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Penoxsulam influence on weed control and rice yield and its residual effect on microorganisms and succeeding greengram

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ABSTRACT

Field investigations were carried out at wetland farm, Agriculture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, during rainy seasons (June to October) of 2014 and 2015 to evaluate penoxsulam on weed control and yield of rice and its residual effect on microorganisms and succeeding greengram crop. Two years of field experimentation, revealed that pre-emergence application of penoxsulam at 22.5 g/ha resulted in significantly lower total weed density, weed biomass and higher weed control efficiency at all the stages. Application of new formulation of penoxsulam (21.7% SC) at 22.5 g/ha as pre-emergence herbicide kept the weed density and biomass below the economic threshold level and increased the grain yield as 5.20 and 5.04 t/ha in 2014 and 2015, respectively in rice. Succeeding greengram crop sown immediately after the rice harvest was not affected by the residue of new formulation of penoxsulam at all tested doses.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world and is consumed by more than 3 billion people (Fageria 2007). It is estimated that, by the year 2025, it will be necessary to produce about 60% more rice than currently produced to meet food needs (Fageria 2007,d GRISP 2013).

The transplanted rice is infested with wide range of weed species during early part of growth stage. Grain yield was drastically reduced if rice crop is not weeded out during early growth stages (Pande *et al.* 1994). Weed control in transplanted rice by mechanical and cultural methods is expensive. Normally two manual weeding are done in lowland rice crop, for which 50 women labours are engaged per hectare. The amount incurred for manual weeding in low land rice works out more than 1200 million for single crop per year in Tamil Nadu alone (Tajuddin and Fellow 2009). Manual weeding although effective and most common practice of weed control in transplanted rice, these have several limitations particularly during peak period, which makes it further problematic. At the time of peak period of labour crisis, delayed weeding causes drastic reduction in rice grain yield. In hand weeding, it is difficult to differentiate and remove the mimic weeds like *Echinochloa colonam* and *Echinochola crus-galli* due to phenotypic similarities between weeds and rice seedlings in the early stages (Rao and Moody 1992).

Therefore, evaluation of new herbicides for wide spectrum control of weed flora is imperative. The present study was undertaken to influence of penoxsulam on weed control and yield of rice and its residual effect on succeeding greengram and microorganisms.

MATERIALS AND METHODS

Field experiments were conducted during rainy seasons (2014 and 2015) at wet land farm of Tamil Nadu Agricultural University in Coimbatore, located at western zone of Tamil Nadu. The geographical location of the experiment site is 11^0 N latitude and 77^0 E longitude with an altitude of 426.7 m above the mean sea level. The soil experimental site was well drained clay loam in texture (44.5% clay, 10.2% silt and 45.7% sand) with low available nitrogen, medium in available phosphorus and high in available potassium. The soil analyzed 234, 15.8 and 467 kg/ha of $KMnO_4$-N, Olsens' P and NH_4OAc-K, respectively with EC of 0.29 dS/m, pH of 8.58 and organic carbon of 0.58%. The experiment was laid out in randomized complete block design (RBD) with nine treatments

and replicated thrice. The gross plot and net plot size adopted was 20 m^2 (5.0 x 4.0 m) and 15.75 m^2 (4.5 m x 3.5 m). Short duration rice variety *'ADT 43'* maturing in 100-110 days suitable for cultivation in Tamil Nadu was used for the study. Treatments consisted of pre-emergence application penoxsulam, [new formulation of penoxsulam (21.7% SC by Crystal Crop Production Private Ltd)] at penoxsulam 20, 22.5, 25, 27.5 and 50 g/ha and were compared with standard check butachlor 1000 g/ha, pretilachlor 750 g/ha, hand weeding (25 and 45 DAT) and unweeded check. The herbicides were applied as pre-emergence at third day after transplanting followed by a hand weeding on 30 days after transplanting (DAT). Hand operated knapsack sprayer fitted with a flat-fan type nozzle (WFN 40) was used for spraying the herbicide adopting a spray volume of 500 L/ha. The recommended dose of 130:40:40 kg N, P_2O_5, K_2O/ha in the form of urea, single super phosphate and muriate of potash were applied to all plots uniformly. Hundred per cent single super phosphate and fifty per cent of nitrogen and muriate of potash was applied as basal, while, remaining dose was top dressed in tillering and panicle initiation in equal split during the course experiment.

The crop was harvested in first week of October during both the years. After harvesting of the rice crop, each plot was manually prepared for sowing of succeeding crop to know the residual effect of herbicides, without disturbing the layout. Succeeding greengram was sown in each plot in winter season. The germination percentage, plant height, dry weight of plants and yield of greengram crop was recorded and data were used for analysis. Microbial population was counted at initial and harvest stage at different dosage of penoxsulam in rice field.

Weed density and biomass

The weed count was recorded species wise using 0.5 x 0.5 m quadrate from randomly fixed places in each plot and the weeds falling within the frames of the quadrate were counted, recorded and the mean value were expressed in number/m^2. The density of grasses, sedges and broad-leaved weeds and the total weeds were recorded at 30 and 45 days after transplanting and expressed in no./m^2. The weeds falling within the frames of the quadrate were collected, and were shade dried and later dried in hot-air oven at 80^0 C for 72 hrs. The dry weight of grasses, sedges and broad-leaved weeds were recorded separately at 30 and 45 days after transplanting and expressed in kg/ha.

Weed control efficiency

Weed control efficiency (WCE) was calculated as per the procedure (Mani *et al.* 1973).

$$WCE\ (\%) = \frac{WDC - WDT}{WDC} \times 100$$

Where

WCE- Weed control efficiency (%), W D C - Weed biomass (g/m^2) in control plot,

WDT- Weed biomass (g/m^2) in treated plot.

Weed index

Weed index (WI) was calculated as per the method (Gill and Kumar 1969)

$$WI = \frac{X-Y}{X} \times 100$$

Where, X=yield (kg/ha) from minimum weed competition plot;

Y=yield (kg/ha) from the treatment plot for which WI is to be worked out.

Microbial analysis

Population dynamics of different types of microorganisms was studied from the soil samples of individual treatment plots.

One gram of soil was weighed and transferred to 10 ml sterile water blank and a thorough shaking was given. This gave the dilution of 10^{-1}, from this using a sterile pipette, one ml of the suspension was transferred to 9 ml water blank to get a dilution of 10^{-2}. Subsequent dilution of10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} were also made accordingly.

The respective media were melted, cooled and poured into the Petri-dishes carrying the respective dilution and the dishes were incubated at 30 °C. After incubation period, the colonies were counted and expressed as colony forming units per gram of soil.

Statistical analysis

The data collected for rice was statistically analysed by following procedure for randomised block design (Gomez and Gomez 2010). The data pertaining to weeds and germination were transformed to square root scale of $\sqrt{x+2}$ and analysed (Snedecor and Cochran 1967). Whenever significant difference existed, critical difference was constructed at 5% probability level.

RESULTS AND DISCUSSION

Effect on weeds

The dominant grassy weed species in the experiment field were *Echinochloa crus-galli* and *Echinochloa colona.* Among the broad-leaved weeds, *Ammania baccifera, Eclipta alba* and *Marsilea quadrifolia* were the dominant weeds. *Cyperus rotundus* was the only sedge present in the experimental field.

Pre-emergence application of new formulation of penoxsulam at 20, 22.5, 25, 27.5 and 50 g/ha followed by one hand weeding at 30 DAT resulted in effective control of grassy weeds, broad-leaved weeds and to some extent sedge. Grassy weeds were effectively controlled with the herbicide. Application of penoxsulam at 22.5 g/ha resulted in the weed control of more than 88% of weeds, but the herbicide inhibited the crop growth **(Table 1)**. The efficacy of penoxsulam application at 25 g/ha as pre- and post-emergence 20.0-22.5 g/ha was reported by Yadav *et al.* (2008).

Post-emergence application of penoxsulam was reported to have an edge over pre-emergence application earlier also (Singh *et al.* 2007). Yadav *et al.* (2007) also reported penoxsulam as an effective post-emergence herbicide against mixed weed flora in rice. Dharumarajan *et al.*(2009) envisaged that herbicides applied at different intervals during critical crop growth period recorded higher weed control efficiency in transplanted rice ecosystems.

Effect on crop

In rice, among the weed control treatments, pre-emergence application of penoxsulam at 22.5/g ha recorded higher grain yield of 5.20 and 5.04 t/ha, during 2014 and 2015, respectively due to better control of weeds at critical stages by providing favorable environment for better growth and development leading to enhanced grain yield. It was at par with pre-emergence application of pretilachlor 750 g/ha (5.00 and 5.00 t/ha in 2014 and 2015, respectively). Hand weeding has resulted in grain yield (4.96 and 4.05 t/ha respectively). Rice

Table 1. Effect of different weed management treatments on total weed density in transplanted rice

Treatment	Weed density (no./m^2)			
	2014		2015	
	30 DAT	45 DAT	30 DAT	45 DAT
Penoxsulam 20 g/ha + HW 30 DAT	8.28(67)	8.96(79)	10.03(99)	8.17(65)
Penoxsulam 22.5 g/ha + HW 30 DAT	4.61 (19)	4.70(20)	3.87(13)	3.46(10)
Penoxsulam 25 g/ha + HW 30 DAT	7.92(61)	8.66(74)	4.35(17)	3.99(14)
Penoxsulam 27.5 g/ha + HW 30 DAT	7.42(54)	8.20(65)	9.74(93)	7.93(61)
Penoxsulam 50 g/ha + HW 30 DAT	7.08(48)	7.95(62)	5.38(27)	5.38(27)
Standard check butachlor 1000 g/ha + HW 30 DAT	5.65(30)	5.68(30)	5.74(31)	5.74(31)
Standard check pretilachlor 750 g/ha + HW 30 DAT	5.12(25)	5.16(25)	6.07(35)	6.07(35)
Hand weeding (25 and 45 DAT)	6.12(36)	6.21(37)	7.19(50)	7.12(49)
Unweeded control	14.73(221)	12.69(163)	18.34(335)	15.54(240)
LSD (p=0.05)	1.75	1.54	0.83	0.72

Figures in parentheses are original, transformed to values $\sqrt{x+2}$

Table 2. Effect of weed management methods on weed control efficiency, yield and weed index of rice

Treatment	2014				2015			
	WCE (%)		Grain yield (t/ha)	WI (%)	WCE (%)		Grain yield (t/ha)	WI (%)
	30 DAT	45 DAT			30 DAT	45 DAT		
Penoxsulam 20 g/ha + HW 30 DAT	68.8	51.5	3.89	25.02	69.30	67.64	2.76	45.18
Penoxsulam 22.5 g/ha + HW 30 DAT	90.9	87.5	5.20	00.00	97.00	95.81	5.04	00.00
Penoxsulam 25 g/ha + HW 30 DAT	71.3	54.7	3.90	25.04	95.90	94.28	4.32	14.35
Penoxsulam 27.5g/ha + HW 30 DAT	75.0	59.8	3.95	24.12	71.20	69.63	3.20	36.55
Penoxsulam 50 g/ha + HW 30 DAT	77.4	62.1	4.00	23.16	93.20	88.70	3.97	21.15
Standard check butachlor 1000 g/ha + HW 30 DAT	86.0	81.3	5.05	2.99	92.10	86.97	3.92	22.28
Standard check pretilachlor 750 g/ha + HW 30 DAT	88.5	84.4	5.11	1.84	91.00	85.19	5.00	00.87
Hand weeding (25 and 45 DAT)	83.3	77.0	4.96	4.72	86.30	79.54	4.05	19.58
Unweeded control	0.0	0.0	2.67	48.71	00.00	0.00	1.97	60.82
LSD (p=0.05)	-	-	5.18	-	-	-	5.46	-

WCE- Weed control efficiency, WI- Weed index

productivity is mainly decided by the weed control efficiency of weed management methods as earlier observed by Sansa *et al.* (2016) who had noted that, post-emergence herbicides offer the most practical, effective and economical method of weed control for increasing grain yield of rice.

The next best treatment was pretilachlor, which might be due to weed free environment created from the early stage up to harvest, leading to the production of effective tillers, longer panicles, and more number of grains/panicle compared to all other treatments. Ramana *et al.*(2007) concurred with this result that higher grain and straw yield were recorded with weed free check.

Unweeded control accounted for lower grain yield, which was due to higher weed index at 48.7 and 60.82% during 2014 and 2015, respectively due to heavy competition of weeds for nutrients, space and light. Among the weed control methods, the lowest weed index in pre-emergence application of penoxsulamat 22.5 g/ha, which might be due to greater competition stress with prolific weed growth and higher nutrient removal by weeds. The yield reduction was observed in unweeded control to the tune of 48.7 and 60.8% respectively.

Bioassay study

The germination of succeeding greengram at 10 DAS was not significantly affected by residual effect of herbicide applied to transplanted rice. The plant stand of greengram ranged from 84 to 90% under all the treatments at 10 DAS. Further, plant height and dry weight of plants recorded at 20 and 40 DAS were also unaffected due to residual effect of different doses of penoxsulam applied in rice **(Table 3)**. Yield of greengram showed no distinct variation due to different doses of penoxsulam. This result was in line

Table 3. Residual effect of penoxsulam applied in rice on the germination (%), plant height, dry matter production and grain yield of succeeding greengram crop

Treatment	2014						2015					
	Crop establish-ment (%)	Plant height (cm)		DMP (t/ha)		Grain yield (t/ha)	Crop establish -ment (%)	Plant height (cm)		DMP (t/ha)		Grain yield (t/ha)
		20 DAS	40 DAS	20 DAS	40 DAS			20 DAS	40 DAS	20 DAS	40 DAS	
Penoxsulam 20 g/ha + HW 30 DAT	88.2	15.1	32.0	0.62	1.20	0.55	88.2	15.1	32.0	0.61	1.17	0.55
Penoxsulam 22.5 g/ha + HW 30 DAT	87.9	15.9	32.0	0.64	1.21	0.55	87.2	15.7	31.5	0.60	1.20	0.55
Penoxsulam 25 g/ha + HW 30 DAT	87.2	15.1	31.0	0.60	1.21	0.55	86.2	15.4	30.4	0.58	1.15	0.55
Penoxsulam 27.5g/ha + HW 30 DAT	85.1	15.2	31.9	0.62	1.21	0.55	85.1	15.5	31.8	0.57	1.16	0.55
Penoxsulam 50 g/ha + HW 30 DAT	84.1	15.4	32.5	0.62	1.21	0.55	88.3	15.0	32.5	0.61	1.15	0.54
Standard check butachlor 1000 g/ha + HW 30 DAT	89.8	15.7	32.8	0.64	1.21	0.55	87.2	15.7	31.6	0.60	1.21	0.54
Standard check Pretilachlor 750 g/ha + HW 30 DAT	89.7	15.9	35.8	0.65	1.20	0.56	88.2	15.7	33.0	0.60	1.20	0.54
Hand weeding	88.1	15.7	34.5	0.63	1.20	0.56	87.4	15.0	32.8	0.62	1.18	0.54
Unweeded control	88.2	15.1	35.3	0.60	1.20	0.55	75.0	15.1	32.1	0.61	1.16	0.54
LSD (p=0.05)	-	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS

NS - Non significant, DMP- Dry matter production

Table 4. Effect of weed management treatments on soil bacteria, fungi and actinomycetes (CFU g^{-1} of soil) in transplanted rice

Treatment	2014						2015					
	Bacteria ($x10^6$ CFU/g)		Fungi ($x10^4$ CFU/g)		Actinomycetes ($x10^2$ CFU/g)		Bacteria ($x10^6$ CFU/g)		Fungi ($x10^4$ CFU/g)		Actinomycetes ($x10^2$ CFU/g)	
	DAT 1st day	H	DAT 1st day	H	DAT 1st day	H	DAT 1st day	H	DAT 1st day	H	DAT 1st day	H
Penoxsulam 20 g/ha + HW 30 DAT	7.91	14.7	4.5	5.2	2.43	4.10	7.30	14.56	4.18	5.18	2.50	4.10
Penoxsulam 22.5 g/ha + HW 30 DAT	7.95	14.7	4.3	5.2	2.42	4.13	7.30	14.21	4.00	5.15	2.40	4.13
Penoxsulam 25 g/ha + HW 30 DAT	7.57	15.0	4.7	5.2	2.40	4.23	7.24	14.56	4.33	5.17	2.29	4.23
Penoxsulam 27.5g/ha + HW 30 DAT	7.67	14.9	4.3	5.2	2.50	4.20	7.16	14.56	4.23	5.16	2.35	4.20
Penoxsulam 50 g/ha + HW 30 DAT	7.64	14.8	4.6	5.2	2.60	4.30	7.10	14.86	4.20	5.19	2.28	4.30
Standard check butachlor 1000 g/ha + HW 30 DAT	7.89	14.9	4.3	5.2	2.47	4.13	7.40	14.06	4.30	5.15	2.48	4.13
Standard check Pretilachlor 750 g/ha + HW 30 DAT	7.45	14.9	4.4	5.2	2.60	4.30	7.50	14.32	4.00	5.16	2.63	4.13
Hand weeding	7.55	14.8	4.4	5.2	2.57	4.37	7.40	14.85	4.54	5.16	2.11	4.31
Unweeded control	7.67	14.9	4.9	5.2	2.42	4.43	7.11	14.12	4.11	5.16	2.33	4.11
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAHS- Day after transplanting, H- Harvest

with the results of Yadav *et al.* (2008) who reported that pre- and post-emergence application of penoxsulam in rice at different doses did not leave any residue in the soil and there was no toxic effect beyond 60 days.

Effect of herbicide residue on soil microorganisms

The microbial content of the soil was not much affected in the early stage, however penoxsulam when applied at 20, 22.5, 25, 27.5 50 g/ha had significant detrimental effect on soil bacteria, fungi and actinomycetes population with a relatively increased microbial population at harvest. There was no significant effect of the herbicide as crop advanced.

The pre-emergence application of penoxsulam at 22.5 g/ha can keep the weed density and biomass reasonably at lower level and enhance the productivity of transplanted rice. The new formulation of penoxsulam at 20, 22.5 25 and 50 g/ha, pre-emergence application of pretilachlor 750 g/ha was found to be safe on the succeeding crops and this might be due to detoxification of herbicides in soil, which did not adversely affect the growth and yield of the succeeding crop in terms of plant height, dry matter production and grain yield of the succeeding greengram during both the seasons **(Table 4)**.

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