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Pre-emergence herbicides are ancillary apt for annual planning of weed management in system intensification

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ABSTRACT

Field experiments were conducted at Viswavidyalaya farm, Jaguli, Nadia following system intensification (SI) package of practices during 2011-2016 on pre-*Kharif* black gram (*Vigna mungo*) and green gram (*Vigna radiata) – Kharif* direct-seeded puddled and transplanted rice (*Oryza sativa) – Rabi* potato (*Solanum tuberosum*) and onion (*Allium cepa)* crop sequences. Balance nutrition of N:P:K:Neem cake at recommended doses were used along with judicious water in critical crop growth stages and ecosafe green labelled pesticides for insect and disease management. For annual planning of weed pest management (APWPM), glyphosate 71 SG + oxyfluorfen 23.5 EC mixture at 1000 g/ha was used after pre-*Kharif* crops besides the application of selective pre-emergence (PE) organic herbicides treatment wise in different crops along with HW, post-emergence (PoE) herbicides and weedy check as standard. The results revealed that PE herbicide treatments recorded 30.5 and 10.3% more productivity over PoE herbicides treated plots and 38.4 and 60.0% over weedy check in blackgram and greengram, respectively. The corresponding values were 2.74 and 5.14% and 32.7 and 31.0% in direct seeded puddled and transplanted rice, respectively. In *Rabi* potato and onion, these figures were 21.1 and 30.4% and 42.0 and 49.0%, respectively. The soil microflora population at harvest recorded increasing in all PE herbicide used plots though an initial decreasing trend upto a month.

Key words: Annual planning of weed management, Herbicides, Pre-emergence, Productivity, Rice based crop sequences, System intensification

System Intensification using more biological inputs through best management practices of farmers' available resources, is the best alternative methodology for sustainable food, nutrition, ecological and health security (Uphoff 1999, Ghosh *et al*. 2014). Weed pest causes globally 11.5% and at national 10.9% production loss (DWR 2015). Field experiments have revealed that number of weed seeds in the anaerobic ecosystem were 477% lesser in upper surface in comparison to under surface of soil upto 0-15 cm depth. The corresponding figures for aerobic and roadside areas were 308 and 390%. Further eco-safe and eco-efficient herbicides in annual planning of weed pest management (APWPM) as pre-emergence is less costly to the farmer and create an eco-sustainable environment with improved yield. APWPM aims to diminish the weed seed bank in crop field prior to crop planting and subsequently by using pre-emergence (PE) herbicides for reducing the weed competition (Ghosh *et al.* 2016) in critical crop weed competition period (CCWCP). With this contemplation, field experiments have been undertaken in common rice based crop sequences in Inceptisol by adopting system intensification and APWPM to evaluate the efficacy of ecosafe pre-emergence herbicides in CCWCP on per cent diminution of weed pest infestation, to find out the soil microflora status for soil health improvement and to assess the concomitant improvement of crop productivity by PE in comparison to post-emergence (PoE) herbicides.

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MATERIALS AND METHODS

Eight field experiments were conducted at University farm, Jaguli, Nadia during 2011-2016 on varied combinations of rice based crop sequences involving black gram and green gram (pre-*Kharif*) – direct-seeded puddled and transplanted rice (DSPR and TR- *Kharif*) – onion and potato (*Rabi*) grown in system intensification and following annual planning of weed pest management. The experimental soil was sandy loam in nature with neutral pH. The climate of the Inceptisol is warm and humid with an average rainfall of 1700 mm/annum of which around 70% rainfall occurs during June to September. The lowest relative humidity is observed in the month of December while the maximum is in July-August.

System intensification methodology was followed for all crops grown in different sequences. The varieties were: black gram (*Vigna mungo*) *cv*. *'Sarada* (*WBU108*)*'*; green gram (*Vigna radiata*) *cv*. '*Sonali (B-1)'*; '*Satabdi (IET 4786)'* for both direct seeded puddled and transplanted rice (*Oryza sativa*); potato (*Solanum tuberosum*) *cv*. *'Kufri Jyoti'* and for onion (*Allium cepa*) *cv*. *'Sukhsagar'*. The crops were grown with optimum plant population and balanced fertilization of N:P:K:Neem cake at 20:40:40:2000 for black gram and green gram, 60:30:30:5000 for both direct-seeded puddled and transplanted rice, 150:100:100:10000 for potato and 80:40:40:5000 kg/ ha in onion. Judicious water (3 cm/irrigation) was used in critical physiological growth stages in all crops besides keeping moist in rice field. Regarding insect and disease pest management only eco safe green labelled pesticide mixtures were used. Glyphosate 71 SG + oxyfluorfen 23.5 EC mixture 1000 g/ha was used after harvesting of pre-*kharif* crops followed by removing of *Cyperus* nuts and weed stubbles during land preparation of *Kharif* rice crop as a part of annual planning of weed management methodology. The selective herbicides used in treatments of eight crop sequences in this experiment during 2011-16 were listed (**Table 1**).

A common mechanical weeding (wheel hoe at 30 DAS in black and green gram and at 30 DAP in onion; rice weeder at 30 DAT in (DSPR) and (TR) and earthing up at 25 DAP in potato) was done in all treatments. Hand weeding (HW) in pre-*Kharif* at 20 DAS, in *Kharif* at 20 and 40 DAT, in *Rabi* potato at 15 DAP and in onion at 20 and 50 DAP were used. Weedy check is common control treatment for all six crops grown in eight varied crop sequences.

Weed (monocot and dicot) density and biomass using quadrate and average of three sites at 30 and 50 DAS/DAT/DAP were recorded from the experimental fields and from the data of total dry weed biomass, the weed control efficiency (WCE) was calculated. The biological yields (grain/tuber/bulb) and major yield attributes (number of pods/plant and number of seeds/pod of *Vigna* spp.; number of panicles/plant and number of filled grains/panicle of *Oryza sativa*; number and weight of tubers (*Solanum* spp.) and number and weight of bulbs (*Allium* spp.) /plant were recorded at harvest from the marked undisturbed areas in each plot. The population of soil microflora in the rhizosphere soil were also recorded at 5, 10, 15 and 30 DAA and at harvest (PE herbicides) and at 3, 10 and 30 DAA and at harvest (PoE herbicides). For microbial analysis by dilution plating the standard

Table 1. Name of chemical herbicides with active ingredient (a.i.), formulation, dose and time of application in crop sequences used in this experiment during 2011-16

Season	Crop	Name of herbicide with a.i. and formulation	Dose (g/ha)	Time of application
Pre-*Kharif*	Black gram	Oxyfluorfen 23.5 EC	100	Pre-emergence- 1 DAS
	Green gram	Pendimethalin 30 EC	750	
		Quizalofop-ethyl 5 EC	50	Post-emergence-20 DAS
Kharif	Direct seeded puddled rice (DSPR)	Oxyfluorfen 23.5 EC	100	Pre-emergence- 1 DAS
		Bispyribac-sodium 10 SC	20	
		Cyhalofop-butyl 10 EC	100	
		Carfentrazone-ethyl 40 DF	25	
		Almix 20 WP	4	Post-emergence-20 DAS
		Pyrazosulfuron-ethyl 10 WP	30	
	Transplanted rice (TR)	Oxyfluorfen 23.5 EC	100	Pre-emergence-1 DAT
		Bispyribac-sodium 10 SC	20	
		Pretilachlor 50 EC	500	
		Pretilachlor 30.7 EC	500	
		Butachlor 50 EC	1250	
		Oxadiargyl 80 WG	100	
		Triasulfuron 20 WG	12	
		Flucetosulfuron 10 WG	20	
		Almix 20 WP	4	Post-emergence-20 DAT
		Pyrazosulfuron-ethyl 10 WP	30	
Rabi	Potato	Oxyfluorfen 23.5 EC	100	pre-emergence-1 DAP
		Pendimethalin 30 EC	750	
		Paraquat dichloride 24 SL	2500	
		Metribuzin 70 WP	600	
		Metribuzin 70 WP	600	Post-emergence-40 DAP
	Onion	Oryzalin - XL 40 SC	6.25 (l/ha)	Pre-emergence-1 DAP
		Pendimethalin 30 EC	750	
		Quizalofop-ethyl 5 EC	50	Post-emergence-20 DAP

methods prescribed by Pramer and Schmidt (1965) were used. A soil dilution was prepared in sterile distilled water by constant shaking and plating were done separately in replicates in specific media. The Plates were incubated at 28 ± 1 ^{0}C for different durations between 5-7 days in BOD incubator and observations in terms of counting of number of colonies/plate were recorded.

RESULTS AND DISCUSSION

The dominant weed flora in all crops grown during pre-*Kharif* (black and green gram), *Kharif* (direct-seeded puddled and transplanted rice) and *Rabi* (potato and onion) seasons under these eight experiments during 2011-16 were listed (**Table 2**). In this experiment, use of PE herbicides in annual planning of weed pest management showed enhanced major yield attributes and superior productivity in comparison to standard PoE herbicides (**Table 3** and **4**, **Figure 1** and **2**).

At 30 DAS, the maximum WCE of 74.33 and 75.37% was recorded against HW treatment in black and green gram, respectively. But 19.31 and 15.28% higher WCE in black and green gram, respectively was observed against two PE herbicides over the PoE herbicide. At 50 DAS, similar trends was observed and the corresponding figures for the maximum was in HW 55.21 and 55.67% and in PE herbicides 10.72 and 11.29% higher WCE over PoE. In DSPR and TR, HW was also recorded maximum WCE of 69.57 and 75.31%, respectively at 30 DAT and 71.60 and 78.90% respectively, at 50 DAT. The four PE herbicides recorded an average WCE of 55.71 and 42.52% at 30 and 50 DAT, respectively while the corresponding figures for two PoE herbicides were 64.25 and 49.69% in DSPR. Thus in direct seeded puddled rice, PoE herbicides showed better weed management (8.54 and 7.17% more WCE at 30 and 50 DAT, respectively over PE herbicides). In transplanted rice the eight PE herbicides recorded an average of 69.08 and 53.16% WCE at 30 and 50 DAT, respectively while the corresponding figures for two PoE herbicides were 66.26 and 55.77% recording 2.82 and 2.61% lesser WCE than PE herbicides.

In potato, the four PE herbicides recorded an average of 20.03 and 24.24% more WCE (92.40 and 66.27% WCE) at 30 and 50 DAP, respectively over one PoE herbicide. HW recorded maximum WCE (69.42%) only at 50 DAP but recorded 0.02% lesser than PE herbicides (maximum WCE 92.38%) at 30 DAP. In onion HW recorded maximum WCE of 71.33 and 61.60% at 30 and 50 DAP, respectively. The two PE herbicides showed an average of 61.90 and 43.96% WCE at 30 and 50 DAP, respectively and these PE herbicides recorded 13.30 and 9.29% more WCE than that of the PoE herbicide used in this experiment (**Table 3**).

Table 2. Dominant weed flora of the experimental field in different seasons during 2011-16

Pre *Kharif* (summer)	*Kharif* (rainy)	*Rabi* (winter)
Monocot weeds	Monocot weeds	Monocot weeds
Brachiaria mutica	*Echinochloa colona*, *Echinochloa formosensis*	*Dactyloctaneum aegyptium*
Dactyloctaneum aegyptium	*Leersia hexendra*	*Digitaria sanguinalis*
Digitaria sanguinalis	*Leptochloa chinensis*	*Eleusine indica*
Eleusine indica	*Panicum maximum*	*Echinochloa colona*
Echinochloa colona	*Cyperus difformis*	*Setaria glauca*
Cyperus rotundus	*Cyperus iria*	*Cyperus rotundus*
Dicot weeds	*Fimbristylis littoralis*	Dicot weeds
Alternanthera sessilis	*Fimbristylis dichotoma*	*Anagallis arvensis*
Amaranthus viridis	*Scirpus juncoides*	*Argemone mexicana*
Commelina benghalensis	*Algal Anabena circinalis*	*Blumea lacera*
Corchorus acutangulas	*(BGA)*	*Chenopodium album*
Digera arvensis	Dicot weeds	*Cleome viscosa*
Euphorbia hirta	*Alternanthera philoxeroides*	*Digera arvensis*
Melilotus alba / indicus	*Ammania baccifera/multiflora*	*Fumaria purviflora*
Melochia corchorifolia	*Bergia capensis*	*Gnaphalium luteoalbum*
Nasturtium indicum	*Eclipta alba*	*Melilotus alba / indicus*
Phyllanthus niruri	*Hypericum japonicum*	*Nicotiana plumbiginifolia*
Physalis minima	*Lindernia ciliate / procumbans*	*Physalis minima*
Scoparia dulcis	*Ludwigia octovalvis*	*Portulaca oleracea*
Spilanthus paniculata	*Lemna minor*	*Solanum nigrum*
Trianthema monogyne	*Marsilea quadrifolia*	*Sonchus arvensis*
Trianthema portulacastrum	*Oldenlandia corymbosa /diffusa*	*Vicia sativa / indica*
	Stellaria media	

The higher weed control efficiency in PE herbicides was mainly due to managing weed seeds in the soil rhizosphere zone before planting and further inhibiting the germinated weeds that emerged during critical crop weed competition period (CCWCP). This helps to create an atmosphere favourable for crop growth utilizing the maximum resources (by reducing the weed competition to minimum since establishment). Further, using mechanical weeding (wheel hoe, rice weeder or earthing up) the later germinated weeds were also managed besides creating soil aeration that helps all crops to improve health. Quizalofop-ethyl in black gram, green gram and onion, recorded more inconsistency in WCE (lower) than that observed in other PoE herbicides as it mainly controlled the monocots only. Similar findings were recorded by Teasdale (1996), Kewat *et al.* (2000), Tiwari *et al.* (2007), Chauhan and Yadav (2013), Parthipan *et al.* (2013).

During pre-*Kharif* season, application of tested PE herbicides showed enhanced numbers of dominant yield attributes over the standard PoE herbicides in both black and green gram crops experimented during 2011-16. Significantly, 3.35 and 3.45 higher number of pods by applying PE herbicides oxyfluorfen 23.5 EC and pendimetahlin 30 EC (mean 14.05 and 15.12) were recorded over PoE herbicide quizalofop-ethyl 5 EC (10.70 and 11.67) in black and green gram, respectively. HW showed highest (14.90 and 15.87) while weedy check the minimum (9.33 and 10.33) number of pods in black and green gram, respectively (**Table 4**).

During *Kharif* season in direct-seed puddled and transplanted rice twice HW at 20 and 40 DAP recorded maximum 12.87 and 16.45 number of panicles/plant while the weedy check plot showed minimum 9.90 and 12.67 number of panicles/plant, respectively (**Table 4**). The four PE herbicides in DSPR and eight PE herbicides in TR recorded a mean 12.38 and 15.37 number of panicles/plant, respectively. These figures are 12.55 and 5.85% higher than that of two PoE herbicides almix 20 WP and pyrazosulfuron-ethyl 10 WP (mean 11.00 and 14.52) used in both DSPR and TR, respectively.

During *Rabi* season in potato, four PE herbicides oxyfluorfen 23.5 EC, pendimetahlin 30 EC, paraquat dichloride 24 SL and metribuzin 70 WP (mean tuber weight 59.03 g) was recorded 10.93 g more mean tuber weight over PoE herbicide metribuzin 70 WP (48.10 g). HW showed highest mean tuber weight of 59.00 g while weedy check the minimum 40.33 g. In onion crop HW showed highest mean bulb weight of 44.7 g and weedy check the

Table 3. Weed control efficiency in black gram and green gram – direct-seeded puddled and transplanted rice – potato and onion crop sequence following APWPM during 2011-16

Treatment	Dose (g/ha)	WCE (%)	
		30 DAS/ DAT/ DAP	50 DAS /DAT /DAP
Pre-*Kharif* season (mid March – mid June)			
Blackgram			
Oxyfluorfen 23.5 EC at 1 DAS	100	73.6	53.4
Pendimethalin 30 EC at 1 DAS	750	71.7	51.3
Quizalofop-ethyl 5 EC at 20 DAS	50	53.3	41.7
Hand weeding at 20 DAS	-	74.3	55.2
Weedy check	-	-	-
Greengram			
Oxyfluorfen 23.5 EC at 1 DAS	100	72.2	54.3
Pendimethalin 30 EC at 1 DAS	750	71.7	54.7
Quizalofop-ethyl 5 EC at 20 DAS	50	56.7	43.2
Hand weeding at 20 DAS	-	75.4	55.7
Weedy check	-	-	
Kharif season (first week of July – end October)			
Direct seeded puddled rice			
Oxyfluorfen 23.5 EC at 1 DAP	100	58.3	43.7
Bispyribac-sodium 10 SC at 1 DAP	20	56.9	44.3
Cyhalofop-butyI 10 EC at 1 DAP	100	53.3	40.4
Carfentrazone-ethyl 40 DF at 1 DAP	25	54.3	41.7
Almix 20 WP at 25 DAP	4	66.7	51.8
Pyrazosulfuron-ethyl 10 WP at 20 DAP	30	61.8	47.5
Hand weeding twice at 20 and 40 DAP	-	69.6	71.6
Weedy check	-	-	-
Transplanted rice			
Oxyfluorfen 23.5 EC at 1 DAT	100	69.6	54.7
Bispyribac-sodium 10 SC at 1 DAT	20	68.9	52.3
Pretilachlor 50 EC at 1 DAT	500	69.6	51.4
Pretilachlor 30.7 EC at 1 DAT	500	71.3	55.1
Butachlor 50 EC at 1 DAT	1250	63.3	49.7
Oxadiargyl 80 WG at 1 DAT	100	68.3	53.9
Triasulfuron 20 WG at 1 DAT	12	67.3	51.3
Flucetosulfuron 10 WG at 1 DAT	20	64.7	54.7
Almix 20 WP at 25 DAT	4	74.3	56.9
Pyrazosulfuron-ethyl 10 WP at 20 DAT	30	67.8	56.8
Hand weeding twice at 20 and 40 DAT	-	75.3	78.9
Weedy check		-	-
Rabi /Winter season (first week of November – end February)			
Potato			
Oxyfluorfen 23.5 EC at 1 DAP	100	93.2	67.4
Pendimethalin 30 EC at 1 DAP	750	89.3	62.4
Paraquat dichloride 24 SL at 1 DAP	2500	91.7	66.9
Metribuzin 70 WP at 1 DAP	600	95.4	68.3
Metribuzin 70 WP at 40 DAP	600	72.4	90.5
Hand weeding at15 DAP	-	92.4	69.4
Weedy check	-	-	-
Onion			
Oxyfluorfen 23.5 EC at 1 DAP	100	68.7	47.3
Oryzalin - XL 40 SC at 1 DAP	6.25 l/ha	60.3	41.9
Pendimethalin 30 EC at 1 DAP	750	56.7	42.6
Quizalofop-ethyl 5 EC at 20 DAP	50	48.6	34.7
Hand weeding at 20 and 50 DAP	-	71.3	61.6
Weedy check	-	-	-

A common mechanical weeding (wheel hoe at 30 DAS in black and green gram and at 30 DAP in onion; rice weeder at 30 DAT in DSPR and TR and an earthing up at 25 DAP in potato) was done in all treatments.

minimum 35.33 g mean bulb weight. Three PE herbicides, oxyfluorfen 23.5 EC, oryzalin 40 SC and pendimetahlin 30 EC (mean bulb weight 41.00 g) recorded 6.61 g more mean bulb weight over PoE herbicide quizalofop-ethyl (30.87 g bulb weight). A common mechanical weeding by wheel hoe was also done at 30 DAP with each treatment that helps to manage the resurgence weed flora (**Table 4**).

All the PE and PoE herbicides treatments and HW recorded more productivity over weedy check in all the experiments during 2011-16. In black and green gram during pre *Kharif* season, 30.5 and 10.3% (38.4 and 60.0% over weedy check) more yield was recorded in PE herbicides treated plots over PoE herbicides treatments. In direct-seeded puddled and transplanted rice, the corresponding figures for PE herbicides over PoE herbicides treatments were 2.74 and 5.14% (32.7 and 31.0% over weedy check) while in potato and onion these figures were 21.1 and 30.4% (42.0 and 49.0% over weedy check), respectively.

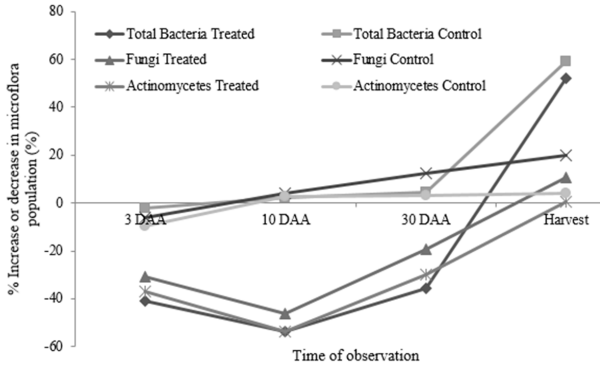
Because of following the annual planning of weed pest management (APWPM), weed seed bank was reduced prior to planting and by using HW or selected herbicides due to which weed competition to crops in their critical crop weed competition stages was further reduced that helped to improve the crop health supplemented by balance nutrition and judicious water use. Ghosh *et al.* (2016) expressed similar opinion while working with PE mixture of botanical and chemical herbicides following APWPM in transplanted rice. The soil microflora population (**Figure 1**) at harvest revealed 0.35 to 152% increase in all PE herbicides used plots in spite of an initial decrease at 30 DAA. But in case of PoE, herbicides treated plots (**Figure 2**) the increasing trend of microflora population after an initial decrease limited only 5.2- 16% at harvest.

PE herbicides treated crops established a healthier crop over PoE herbicides by minimizing weed pest competition since initial stage. Therefore, the PE herbicides treated plots recorded better productivity over PoE herbicides treated plots in all the experimented crops as the major yield attributing characters like number of pods (black and green gram), panicle numbers (rice), tuber or bulb weight (potato and onion) showed higher in PE herbicides over PoE herbicide treated plots. PoE herbicides are usually applied in the crop critical physiological growth stages like branching, nodulation, tillering, tuber or bulb formation *etc*. which ultimately affected the major yield attributes by forcing the crop plants to face an initial competition of resources with weed

Table 4. Major yield attributes and productivity of black gram/green gram – DSP rice/TR rice – potato/ onion crop sequence following APWPM during 2011-16

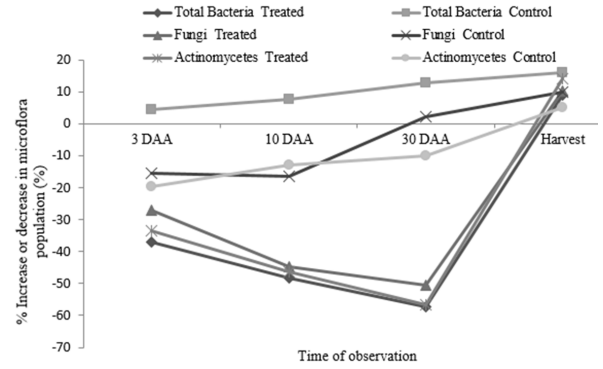
Treatment	Dose (g/ha)	Major yield attribute No. of pods/plant	Yield (t/ha) Seed yield
Pre-Kharif season (mid March – mid June)			
Blackgram			
Oxyfluorfen 23.5 EC at 1 DAS	100	14.67	1.19
Pendimethalin 30 EC at 1 DAS	750	13.43	1.08
Quizalofop-ethyl 5 EC at 20 DAS	50	10.70	0.87
Hand weeding at 20 DAS	-	14.90	1.26
Weedy check	-	9.33	0.82
LSD (p=0.05)		1.11	0.15
Greengram			
Oxyfluorfen 23.5 EC at 1 DAS	100	15.33	0.99
Pendimethalin 30 EC at 1 DAS	750	14.90	0.93
Quizalofop-ethyl 5 EC at 20 DAS	50	11.67	0.87
Hand weeding at 20 DAS	-	15.87	0.97
Weedy check	-	10.33	0.60
LSD (p=0.05)		1.24	0.09
Kharif season (first week of July – end October)		No. of panicles/ plant	Grain yield
Direct-seeded puddled rice			
Oxyfluorfen 23.5 EC at 1 DAP	100	12.82	3.23
Bispyribac sodium 10 SC at 1 DAP	20	12.67	3.19
Cyhalofopbutyl 10 EC at 1 DAP	100	11.70	3.14
Carfentrazone ethyl 40 DF at 1 DAP	25	12.33	3.18
Almix 20 WP at 25 DAP	4	11.10	3.11
Pyrazosulfuron-ethyl 10 WP at 20 DAP	30	10.90	3.09
Hand weeding twice at 20 and 40 DAP	-	12.87	3.30
Weedy check	-	9.90	2.40
LSD (p=0.05)		0.82	0.13
Transplanted rice			
Oxyfluorfen 23.5 EC at 1 DAT	100	15.12	4.15
Bispyribac-sodium 10 SC at 1 DAT	20	15.47	4.19
Pretilachlor 50 EC at 1 DAT	500	15.33	4.17
Pretilachlor 30.7 EC at 1 DAT	500	16.33	4.26
Butachlor 50 EC at 1 DAT	1250	14.80	4.04
Oxadiargyl 80 WG at 1 DAT	100	15.90	4.23
Triasulfuron 20 WG at 1 DAT	12	14.97	4.06
Flucetosulfuron 10 WG at 1 DAT	20	15.00	4.12
Almix 20 WP at 25 DAT	4	14.70	3.98
Pyrazosulfuron-ethyl 10 WP at 20 DAT	30	14.33	3.92
Hand weeding twice at 20 and 40 DAT	-	16.45	4.45
Weedy check	-	12.67	3.17
LSD (p=0.05)		0.92	0.13
Rabi/winter season (first week of November – end February)		Average tuber weight (g)	Tuber yield
Potato			
Oxyfluorfen 23.5 EC at 1 DAP	100	59.60	31.86
Pendimethalin 30 EC at 1 DAP	750	56.33	27. 70
Paraquat dichloride 24 SL at 1 DAP	2500	57.20	29. 33
Metribuzin 70 WP at 1 DAP	600	63.00	33. 20
Metribuzin 70 WP at 40 DAP	600	48.10	25. 20
Hand weeding at 15 DAP	-	59.00	32.58
Weedy check	-	40.33	21.50
LSD (p=0.05)		7.39	1.06
Onion		Average bulb weight (g)	Bulb yield
Oxyfluorfen 23.5EC at 1DAP	100	43.50	29.50
Oryzalin - XL 40 SC at 1 DAP	6.25 /ha	41.33	27.67
Pendimethalin 30 EC at 1 DAP	750	41.00	26.30
Quizalofop-ethyl 5 EC at 20 DAP	50	35.33	21.33
Hand weeding at 20 and 50 DAP	-	44.70	31.56
Weedy check	-	30.87	18.67
LSD (p=0.05)		5.31	2.72

A common mechanical weeding (wheel hoe at 30 DAS in black and green gram and at 30 DAP in onion; rice weeder at 30 DAT in DSPR and TR and earthing up at 25 DAP in potato) was done in all treatments



PE Herbicides- Initial microflora population: Total bacteria 51. 00 CFU x 10 ^{6}/g Fungi: 20.25 CFU x 10 ^{4}/g and Actinomycetes 130.72 CFU x 10 ^{5}/g of soil

Figure 1. Effect of PE herbicides used in various field crops on percent increase or decrease of the average total bacteria, total fungi and total actinomycetes population in the rhizosphere soil of experimental fields during 2011-16



PoE Herbicides- Initial Microflora population: Total Bacteria 56. 50 CFU x 10 ^{6}/g Fungi: 24.00 CFU x 10 ^{4}/g and Actinomycetes 151.00 CFU x 10 ^{5}/g of soil

Figure 2. Effect of PoE herbicides used in various field crops on percent increase or decrease of the average total bacteria, total fungi and total actinomycetes population in the rhizosphere soil of experimental fields during 2011-16

plants. Further the reduced microflora population may unable to supply better resources particularly nutrients for establishing higher yield attributes in various crops and as a result the productivity was also suffered in PoE herbicides treated plots. Das *et al.* (2014) and Ghosh *et al.* (2015) expressed similar views working with PoE herbicides and PE botanicals, respectively in this inceptisol.

Therefore, for increasing sustainable productivity in crops grown in sequence with system intensification methodology, the annual planning of weed pest management including ecosafe PE herbicides with mechanical weeding may be the better option to replace the traditional costly hand weeding.

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