi from 14-15 January, 2013
- National Workshop on Foresight and Future Pathways of Agricultural Research through Youth in India at New Delhi from 1-2 March, 2013

V.S.G.R. Naidu

- AICRP-WC Workshop held at KAU, Thrichur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrichur from 19-20 April, 2012

C. Kannan

- AICRP-WC Workshop held at KAU, Thrichur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012

P.P. Choudhury

- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- ICAR Chemists' Conclave at IARI, New Delhi from 14-15 January, 2013

Bhumesh Kumar

- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012
- National Workshop on Foresight and Future Pathways of Agricultural Research through Youth in India at New Delhi from 1-2 March, 2013

Raghwendra Singh

- Third International Agronomy Congress at IARI, New Delhi from 26-30 November, 2012
- ARRW Golden Jubilee International Symposium-2013 at CRRI, Cuttack from 2-5 March, 2013

Meenal Rathore

- ARRW Golden Jubilee International Symposium-2013 at CRRI, Cuttack from 2-5 March, 2013

Yogita Gharde

- Eighth International Triennial Calcutta Symposium on Probability and Statistics held at Kolkata from December 27-30, 2012

Dibakar Ghosh

- ARRW Golden Jubilee International Symposium-2013 at CRRI, Cuttack from 2-5 March, 2013

M.S. Raghuvanshi

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012
- Biennial Conference of ISWS at KAU, Thrissur from 19-20 April, 2012

O.N. Tiwari

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012

Pankaj Shukla

- AICRP-WC Workshop held at KAU, Thrissur from 17-18 April, 2012

18.2. Technical seminars at the Directorate

Technical seminars by outside experts and scientists of the Directorate were introduced. The details are given in Table 1.

Table 1. Lectures delivered by outside experts and scientists of the Directorate

Speakers	Topic	Date
1. R.P. Nachane, CIRCOT, Mumbai	General procedure for management of intellectual property	12 June, 2012
2. Sushil Kumar	Aquatic weed problem and their management in India	27 July, 2012
3. Anil Dixit	Herbicide tolerant crops – challenges and opportunities	31 August, 2012
4. Yogita Gharde	Forecasting methods in agriculture	5 October, 2012
5. Bhumesh Kumar	Bioprospection of weed species for food security under the regimes of climate change	29 October, 2012
6. P.J. Khankhane	Weed utilization: potential and prospects for control of soil and water pollution	22 November, 2012
7. H.S. Bisen	Design, development and evaluation of different self-propelled power weeders in India and abroad	31 January, 2013
8. N.T. Yaduraju, ICRISAT, Hyderabad	Agropedia - Knowledge repository and social networking platform	20 February, 2013
9. C. Kannan	Host plant defense against parasitic weeds	28 February, 2013
10. P.P. Choudhury	Microwave: from kitchen to field	30 March, 2013

19. All India Coordinated Research Project on Weed Control

Directorate has 22 coordinating and 7 volunteer centres located at different state agricultural universities for carrying out network research and generating location-specific technologies on weed management in different crops, cropping systems and non-crop situations.

Salient research achievements made during 2012-13 are presented below:

19.1. Weed surveillance

- New weeds species, viz. *Tithonia diversifolia* and *Mikania micrantha* in hilly zone; *Ipomoea triloba* in sugarcane fields in Chamarajanagar and Mysore districts; *Ambrosia psilostachya* in Turuvekere taluk; *Ipomoea pes-tigridis* in clay-loam soils in cotton and sugarcane fields in Hiriyur and Davanagere areas; *Ipomoea cairica*, *Ipomoea staphylina* and *Ipomoea occinea* in many areas on road side were noticed in Southern Karnataka.

Ambrosia psilostachya

Ipomoea triloba

- *Alternanthera triandra* has emerged as a new problem in direct-seeded rice in Chhattisgarh. This is also invading road sides and field bunds in areas around Raipur.
- *Mikania micrantha, Parthenium hysterophorus, Eichhornia crassipes* and *Alternanthera philoxeroides* were prominent weeds observed in East and South Eastern Coastal Plain Zone of Odisha. In Mid- Central Table Land Zone, *Celosia argentea* was reported in groundnut and pulses under rainfed upland situation. *Phragmites karka*, covering one-tenth area of the Chilika Lagoon lake, posed a serious problem in navigation and fishing.
- *Cuscuta chinensis* was observed in berseem in Ambala, Yamuna Nagar, Karnal, Kaithal, Tohana, Kurukshetra and Kaithal areas of Haryana. Infestation of *Orobanche aegyptiaca* was also observed in mustard in sand dunal areas of Meham, Mirchpur, Choudhriwas and Juglan (Hisar), Kathura (Gohana), Odhan (Sirsa) and Bhatto (Fatehbad).
- In Dibrugarh district of Assam, *Eichhornia crassipes* was found to be the most dominant weed in the summer season, followed by *Ipomoea carnea*. Among broadleaved species, *Monochoria vaginalis* was the most dominant weed, followed by sedges, viz. *Eleocharis acutangula* and *Fimbristylis littoralis* in the transplanted rainy season rice.
- Weed surveillance in different parts of Punjab indicated that intensity of *Phalaris minor* was on the increase in wheat. *Poa annua* was likely to become important weed in wheat, berseem and oats; *Ipomoea* in berseem; and weedy rice in transplanted rice. *Dactyloctenum aegyptiacum, Leptochloa* sp. and *Eragrostis* sp. were on the increase in direct-seeded rice, replacing *Echinochloa* sp.
- In the central part of Kerala in Thrissur, incidence of weedy rice (*Oryza spontanea*) and Chinese sprangletop (*Leptochloa chinensis*) was seen in most rice fields in alarming densities. In upland crops, *Alternanthera betzickiana*, *Axonopus compressus* and *Hyptis capitata* are emerging as problem weeds.

19.2. Weed biology and physiology

- At Jorhat, morphological dissimilarity amongst *Echinochloa colona* germplasm was considerably higher than that of *E. glabrescens*. At Sriniketan, the highest emergence (61%) was recorded in fresh seeds of *E. colona* which started within 10 DAS and decreased with increase in age of seeds.
- Weedy rice species so far collected and identified in Assam was *Oryza rufipogon*. At Palampur, infestation was highest in direct-seeded rice, followed by direct-seeded puddled rice and least in transplanted rice

(Table 1). At Pusa, weedy rice found in deep water areas in Darbhanga and Madhubani districts were *Oryza rufipogan* and *Oryza spontanea*. The yield loss due to weedy rice varied from 20-45%.

Table 1 : Distinguishing characters of rice an weedy rice observed at Palampur

Character	Rice	Weedy rice
Flag leaf	Small	Long
Stem	Flattened	Round
Leaves	Dark green colour	Light green colour
Spikelets	Awnless, small awned	Awned and course grains
Maturity and shattering	Late maturing and less shattering	Early maturing and early shattering

- *Phalaris minor* showed resistance against clodinafop-propargyl in Kaithal, Karnal, Jind, Panipat and parts of Fatehbad, Ambala and Kurukshetra districts of Haryana. Mesosulfuron + iodosulfuron (*RM*), sulfosulfuron + metsulfuron (*RM*) at 32 g/ha and pinoxaden at 50 g/ha performed well with 80-92% control of *P. minor* and resulting in the highest yield of wheat.

19.3. Weed management in crops and cropping systems

- For control of complex weed flora in direct-dry seeded rice, application of pendimethalin @ 1000 g/ha PE followed by bispyribac-Na @ 25 g/ha + one hand weeding at 45 DAS resulted in the lowest weed density, weed biomass and higher grain yield at Pantnagar, Bhubaneswar, Hyderabad, Bengaluru, Ranchi, Palampur and Raipur; whereas application of pendimethalin @ 1.0 kg/ha *fb* manual weeding at 25 DAS was found most effective at Jorhat and Dapoli.
- In turmeric, pre-emergence application of pendimethalin @ 1.0 kg/ha, metribuzin @ 0.7 kg or atrazine @ 0.75 kg/ha *fb* straw mulching @ 10 t/ha + 2 hand weedings on 45 and 75 DAP recorded less weed density, dry weight and highest rhizome yield at Hisar, Ludhiana, Palampur and Coimbatore. At Pusa, atrazine @ 0.75 kg/ha *fb* fenoxaprop @ 67 g/ha+ metsulfuron @ 4 g/ha and at Jorhat metribuzin @ 700 g/ha + hoeing were found most effective (Table 2).

Table 2 : Effect of herbicides on rhizome yield (t/ha) of turmeric

Treatment	Ludhiana	Palampur	Pusa	Jorhat
Metribuzin @ 0.7 kg/ha *fb* two hoeings	10.8	5.4	41.6	13.1
Metribuzin @ 0.7 kg/ha *fb* fenoxaprop @ 67 g/ha+ metsulfuron @ 4g/ha	8.2	2.8	48.3	10.1
Metribuzin @ 0.7 kg/ha *fb* straw mulch @ 10 t/ha *fb* one HW	18.2	13.7	45.1	11.6
Pendimethalin @ 1.0 kg/ha *fb* two hoeings	12.0	6.3	42.8	12.8
Pendimethalin @ 1.0 kg/ha *fb* fenoxaprop at @ 67 g/ha+ metsulfuron @ 4g/ha	0.9	2.8	49.5	11.1
Pendimethalin @ 1.0 kg/ha *fb* straw mulch @ 10 t/ha *fb* one HW	16.8	13.4	45.8	12.8
Atrazine @ 0.75 kg/ha *fb* fenoxaprop at @ 67 g/ha+ metsulfuron @ 4 g/ha	9.8	2.3	50.6	10.5
Atrazine @ 0.75 kg/ha *fb* straw mulch @ 10 t/ha *fb* one HW	16.7	12.0	46.1	12.6
2 hand weedings	17.1	7.0	52.5	12.6
Weedy check	4.2	2.9	29.3	3.6
LSD (P=0.05)	**4.7**	**2.4**	**3.9**	**2.4**

- Imazethapyr @ 50-70 g, imazethapyr + imazamox (*RM*) @ 60-80 g, imazethapyr + pendimethalin @ 800-1000 g/ha provided effective control of *E. colona* in greengram. Pendimethalin @ 1000 g/ha as pre-emergence was effective against *D. aegyptium* and lost its efficacy 20 days after its use at Hisar and Ludhiana.

19.4. Long-term trial on tillage in different cropping systems

- In rice-wheat cropping system at Ranchi, Kanpur and Faizabad, conventional tillage in rice and wheat recorded significantly reduced weed dry matter accumulation as compared to zero-conventional and zero–zero tillage.
- In rice-rice cropping system at Bhubaneswar and Thrissur, the practice of conventional tillage reduced weed densities to the tune of 29-44%. However in zero tillage plots, there was a shift from common weeds to *Eleocharis*. Grain and straw yields were higher with conventional tillage/ conventional-zero tillage and lowest with continuous zero tillage.
- In maize-sunflower cropping system at Coimbatore and Bengaluru, lower density and dry weight of weeds with higher yield were recorded in CT-CT and atrazine @ 0.5 kg/ha + hand weeding on 45 DAS. At 60 DAS, density of all weeds showed an increasing trend as compared to 30 DAS. The yield of sunflower was higher in continuous conventional tillage than zero tillage.

19.5. Weed management in conservation agriculture systems

- In rice-wheat cropping system, the lowest weed density at 60 days stage was obtained with DSR (ZT)-wheat (ZT)-cowpea (ZT), followed by TPR (CT)-wheat (CT) at Pantnagar. At Pusa and Bengaluru, conventional tillage had slightly lower weed density and dry weight as compared to zero tillage at all stages. The lowest weed count (11.2 /m^2) and dry weight (22.8 g/m^2) were recorded at 60 DAS under CT (transplanted)-ZT-ZT, being statistically at par with CT (transplanted)-CT but significantly superior to rest of the treatments.
- Adopting conventional tillage for transplanted rice (4.41 t/ha) or direct-seeded rice (4.18 t/ha) gave significantly higher yields than zero tillage with direct-seeded rice (3.34 t/ha) at Bengaluru. Similarly at Pusa, the highest grain yield of rice (4.21 t/ha) was recorded under CT (transplanted)–CT, which was statistically at par with CT (transplanted)-ZT-ZT. However, DSR gave more grain yield as compared to transplanted systems at Pantnagar.
- In rice-rice cropping system at Coimbatore, lower weed dry weight was observed in conventional tillage (TPR) - conventional tillage system and conventional tillage (DSR)-CT-ZT. Integrated weed management recorded lower weed dry weight, which was closely followed by chemical method of weed control. Higher grain yield was observed in conventional tillage - conventional tillage system (5.60 t/ha) and transplanted - conventional tillage system (5.28 t/ha).
- In rice-maize cropping system at Hyderabad, the lowest weed dry matter was recorded with early post-emergence application of bispyribac-Na @ 20 g/ha *fb* mechanical weeding and pre-emergence application of pretilachlor @ 0.5 kg/ha *fb* post-emergence application of cyhalofop-p-butyl + almix (metsulfuron-methyl + chlorimuron-ethyl) at 25 DAT (20.7 g/m^2).

19.6. Long-term herbicide trial in different cropping systems

- In rice-rice cropping system at Jorhat, the highest grain yield in both autumn and winter rice crops in sequence was obtained with butachlor + 2,4-D rotated with pretilachlor (100% chemical fertilizer), closely followed by butachlor + 2,4-D rotated with pretilachlor (75% NPK through chemical fertilizer, 25% through organic source). Rotation of butachlor with pretilachlor was very effective in reducing the population of *Monochoria vaginalis* and *Sagittaria guayanensis, Eleocharis dulcis* and *Cyperus iria.*
- At Coimbatore in lowland transplanted rice-rice cropping system, the effect on weed density and dry weight was minimum under rotational use of herbicides (butachlor in rainy and pretilachlor in winter) with integration of nutrients. Weed shift from broadleaved weed (*Marsilea quadrifolia)* to grasses *(Echinochloa crusgalli)* and sedges (*Cyperus difformis*) was also observed.

- At Bengaluru in rice-rice cropping system, sequential application of butachlor @ 0.75 kg + 2,4-D EE @ 0.4 kg/ha at 3 DAT during rainy season *fb* application of pretilachlor @ 0.75 kg/ha as pre-emergence in summer resulted in grain yield similar to hand weeding. The use of herbicides continuously did not alter the soil physico-chemical properties nor affected the microbial growth or beneficial micro-organisms in rice–rice system over a period of 14 cropping cycles.
- In rice-wheat system at Hisar, continuous use of clodinafop @ 60 g/ha provided effective control of *P. minor* in wheat. The continuous or rotational use of clodinafop provided comparable yields with weed-free plots. In rice, the performance of continuously used clodinafop in wheat and butachlor in rice provided effective control of weeds. There was no sign of development of resistance in *Echinochloa crusgalli* against continuously-used or rotationally-applied herbicides.
- At Palampur in transplanted rice-wheat cropping system, irrespective of continuous or rotational use of herbicides in rice and wheat, use of 75% N through fertilizer + 25% N through *Lantana* in rice resulted in significantly higher grain yield of rice and wheat.
- At Ludhiana, sequential application of trifluralin (1.2 kg/ha) and 2,4-D (0.5 kg/ha) recorded the highest wheat grain yield, net returns and B:C ratio. It was at par with sequential application of sulfosulfuron and 2,4-D, and rotational herbicides. In rice, sequential application of butachlor (1.5 kg/ha) and metsulfuron (0.015 kg/ha) recorded the highest rice grain yield and B:C ratio. It was at par with sequential application of anilophos and metsulfuron.
- In rice-mustard cropping system at Sriniketan, repeated and rotational application of pretilachlor / butachlor resulted in disappearance of *Hydrolea zeylanica*, decrease in the density of *Fimbristylis miliacea* and increase in the density of *Cynodon dactylon* and *Digitaria sanguinalis* after 10 years of application.

19.7. Management of problematic/invasive/ parasitic/aquatic weeds

- At Hisar, post-emergence application of glyphosate @ 25 g/ha at 30 DAS followed by its use @ 50 g/ha at 55 DAS provided effective control (79%) of *Orobanche* in mustard. At Gwalior, number of *Orobanche* shoots was the lowest when mustard was applied with trifluralin @ 1.5 kg/ha + neem oil 1% PPI, followed by glyphosate @ 25 g/ha with 2% ammonium sulphate at 40 DAS.
- At Bhubaneswar, stale seedbed *fb* pre-emergence application of pendimethalin @ 1.0 kg/ha recorded the lowest *Cuscuta* density at 30 and 60 DAS and highest yield of niger. Ploughing before sowing and application of pendimethalin @ 1.0 kg/ha as pre-emergence sand-mix resulted in significantly higher yield of field bean and lower infestation of *Cuscuta* at Dapoli.
- At Bengaluru, *Dendrophthoe* was observed on sapota trees. Padding of cotton with the paste of 4 g copper sulphate + 0.5 g 2,4-D Na salt on the cuts of *Dendrophthoe* shoots caused 100% defoliation after 2 months without regeneration up to 6 months. The younger shoots showed drying after 2 months.
- At Thrissur, *Taxillus cuneatus* (*Loranthus*) was observed on apple, peach, plum and pomegranate. Ethrel application @ 25 ml/l and padding with 2,4-D (1 g/20 ml) was found effective for controlling *Loranthus*.

Ethrel application for controlling *Loranthus*

19.8. Biological weed management

- *Zygogramma bicolorata* behaved differently at different places of its release. There was no establishment of the beetle at the released sites at Anand, Jorhat, Ranchi, Thrissur, Sriniketan, Dapoli and Hisar. However, the beetles established well at Kanpur, Palampur, Pantnagar, Parbhani, Faizabad, Ludhiana and Gwalior centres, with its effect varying from 10-70%.

- Broadcasting of seeds of *Cassia tora* during April-May well before the onset of monsoon on infested sites of *Parthenium* successfully replaced *Parthenium* by September-October.

- *Neochetina* spp. weevils multiplied and caused excellent control of water hyacinth. Alligator weed replaced the niche vacated by water hyacinth. Augmentation also helped in population build-up of weevil, which controlled most of the water hyacinth.

Sequence of control of water hyacinth by *Neochetina* spp.

19.9. Herbicide residues and environmental quality

- In pearlmillet-groundnut and groundnut-fingermillet cropping systems at Bengaluru and Anand respectively, the residues of pendimethalin were below detectable level (0.01 mg/kg) in both soil and kernels of groundnut. In fingermillet, the residues of butachlor were found below detectable level (0.01 ppm) in soil, grain and straw. Atrazine residues were detected up to 30 days in soil after its application in pearlmillet, while the residues were below detection limit in grain and straw of pearlmillet.

- 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.

- Residues of butachlor and pretilachlor were found below detectable level in pond adjacent to fields where herbicides were applied in rice at Bengaluru. The residues of pyrazosulfuron-ethyl were seen up to 4th week after application in underground water (0.0052 and 0.0061 µg/g at 25 g and 50 g/ha dose, respectively). However after 45 days, it was below detectable limits in underground water at both the doses.

- Carfentrazone-ethyl was detected in wheat foliage up to 30 days after application, and its metabolite chloropropionic acid was detected up to 7 days. Thereafter, both the compounds were found below detectable limits at Coimbatore.

19.10. Transfer of technology

- During 2012, AICRP-WC centres conducted 369 frontline demonstrations on location-specific weed management technologies, and broadcast 29 radio and 21 TV talk-shows. In addition to this, 51 training programmes were conducted, 28 handouts, folders, pamphlets, bulletins/ booklet in various languages were published and distributed to the farmers and other end-users.

- In 9 frontline demonstrations in transplanted rice at Mandya, Karnataka, use of bispyribac-sodium @ 20 g/ha at 20 DAP resulted in 18% more rice grain yield, saved weeding cost by ₹ 3900/ha and increased income by ₹ 6900/ha over weedy check.

- In onion, 10 FLDs at Viraliyur Taluk of Coimbatore revealed that application of pre-emergence oxyfluorfen @ 250 g/ha (3 DAS) + twin wheel-hoe weeding (40 DAS) increased yield by 15.9-43.1% over farmers' practice.

- In 20 frontline demonstrations on transplanted rice at Ranchi, pyrazosulfuron @ 0.02 kg/ha recorded 33.2% higher grain yield (3.45 t/ha) and 39.7% higher net returns (₹ 28,061/ha) compared with farmer's practice.

20. DISTINGUISHED VISITORS

Dr. S.S. Baghel, Former Vice Chancellor, CAU, Imphal	19 March, 2012
Dr. V.M Bhale, Registrar, PDKV, Akola	19 March, 2012
Dr. R.P. Thakur, Former Principal Scientist, ICRISAT, Hyderabad	19 March, 2012
Dr. S.C. Modgal, former Vice Chancellor, GBPUAT, Pantnagar	2 May and 30 June, 2012
Dr. R.J. Rabindra, Former Director, NBAIM, Bengaluru	2 May, 2012
Dr. B.C. Barah, Member, QRT and former Director, NCAP, New Delhi	2 May, 2012
Dr. B.S. Parmar, Former Joint Director, IARI, New Delhi	2 May, 2012 22-23 February, 2013
Dr. S.K. Dhyani, Director, NRCAF, Jhansi	21 May, 2012
Dr. A.K. Pandey, Chairman, M.P. Private Universities Regulatory Commission, Bhopal	14 June, 2012
Dr. R.S. Tripathi, Former Director of Research, IGKV, Raipur	16 June, 2012
Dr. A.K. Vyas, Head, Division of Agronomy, IARI, New Delhi	30 June, 2012
Dr. S.S. Shrimali, Principal Scientist, CSWCRTI, Dehradun	30 June, 2012
Dr. S.D. Upadhyay, Head, Department of Forestry, JNKVV, Jabalpur	30 June, 2012
Dr. N.F. Almubarak, Weed Scientist, University of Diyala, Iraq	20 September, 2012
Dr. B.P. Tripathy, Joint Director (Agriculture), Jabalpur, Madhya Pradesh	16 October, 2012
Dr. R.P. Singh, Secretary General, IAUA, New Delhi	20 October, 2012
Dr. Nicholas Davis, Social Scientist, BISA–CIMMYT, New Delhi	19 October, 2012
Dr. R.K. Gupta, South Asia Coordinator, CIMMYT-India, New Delhi	30 October, 2012
Dr. N.N. Pathak, Vice Chancellor, JNKVV, Jabalpur	31 October, 2012
Dr. R.K. Gupta, South Asia Coordinator, CIMMYT-India, New Delhi	5 November, 2012
Dr. Bhagirath S. Chauhan, Weed Scientist, IRRI, Los Banos, Philippines	24 November, 2012
Dr. S.S. Tomar, Director of Research, JNKVV, Jabalpur	13 December, 2012
Dr. D.V. Singh, Former Head, Division of Plant Pathology, IARI, New Delhi	December, 2012
Dr. S. Rajendra Prasad, Director, Directorate of Seed Research, Maunath Bhanjan	December, 2012
Sh. Prabhat Sahu, Mayor, Jabalpur City	19 February, 2013
Dr. K.K. Saxena, Director of Extension, JNKVV, Jabalpur	19 February, 2013
Dr. T.V. Muniyappa, Former President, ISWS, Bangaluru	20 February, 2013
Dr. N.T. Yaduraju, President, ISWS and ICRISAT, Hyderabad	20 February, 2013
Dr. Megh Singh, Weed Scientist, University of Florida, US	20 February, 2013
Dr. S.K. Rao, Dean (Faculty), JNKVV, Jabalpur	20 February, 2013
Dr. R.K. Malik, Coordinator, CIMMYT, New Delhi	22-23 February, 2013
Dr. R.S. Balyan, Former Director, Students Welfare, CCSHAU, Hisar	22-23 February, 2013
Dr. Bhushan Lal Jalali, Former Director of Research, CCSHAU, Hisar	22-23 February, 2013
Dr. B. Gangwar, Director, PDFSR, Modipuram, Meerut	February, 2013
Dr. Sain Dass, Former Director, Directorate of Maize Research, New Delhi	28 March, 2013
Er. A.K. Trivedi, Chief Engineer, CIMMYT-India, New Delhi	30 October, 2012 28 March, 2013




21. PERSONALIA

21.1. Scientific staff

Names		Specialization
	**Dr. A.R. Sharma** Director Email: sharma.ar@rediffmail.com Mobile: 9425807290	Weed management, conservation agriculture and nutrient management
	**Er. H.S. Bisen** Pr. Scientist (Agril. Engg.) Email: bisenhs@gmail.com Mobile: 9425388101	Mechanical weeding tools, spraying techniques and machinery
	**Dr. P.K. Singh** Pr. Scientist (Agril. Extn.) Email: drsinghpk@gmail.com Mobile: 9425388721	Technology transfer, demonstrations, adoption and impact assessment
	**Dr. Ved Prakash Singh** Pr. Scientist (Agronomy) Email: vpsinghnrcws@gmail.com Mobile: 9424306051	Weed management in cropping systems, orchards, and conservation agriculture
	**Dr. Sushil Kumar** Pr. Scientist (Entomology) Email: sknrcws@gmail.com Mobile: 9425186747	Biological control of weeds, aquatic weed management, and weed and agro-waste utilization
	**Dr. Anil Dixit** Pr. Scientist (Agronomy) Email: dranildixit@in.com Mobile: 9424371588	Integrated weed management in crops and cropping systems, herbicide tolerant crops
	**Dr. K.K. Barman** Pr. Scientist (Soil Science) Email: barmankk@gmail.com Mobile: 9826811536	Integrated weed management and environmental quality
	**Dr. R.P. Dubey** Pr. Scientist (Agronomy) Email: dubeyrp@gmail.com Mobile: 9425412041	Integrated weed management and organic agriculture
	**Dr. D.K. Pandey** Pr. Scientist (Pl. Physiology) Email: dayapandey@hotmail.com Mobile: 9893659994	Allelopathy, natural herbicidal molecule isolation, seed biology and aquatic weeds

	**Dr. P.J. Khankhane** Sr. Scientist (Soil Science) Email: pjkhankhane@yahoo.com.ph Mobile: 9926715757	Bioremediation, soil and water quality, weed utilization and plant biomass management, wetland management
	**Dr. Shobha Sondhia** Sr. Scientist (Organic Chemistry) Email: shobhasondia@yahoo.com Mobile: 9425464997	Environmental impact of herbicides, mode of degradation, biomolecules, method development for herbicide residues and herbicide mitigation measures
	**Dr. V.S.G.R. Naidu** Sr. Scientist (Eco. Botany) Email: naidudwsr@gmail.com Mobile: 8790819002	Weed seed/seedling identification, weed dynamics under climate change, and weed ecology
	**Dr. C. Kannan** Sr. Scientist (Pl. Pathology) Email: agrikannan@gmail.com Mobile: 9425865057	Biological management of water hyacinth and parasitic weeds, systemic induced resistance in host, microbial composting and bioethanol
	**Dr. Partha Pratim Choudhury** Sr. Scientist (Organic Chemistry) Email: parthatinku@yahoo.com Mobile: 9179457045	Fate of herbicides in the environment, decontamination techniques, impact of solar UV-fraction on small organic molecules
	**Dr. Bhumesh Kumar** Sr. Scientist (Pl. Physiology) Email: kumarbhumesh@yahoo.com Mobile: 9806622307	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: 9806637031	Weed ecology, integrated weed management and conservation agriculture
	**Dr. Meenal Rathore** Sr. Scientist (Biotechnology) Email: mnl.rthr@gmail.com Mobile: 8989755865	Molecular tools to assess diversity and study biology of weeds, characterization of weed rice biosimilars
	**Dr. Yogita Gharde** Scientist (Agril. Statistics) Email: yogita_iasri@rediffmail.com Mobile: 9425412748	Modelling on crop-weed associations
	**Ms. C. Sarthambal** Scientist (Microbiology) Email: csaratha@yahoo.co.in	Soil microbiology
	**Mr. Dibakar Ghosh** Scientist (Agronomy) Email: dghoshagro@gmail.com Mobile: 8989190213	Weed ecology and weed management in conservation agriculture

21.2. Technical staff

1. Dr. M.S. Raghuwanshi	T-7-8 (Technical Officer)	13. Sh. J.N. Sen	T-5 (Technical Officer)
2. Sh. R.S. Upadhyay	T-7-8 (Farm Manager)	14. Sh. K.K. Tiwari	T-4 (Field Assistant)
3. Sh. Sandeep Dhagat	T-7-8 (Technical Officer)	15. Sh. M.K. Meena	T-4 (Field Assistant)
4. Sh. Mukesh Bhatt	T-6 (Artist-cum-Photographer)	16. Sh. S.K. Tiwari	T-4 (Field Assistant)
5. Sh. V.K.S. Meshram	T-6 (Artist)	17. Sh. S.K. Bose	T-4 (Field Assistant)
6. Sh. G.R. Dongre	T-6 (Draftsman)	18. Sh. G. Vishwakarma	T-4 (Field Assistant)
7. Sh. Basant Mishra	T-5 (Sr. Photographer)	19. Sh. Ajay Pal Singh	T-3 (Field Assistant)
8. Sh. O.N. Tiwari	T-5 (Technical Officer)	20. Sh. Premlal	T-2 (Driver)
9. Sh. M.P. Tiwari	T-5 (Farm Mechanic)	21. Sh. D.K. Sahu	T-2 (Driver)
10. Sh. Pankaj Shukla	T-5 (Technical Officer)	22. Sh. B. Prasad	T-2 (Driver)
11. Sh. R.N. Bharti	T-5 (Librarian)	23. Sh. Sebastein Das	T-2 (Driver)
12. Sh. S.K. Parey	T-5 (Technical Officer)		

21.3. Administrative staff

1. Sh. Wajyoddin	Administrative Officer (sought VRS on 30 August, 2012)	4. Ms. Nidhi Sharma	Private Secretary
		5. Sh. R. Hadge	Assistant
2. Sh. R.K. Giri	Administrative Officer (joined on 5 November, 2012)	6. Sh. T. Lakhera	Assistant
		7. Sh. B.P. Uriya	Assistant
3. Sh. J.P. Kori	Asstt. Administrative Officer (sought VRS w.e.f. 31 January, 2013)	8. Sh. Francis Xavier	Sr. Clerk
		9. Sh. M.K. Gupta	Personal Assistant

21.4. Supporting staff

1. Sh. Veer Singh	Skilled Support Staff	12. Sh. Anil Sharma	Skilled Support Staff
2. Sh. A.K. Tiwari	Skilled Support Staff	13. Sh. Ram Kumar	Skilled Support Staff
3. Sh. Shiv K. Patel	Skilled Support Staff	14. Sh. Naresh Singh	Skilled Support Staff
4. Sh. S.L. Koshta	Skilled Support Staff	15. Sh. Gajjulal	Skilled Support Staff
5. Sh. J.P. Dahiya	Skilled Support Staff	16. Sh. S.C. Rajak	Skilled Support Staff
6. Sh. Madan Sharma	Skilled Support Staff	17. Sh. Gangaram	Skilled Support Staff
7. Sh. J. Vishwakarma	Skilled Support Staff	18. Sh. Santosh Kumar	Skilled Support Staff
8. Sh. Raju Prasad	Skilled Support Staff	19. Sh. Sant Lal	Skilled Support Staff
9. Sh. Jagoli Prasad	Skilled Support Staff	20. Sh. Mahendra Patel	Skilled Support Staff
10. Sh. Jagat Singh	Skilled Support Staff	21. Sh. Nemichand Patel	Skilled Support Staff
11. Sh. C.L. Yadav	Skilled Support Staff	22. Sh. Mohan Lal Dubey	Skilled Support Staff

21.5. Promotions

- Dr. K.K. Barman was promoted to the post of Principal Scientist (Soil Science) w.e.f. 16 September, 2009
- Dr. R.P. Dubey was promoted to the post of Principal Scientist (Agronomy) w.e.f. 1 January, 2010
- Sh. J.P. Kori was promoted to the post of Assistant Administrative Officer w.e.f. 24 July, 2012
- Sh. Manoj Gupta was promoted to the post of Personal Assistant w.e.f. 24 July, 2012
- Sh. Francis Xavier was promoted to the post of Senior Clerk w.e.f. 24 July, 2012

21.6. New postings

Dr. Yogita Gharde, joined as Scientist (Agricultural Statistics) on 1 April, 2012 after transfer from IASRI, New Delhi

Sh. R.K. Giri, joined as Administrative Officer on 5 November, 2012 after promotion from CIAE, Bhopal

21.7. Farewell to staff members

Dr. V.S.G.R. Naidu, Sr. Scientist (Economic Botany) left on 21 May, 2012 to join as Programme Coordinator, KVK at CTRI, Rajamundri

Sh. Wajyoddin, Administrative Officer sought voluntary retirement from service on 30 August, 2012

Sh. J.P. Kori, Assistant Administrative Officer sought voluntary retirement from service on 31 January, 2013

22. ON-GOING RESEARCH PROGRAMMES

Research programmes and sub-programes		Co-Principal Investigator	Associates
1.	**Development of sustainable weed management practices in diversified cropping systems** **Programme Leader: Dr. V.P. Singh**		
	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. Anil Dixit Dr. R.P. Dubey Dr. Yogita Gharde Dr. P.P. Choudhury Dr A.R. Sharma
	1.2. Systems approach to weed management	Dr. R.P. Dubey	Dr. V.P. Singh Dr. Anil Dixit 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. Anil Dixit	Dr. R.P. Dubey Dr. V.P. Singh Dr. Raghwendra 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. Anil Dixit Dr. V.P. Singh
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

Research programmes and sub-programes		Co-Principal Investigator	Associates
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. Anil Dixit 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	Er. H.S. Bisen Dr. P.K. Singh Dr. V.P. Singh Dr. Sushil Kumar Dr. D.K. Pandey Dr. Anil Dixit	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. RECOMMENDATIONS OF REVIEW COMMITTEES

23.1. Quinquennial Review Team

QRT reviewed the work done by DWSR and AICRP on Weed Control during the period from 2006 - March, 2012, and the report was submitted to the ICAR in August 2012. Major recommendations are as follows:

DWSR

Research

1. Reorganization of the research projects into programme mode with multi-disciplinary approach. In these programmes, there should be greater emphasis on stakeholders' participation from beginning to the end. The proposed programmes are as follows:

i. Sustainable weed management strategies in diversified cropping systems.

ii. Weed management under the regime of climate change and herbicide resistance.

iii. Management of problem weeds in crop and non-cropped areas.

iv. Environmental impact of herbicides.

v. Transfer of technology and impact assessment.

2. DWSR needs to lay emphasis on basic and strategic research on weed management taking into consideration the weed shift in the context of climate change. Some potential areas are:

i. Development of weed competitive crop plants.

ii. Development of cost-effective and biodegradable organic herbicides (Corn gluten based organic weed killers, vinegar–based herbicides like Burnout II etc.). Products suitable for organic farming would be useful.

iii. Long-term studies on the safety of chemical herbicides on non-target species. Study the metabolic and environmental transformation products, terminal residues (including bound and conjugated residues), human and environment toxicology of transformation products and allied aspects.

iv. Weed utilization to improve the livelihood of farmers. Profiles of major weeds in terms of nutrient (for human, animal and plant), medicinal, manurial (including green manure), toxicological, pest harboring ability, efficacy as mulch, biofuel production capacity and efficiency and other beneficial uses may be developed to identify the domains where these plants can find remunerative outlets. This will help in improving the livelihood of farming community of small and marginal farmers.

v. Workout the biochemical basis of resistance/ cross resistance in *Phalaris minor* to herbicides.

vi. Impact of climate change on the weed shift and degradation of herbicides in different matrices.

vii. Studies on weed molecular biology relating to characterization of weedy rice.

viii. Anticipatory action for management of potential invasive weeds including weed risk analysis may be taken up for timely action.

ix. Development of precise application technology for new generation ultra low-dose high potency herbicides.

x. A review of work on submerged and aquatic weeds is required for strategical planning. Last five years work on this subject has not yielded desired results.

3. To promote eco-friendly weed management, there is a need to develop a balanced research programme focusing on sustainable chemical and non-chemical management practices. Cultural, biological and mechanical methods of weed control need to be incorporated in developing weed management strategies. To strengthen this, IWM models for crops and cropping systems region-wise need to be developed.

4. A proper strategy for the management of weeds in various aquatic bodies adopting eco-friendly approaches is essential. For alien invasives, co-evolved biological control agents may be considered. For management of *Mikania micrantha*, the rust sp. *Puccinia spegazinnii* with broader genetic base should be considered. Similarly for *Parthenium*, the seed weevil and other agents like Carmenta moth may be imported. *Heteropsylla spinulosa* may be imported for the management of *Mimosa diplostricha*.

For quarantine requirement, the state-of-the-art facility at NBAII may be utilized. Cost-effective mechanical methods may also be developed coupled with weed biomass utilization.

5. A document outlining the state-of-art information on the effect of herbicide tolerant GM crops on the management of key weeds affecting the crop in reference needs to be developed.

6. It may be desirable that the Directorate/ Coordinator Cell develop a standard protocol for release of weed management practices to farmers rather than each centre following its own protocol. This will strengthen safer and more scientific weed management at the national level.

7. Weed management recommendations should be incorporated in all OFTs and FLDs in farmer's fields. Economic analysis of technologies should be worked out at OFT and FLD level.

8. Carefully identified up-scalable success stories on weed management technologies should be documented and appropriately disseminated. For example:

i. management of herbicide resistance in *Phalaris minor*.

ii. post-emergence herbicides in direct-seeded rice, pulses.

iii. integrated management of *Striga* in sugarcane.

iv. developing and evaluating the efficiency of mechanical weeding tools like cycle wheel-hoe and power-operated weeding tools and implements particularly for reducing the human and animal drudgery should become a part of network programme at all the coordinating centres.

9. The research work at DWSR and AICRP-Weed Control needs to be prioritized. Projects of national importance with high perception should get priority. All basic research programmes should have direct relevance to solving the weed problems at farm level.

10. Transform the residue unit of DWSR into a duly Accredited National Referral Unit on herbicides with mandate to:

i. develop, verify and modify analytical methods for uniform adoption by various laboratories.

ii. ensure accuracy and precision of analysis at various centres of AICRP.

iii. overview the results generated by various laboratories for their reliability.

iv. establish/ensure compliance to MRLs on edible crops and commodities.

v. develop guidelines on herbicide safety in environment.

vi. develop decontamination technologies in different substrates.

For this purpose, it must be adequately staffed, equipped and provided with requisite infrastructure in a time-bound schedule. To ensure that capability to handle the upgraded facilities, if not existing, is developed over time, linkage with the nearby chemistry strongholds on mutually beneficial terms is suggested.

11. Monitoring of residues in different matrices (environment, food, feed, fibre, etc.) needs to be planned meticulously. These results need to be made available to public for safety through appropriate authority.

12. While investigating the effect of climate change on weed shift, sight may not be lost of the possible effect of climate change on the fate of herbicides in environment. It is of particular significance when the residue data generated on a chemical several years back is relied upon in decision making.

13. There is a need to establish weed management data repository and develop effective Management Information System (MIS) at DWSR. A systematic compilation, retrieval and utilization cross country multi-year data of technology generating system is a pre-requisite for future strategy.

14. QRT observed that information on impact of weed management technologies is scanty. Impact assessment needs to be undertaken by using suitable indicators and the analytical tools at district/ block levels through competent independent agencies. Socio-economic impact of weed management technologies needs to be properly analyzed and such information can be disseminated.

15. Scientists should be encouraged to publish quality research papers in reputed journals.

Infrastructure

1. DWSR should utilize the KVK platform for disseminating weed management technology.
2. Provision for a training hostel may be made in XII plan.

Collaboration and linkages

1. In view of increased risk due to alien invasive weeds from neighboring countries, effective linkages for management should be established with institutions of other countries and international organizations involved in weed management research.
2. DWSR should become a partner with IARI and other national laboratories in development of new indigenous herbicide molecules.
3. QRT observed that there is a need to strengthen the collaboration with different stakeholder agencies like other AICRPs, SAUs, KVKs, ICAR institutes, State Department of Agriculture, DAC (GOI), herbicide industry and Civil Society Organizations (CSOs) for effective dissemination and adoption of weed management technologies. A suitable mechanism should be in place for ensuring feedback on the collaborative agencies for making technology transfer.
4. Innovative institutional framework may be created for effective scale-up strategy. The feed-back and farmer-scientist-policy maker interface for technology refinement and up-gradation are needed. The pathway of technology roll-out in collaboration with stakeholders may be appropriately identified and adapted across various agro-ecological systems and diverse socio-economic set up.

Human Resource Development

1. Capacity building of scientists in new emerging areas like climate change, herbicide resistance, conservation agricultural practices, crop modeling, precision farming, GIS, bioinformatics, MIS should be undertaken.
2. DWSR may take up students research guidance activity in approved institutions.

AICRP on Weed Control

Administrative

1. Centre-wise recommendations of the QRT must be communicated to different centres of AICRP on weeds after approval by the Council without any delay.
2. The scientific and other posts lying vacant at centres should be filled without further delay.
3. Frequent shifting of scientists in the AICRP should be stopped as this adversely affects the continuity and performance of the centre.
4. A post of Jr. Agronomist (Weed Science) may be included at all the coordinating centres.
5. The recurring contingency may be enhanced from ₹ 80,000 to ₹ 2.5 lakhs/scientist/year. Financial discipline by coordinating centres has to be followed.
6. Adequate contingency for hiring vehicles may be proposed in the XII Plan EFC proposal.

Research and related issues

1. Based on surveillance data, each coordinating centre may identify at least five emerging weeds which are likely to become major problem in the next five years and work out their management strategies.
2. Greater emphasis may be laid on weed management in plantations, orchards, vegetables, floriculture and other horticultural crops at the relevant centres.
3. IWM packages need to be spelt out clearly for different crops and cropping systems region-wise.
4. It has been observed that most of the results of experiments on persistence, environmental distribution and contamination, safety and allied aspects relating to herbicides are interpreted based on qualitative data generated by bioassay method. It is, therefore, recommended that centres which are already equipped with Gas Liquid Chromatograph (GLC) or High Performance Liquid Chromatograph (HPLC) should be strengthened by providing GC-MS/ LC-MS, either as independent units or MS units compatible with the existing Chromatographs. The centres lacking GC/ LC at present be provided these equipments.

5. Coordinating centres must not deviate from the methodology / technical programme approved by the PC unit.

6. Analysis of weed survey data in respect to weed shift should be compiled over the years/ decades and inferences drawn by the coordinating centres.

7. In states with higher tribal population and hill regions like North Eastern Hills region, Chhattisgarh, Odisha, Jharkhand, Himachal Pradesh and Uttarakhand, weed management has all together a different social dimension. Weeding is mostly done for fodder purposes in these regions. Besides studying the economics of weeding, social factors for weeding and characterization of weed problems may also be taken up. Sustainability of weeding vis-a-vis no weeding, and weeding only for fodder in tribal and hill region may be studied with proper reasoning. The role of weed management practices on biodiversity of flora and fauna may also be studied.

8. OFTs / FLDs must be conducted before passing on weed management recommendations to farmers. Technology demonstrations should be based on validated results coming out of OFTs and FLDs.

9. Participatory research for developing weed management technologies should be adopted.

10. The details of the farmers' practices as mentioned in technical programme need to be specified.

11. Awareness amongst the farmers needs to be created for utilizing ICTs.

12. The committee has suggested impact analysis of weed management technologies released to the farmers. The same should be followed by AICRP-WC centres.

13. Scientists should publish research papers only in NAAS rated journals.

Collaboration and linkages

1. Scientists of the coordinating centres should collaborate with relevant disciplines like entomology, pathology, economics, agricultural engineering and others within the SAUs / NARS, which is found lacking.

Human Resource Development

1. Capacity building of scientists in new emerging areas like climate change, herbicide resistance, conservation agricultural practices, residue analysis, GIS should be undertaken on a periodic basis.

23.2. Institute Research Committee

Recommendations of IRC meeting held on 14 and 16 June, 2012 are as follows:

1. Member Secretary IRC should present the Action Taken Report on the major recommendations of the IRC at the start of the meeting in future. The ATR on specific recommendations should be presented by the concerned scientist.

2. All pending RPFs should be submitted by the concerned scientists immediately. The RPF-III of the projects completed during 2011-12 or earlier, and RPF-II for all years up to 2011-12 should be submitted. The ongoing experiments under some of the projects may be suitably incorporated in the newly-launched research programmes from 2012-13.

3. Five newly-launched research programmes will be led by the identified Programme Leaders. The RPF-I of these programmes should be submitted as per the new format. The programmes should be thoroughly discussed with all concerned scientists, and made more focussed, result-oriented, multi-disciplinary and collaborative, involving even scientists from other institutions.

4. Time allocation for all scientists will be as follows: Research – 65%, extension – 25%, teaching / training – 10%. Total time allocation for each scientist should not exceed 100.

5. A scientist can be associated in a maximum of 3 research programmes – one as PI and two as Co-PI, or 3 as Co-PI.

6. No records of service projects are available in the PME Cell. A proper report on the activities undertaken under these projects should be submitted by the concerned scientists.

7. All scientists will be involved in on-farm research activities from the coming rainy season. Suitable teams of 3-4 scientists will be constituted and assigned responsibility for effective transfer of technology in different areas around Jabalpur under the overall supervision of the programme leader.

8. All scientists having field experiments should visit their experiments on a daily basis. It is essential that

they carry out all important activities including layout, sowing, application of treatments, data recording, harvesting / threshing etc. under their direct supervision. A joint visit of all scientists will be organized every month to the field, net house as well as laboratory experiments.

9. It was observed that publication record of most projects / scientists was not satisfactory. Many scientists have not published their research findings in good quality journals. It was emphasized that each scientist must publish at least two quality research papers as a senior author in a year.
10. Newly-joined scientists should be suitably included in the proposed research programmes, and given an ample opportunity to exhibit their potential and achieve excellence in their careers.
11. Promising results from different studies should be shared with other scientists, and further extended to large areas for demonstration on farmers' fields.
12. All experiments including on-farm trials / demonstrations should be properly maintained and display boards providing the required information should be fixed.
13. Scientists should apply for awards and recognitions of other organizations including NAAS, ICAR etc. Application should also be submitted for the ICAR Award for Directorates / NRCs and AICRPs.
14. Scientists should submit project proposals for external funding from different organizations, including MPBT, DST, DBT, ICAR, Ministry of Agriculture and others.

23.3. Research Advisory Committee

RAC meeting was held on 22-23 February, 2013. General recommendations are as follows:

1. Develop a good quality “Weed Atlas” by including quality photos of species at various growth stages including seed, seedlings, reproductive parts (inflorescence/flower), and mature plant with key identifying characteristics
2. Strengthening of herbicides residue studies and developing a detailed protocol for herbicide residue analysis i.e. method of sampling, processing of samples, and sending samples to referral residue labs.
3. Work on isolation/ extraction of allelochemicals like parthenin, nimbin, solanin and other phenolic compounds has been done. Now it is a time to move to another step of demonstration in the field. For formulation of metabolites, linkage with IARI and IBFT should be developed.
4. Screening trials on herbicide molecules/ formulations should be minimized and more efforts should be put for long-term basic and strategic research.
5. More emphasis should be given on molecular basis of herbicide resistance, viz. mechanism of resistance, genetics of resistance and causes of resistance. We need to study the behavior of top ranking herbicides in plants and develop models for how long a candidate herbicide will take to develop resistance in the target weeds.
6. Lot of work on extraction of allelochemicals from Parthenium, neem, soda apple etc. has been done. More focus should be given on testing these chemicals under field condition.
7. Weed risk analysis should be the priority of this Directorate. Diagnostic tools/kits for weed identification and weed seed identification should be developed.
8. Weedy rice in DSR is an emerging issue and requires more in-depth studies for finding out the reasons of its occurrence.
9. Emphasis should be given on studying the biology and management of water hyacinth and *Orobanche*.
10. Emphasis for residue studies should be given for stable herbicides like dinitroanilines, phenyl urea, phenoxy, fop group etc.
11. Photo-transformation data should be correlated with field situation.
12. Emphasis should be given on controlled release of herbicides. For the purpose, collaboration with IARI and IICT may be made.
13. Adoption and impact assessment of weed management technologies at the national level should be undertaken.
14. Work should be undertaken on biostatistics and modeling, including dose-response equations of herbicide mixtures.
15. Weed contests need to be organized for the benefit of students to create greater awareness.

24. 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–June, while the coldest months are December–January when the minimum temperature often goes below 5°C. The average annual rainfall is 1380 mm, most of which (90%) is received during June–September. In the year 2012, total annual evaporation was 1572 mm, while the total annual rainfall was 1354 mm. This rainfall was close to the average of last 45 years but the distribution was erratic. There was good rainfall in the month of January, which was 30 mm more than normal. The period from February to May was totally dry. Heavy pre-monsoon showers (121.6 mm) were received during mid-June, but thereafter there was a prolonged dry spell up to the second week of July. This resulted in large scale damage to the previously-sown crops of soybean and direct-seeded rice, forcing even resowing of these crops in many areas around Jabalpur. However, there was no drought like situation in the region as it prevailed in many other parts of the country. There were heavy rains during the later half of July which even caused flooding of upland crops. Although rainfall during August-September was lower than normal, it was reasonably well distributed. The mean maximum relative humidity during hot weather (April-June) ranged from 47-60% and mean minimum relative humidity was 17-35%. The mean maximum daily sunshine of 8.7 hr was in February and mean minimum of 3.2 hr in August. Weather data obtained from the adjacent meteorological observatory of JNKVV, Jabalpur are presented in Table 1 and Figure 1.

Table 1: Monthly mean maximum and minimum air temperature, rainfall, sunshine and evaporation at Jabalpur during 2012

Month	Temperature (°C)		Humidity (%)		Rainfall (mm)		Sunshine (hr/day)	Evaporation (mm)
	Maximum	Minimum	Maximum	Minimum	Average (45 yrs)	2012		
January	28.2	8.8	92	53	19.4	49.4	6.5	53.7
February	27.6	9.3	88	32	23.5	0.0	8.7	79.2
March	33.2	13.1	72	18	15.6	0.0	8.3	146.1
April	38.7	19.9	47	17	3.7	0.0	8.0	208.5
May	41.2	23.4	37	17	10.2	0.0	6.4	309.5
June	38.4	25.7	60	35	178.8	130.4	5.8	246.4
July	31.5	23.7	89	76	387.2	671.2	4.6	103.6
August	28.8	23.0	92	80	456.8	346.4	3.2	71.4
September	31.2	23.4	91	69	217.5	150.6	5.2	92.5
October	32.2	18.0	84	36	39.8	2.3	8.6	108.3
November	28.1	12.6	87	35	12.8	0.0	7.6	77.5
December	26.6	9.1	89	32	14.7	3.2	8.5	75.6
Total	-	-	-	-	**1380.0**	**1353.5**	-	**1572.3**

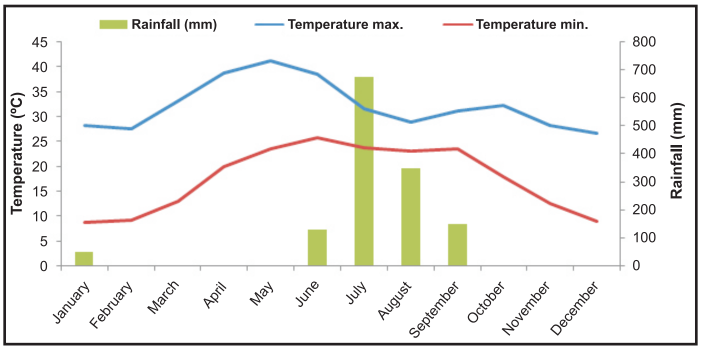


Figure 1: Mean monthly maximum and minimum air temperature, and total monthly rainfall at DWSR, during 2012

OUR NEW INITIATIVES DURING 2012-13

1. More than 20 research projects running at this Directorate were reorganized into five major research programmes. Focussed programmes on conservation agriculture, climate change, problematic weeds, herbicide residues and on-farm research were launched in a multi-disciplinary mode.
2. Six Nodal Officers were identified from HQ for effective collaboration with ICAR Institutes of Crops, Horticulture and NRM Division in different regions of the country. They are interacting with the identified weed scientist and also visiting these institutes for refinement of weed management programme.
3. Network programmes of AICRP-Weed Control were strengthened in the Biennial Workshop held during April, 2012. Effective system of monitoring research and extension work at 22 main centres and 7 voluntary centres was developed.
4. A major initiative was taken to show visibility of our research efforts on the farmers' fields. Six teams, each with three scientists, were constituted, and assigned a cluster of 2-3 villages, located about 50-80 km from Jabalpur. Each member of the team is visiting the locality on a specific day every week; thus sparing about 15-20% of his time for 'On-Farm Research'.
5. A major programme on conservation agriculture – based technologies was undertaken at HQ and AICRP-WC centres. The entire farm of the Directorate was covered under zero-till sown winter crops, and burning of residues including weeds was completely stopped. A composting unit was established for converting available biomass into nutrient-rich manure.
6. Initiatives for modernization and reducing file / paper work in the office were undertaken. Biometric system for marking attendance and Online Leave Management System were introduced.
7. Website of the Directorate was updated and improved. All information of weed database including weed seed and seedling identification was uploaded on the website.
8. Steps were taken for modernization and mechanization of the experimental farm, i.e. for improving drainage, laser land leveling, reorganization/renaming of farm/blocks, crop diversification etc. Joint visits with all scientists were organized regularly to examine the field/lab experiments.
9. An Agreement of Understanding was signed with JNKVV and National Seeds Corporation for seed production on non-experimental area of the research farm. More than 1000 q seed of rice, wheat, maize and chickpea was produced during the last two seasons.
10. Four training programmes on "Advances in Weed Management" were organized for Uttar Pradesh State Officers, Agriculture Development Officers from different states, scientists from ICAR Institutes and SAUs and agricultural Offices / progressive farmers from Maharashtra.
11. '*Parthenium* Awareness Week' was organized on a much larger scale during 16-22 August, 2012, which was widely covered by the national and local print and electronic media. A scientist of the Directorate received ICAR award for this work.
12. Monthly meetings with scientists including technical seminars by the scientists of the Directorate as well as outside experts were started.
13. IMC meeting was held after a gap of 3 years, and the report of QRT was submitted on time. IRC meetings were held, and the work done by the scientists was reviewed by external experts after a long gap.
14. PME cell was made functional and strengthened further. All records of RPFs were updated, and contract research / consultancy projects were implemented through the PME Cell as per ICAR guidelines. Irrational distribution of honorarium was stopped.
15. Two projects were approved under NFBSFARA. More such proposals for external funding were submitted to different agencies. Collaboration with JNKVV, RDVV and other universities/colleges for PG students research / guidance was started.
16. Mandated programmes of the Directorate such as Agricultural Education Day and Foundation Day were organized for the first time.
17. Rule of law was established and prescribed norms were followed in administrative and financial management. Director's residence in the campus, which was constructed long time back but remained virtually vacant, was occupied by the present Director.
18. Issues between the two rival factions of Indian Society of Weed Science were resolved. Elections for constituting a new representative Executive Council were conducted in a fair and transparent manner during December, 2012.

ABBREVIATIONS

AAS : Atomic Absorption Spectrophotometer
AAU : Anand Agricultural University
AAU : Assam Agricultural University
AICRP : All India Coordinated Research Project
ANGRAU : Acharya NG Ranga Agricultural University
APX : Ascorbate peroxidase
AKMU : Agriculture Knowledge Management Unit
BAU : Birsa Agricultural University
BSKV : Baba Saheb Ambedkar Krishi Vidhya Peeth
CAU : Central Agricultural University
CAZRI : Central Arid Zone Research Institute
CCSHAU : Choudhary Charan Singh Haryana Agricultural University
CeRA : Consortium for e-Resources in Agriculture
CIAE : Central Institute of Agricultural Engineering
cm : Centimeter
CO_2 : Carbon di-oxide
CRRI : Central Rice Research Institute
CSAUAT : Chandra Shekher Azad University of Agriculture and Technology
CTRI : Central Tobacco Research Institute
DAA : Days after application
DARE : Department of Agriculture Research and Education
DAS : Days after sowing
DAT : Days after transplanting
DBT : Department of Biotechnology
DOR : Directorate of Oilseed Research
DRDO : Defense Research and Development Organization
DRMR : Directorate of Rapeseed-Mustard Research
DSR : Direct-seeded rice
DST : Department of Science and Technology
EC : Emulsifiable Concentrate
FACE : Free Air CO_2 Enrichment
FYM : Farm yard manure
GBPUAT : Govind Ballabh Pant University of Agriculture and Technology
GC : Gas Chromatograph
GLC : Gas Liquid Chromatograph
GPX : Glutathione peroxidase
GR : Glutathione reductase
HPLC : High Performance Liquid Chromatography
HRD : Human resource development
HW : Hand weeding
IARI : Indian Agricultural Research Institute
ICAR : Indian Council of Agricultural Research
IGKV : Indira Gandhi Krishi Vishwa 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
JNKVV : Jawaharlal Nehru Krishi Vishwa Vidyalaya
KAU : Kerala Agricultural University
KVK : Krishi Vigyan Kendra
LAN : Line Area Network
LC-MS/MS : Liquid Chromatography–Mass Spectroscopy/ Mass Spectroscopy
LD : Lethal dose
LSD : Least square difference
MAU : Maharashtra Agricultural University
MPBT : Madhya Pradesh Biotechnology
NAIP : National Agricultural Innovative Program
NBAII : National Bureau of Agriculturally Important Insects
NDUAT : Narendra Dev University of Agriculture and Technology
NGO : Non-Governmental Organization
NPK : Nitrogen, phosphorous, potash
NRM : Natural Resource Management
OUAT : Orissa University of Agriculture and Technology
PAU : Punjab Agricultural University
PBSR : Puddled broadcast sowing with sprouted seeds
PE : Pre-emergence
PME : Prioritization, Monitoring and Evaluation
PO : Post emergence
QRT : Quinquennial Review Team
RAC : Research Advisory Committee
RAU : Rajendra Agricultural University
RAU : Rajasthan Agricultural University
RDVV : Rani Durgavati Vishwa Vidyalaya
RFD : Results Framework Documents
RVSKVV : Rajmata Vijayaraje Sindhia Krishi Vishwa Vidyalaya
SAU : State Agricultural University
SKHPKV : Shravan Kumar Himachal Pradesh Krishi Vishwa Vidyalaya
SKUAST : Sher-e-Kashmir University of Agricultural Science and Technology
SOD : Superoxide dismutase
SRI : System of rice intensification
TNAU : Tamil Nadu Agricultural University
TP : Transplanted rice
TSP : Tribal sub-plan
UAS : University of Agricultural Sciences
VB : Vishwa Bharati
VSAT : Very small aperture terminal
WAS : Weeks after sowing
WCE : Weed control efficiency
WP : Wettable powder

DWSR in the NEWS


The Hitavada

DWSR training on weed management ends with beneficial info sharing

Directorate of Weed Science Research celebrates Silver Jubilee

गाजरघास से कम्पोस्ट बनाकर पैदावार

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रजत जयंती स्थापना दिवस
22 अप्रैल, 2013

सस्ती व सुलभ तकनीक किसानों तक पहुंचाएं

खरपतवार विज्ञान अनुसंधान निदेशालय में रजत जयंती दिवस मनाया

खरपतवार प्रबंधन पर 10 दिनी

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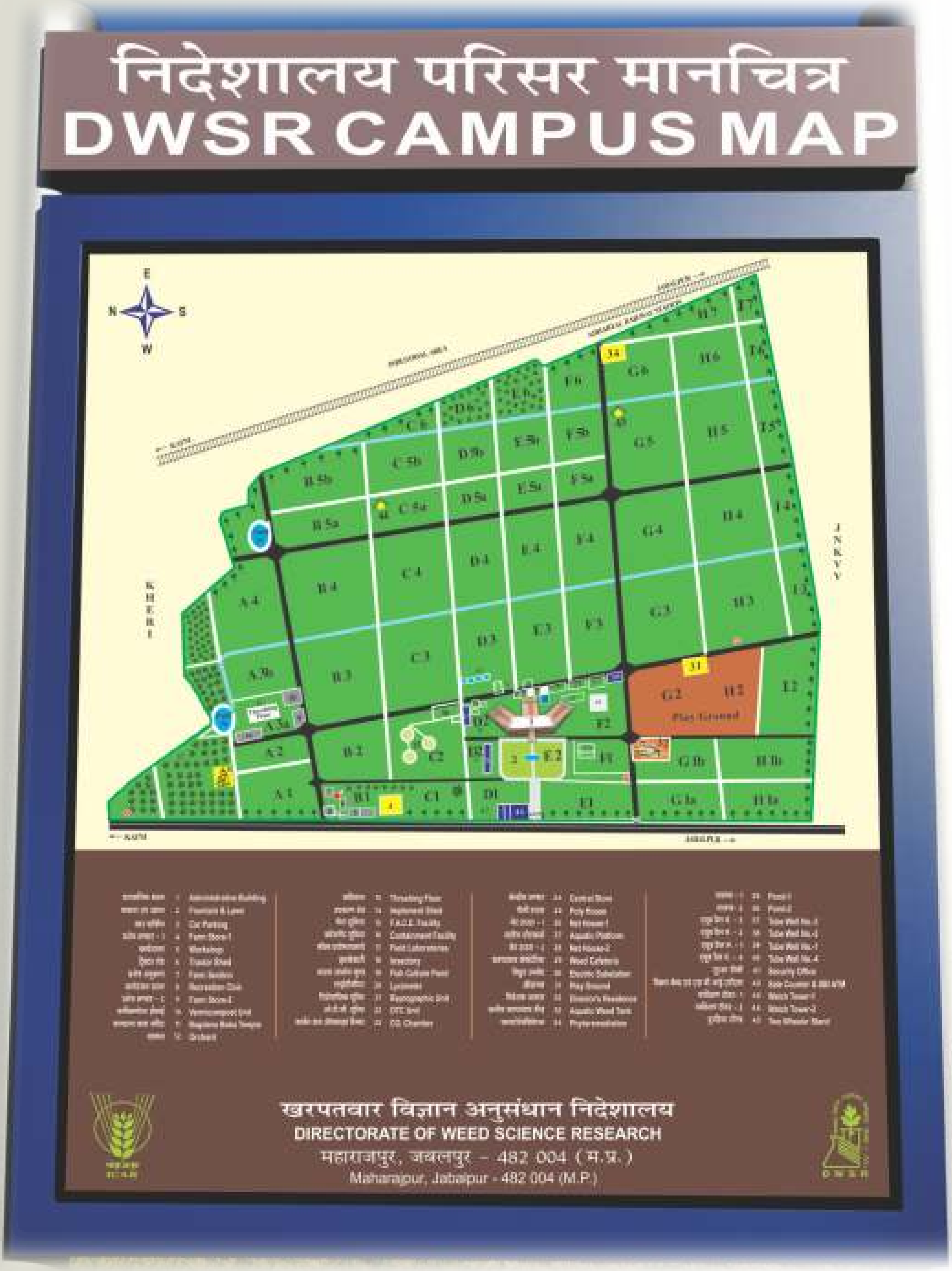
Over 5000 farmers avail benefits of Kisan Mela

DWSR Director Dr Sharma cautions on possible threat of parthenium

हिन्दी हमारी सशक्त भाषा

पत्रिका 15.9.12



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

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