Indian Journal of Weed Science **50**(4): 333–339, 2018

Print ISSN 0253-8040 Online ISSN 0974-8164

Penoxsulam + cyhalofop-butyl (premix) evaluation for control of complex weed flora in transplanted rice and its residual effects in rice-wheat cropping system

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Article information

DOI: 10.5958/0974-8164.2018.00072.2

Type of article: Research article

Received : 7 August 2018
Revised : 8 November 2018
Accepted : 10 November 2018

Key words
Complex weed flora

Rice-wheat cropping system

Penoxsulam

Transplanted rice

Weed flora

ABSTRACT

Field experiments were conducted to evaluate the efficacy of penoxsulam 1.02% w/w (1.0% w/v) + cyhalofop-butyl 5.1% w/w (5.0% w/v) as post-emergence (PoE) in transplanted rice at CCS Haryana Agricultural University, Regional Research Station, Karnal during *kharif* 2010 to 2011, along with its phyto-toxicity on rice crop (*Kharif* 2010 to 2012), residual phyto-toxicity on wheat crop (*Rabi* 2010-11 to 2012-13), its residual studies in soil, straw and rice grains in lab (2017) and also multi-locational adaptive trials on rice during *Kharif* 2017. Penoxsulam + cyhalofop 135 g/ha reduced the density and dry weight of *Echinochloa crusgalli* and other aerobic grassy weeds (0.0- 3.3/m^2 and 0.0-26.3 g/m^2) and broad-leaf weeds (30.7-36.7/m^2 and 0.0-4.7 g/m^2) over its lower doses (105 and 120 g/ha) and was at par with its higher dose (150 g/ha), and it provided almost complete control of sedges during both the years. There was no significant effect of herbicidal treatments on the plant height and panicle length of the crop during both the years. Penoxsulam + cyhalofop 135 g/ha resulted in significantly higher number of effective tillers/ mrl (49.0 in 2010 and 53.3 in 2011) than cyhalofop 80 g/ha (33.8.0 in 2010 and 49.8 in 2011) and weedy check (27.0 in 2010 and 32.5 in 2011), and penoxsulam + cyhalofop 105 g/ha during 2011 (46.5 in 2010 and 51.5 in 2011). The grain yield in plots treated with penoxsulam + cyhalofop 135 g/ha (5.46 t/ha in 2010 and 5.53 t/ha in 2011) was higher than its lower doses (105 and 120 g/ha) and at par with higher dose (150 g/ha) during both the years. Penoxsulam + cyhalofop 135 g/ha provided grain yields similar to penoxsulam 22.5 g/ha, pretilachlor 750 g/ha, butachlor 1500 g/ha and weed free check; and higher than cyhalofop 80 g/ha, bispyribac-sodium 20 g/ha and weedy check during both the years. Weeds growing throughout the crop season caused 68.8% and 45.8% reduction in the grain yield during 2010 and 2011, respectively. Penoxsulam + cyhalofop 135 g/ha provided net returns (` 24945-29325/ha) and B-C ratio (1.80-1.91) almost similar/ higher to recommended PoE application of penoxsulam 22.5 g/ha (` 23756-29368/ha; 1.79-1.95). There was no phyto-toxicity of penoxsulam + cyhalofop even up to 600 g/ha on transplanted rice as well as succeeding wheat crop. Residues of penoxsulam + cyhalofop applied at 135 and 270 g/ha were below detectable level in soil, straw and grains of rice at harvest during 2010-11 to 2012-13. Penoxsulam + cyhalofop 135 g/ha applied at 15-20 DAT in rice (scented as well as coarse rice varieties) at 12 locations provided 92-97% control of weeds and average grain yield of 4.13 t/ ha as compared to 3.83 t/ha in check herbicide bispyribac-sodium 25 g/ha. Penoxsulam + cyhalofop 135 g/ha resulted in average total monetary gain of ` 9665/ha and a net returns of ` 8465/ha.

INTRODUCTION

Rice is the staple food of more than 60% of the world population and there is urgent need to increase productivity and production to meet the food demands of the consistently growing population (Fageria 2007). It is grown in India over an area of 44 m ha with total production of 105 m tones, amounting to 40% of the total food grain (Economic Survey 2015-16). Productivity of rice is low in the country and among different constraints, weeds pose a major

threat. Weed infestation in transplanted rice in India has been reported to cause yield reductions of 27-68% (Yadav *et al*. 2009, Manhas *et al*. 2012, Duary *et al*. 2015, Hossain and Malik 2017). Most of currently recommended herbicides (butaclor, pretilachlor, anilofos and oxadiargyl) for transplanted rice are applied as pre-emergence (PE). Which many a time do not perform well particularly when crop is subjected to water scarce conditions immediately after transplanting. Hence, there is need for post-emergence herbicides for control of complex weed flora in transplanted rice. Penoxsulam has been reported very effective in controlling of complex weed flora in transplanted rice (Mishra *et al*. 2007, Yadav *et al*. 2008) but its recommended application window of 8-12 days after transplanting (DAT) as spray in puddle transplanted rice fields is a practical limitation. Bispyribac-sodium is most commonly being used herbicide for post-emergence (PoE) control of weeds in transplanted rice (Yadav *et al*. 2009). However, some of grassy, few broad-leaf weeds and sedges are not controlled effectively by alone application of these herbicides and farmers often use 2,4-D, premix of chlorimuron + metsulfuron, ethoxysulfuron or pyrazosulfuron as sequential post-emergence herbicides or tank mixture for control of diverse weed flora. Generally, single application of premix or tank-mix combination of herbicides either pre-emergence or PoE would be more economically option for effective management of weeds. Spray of PoE combination is generally preferred over PE as it offers opportunity to choose the suitable herbicides according to weed flora infesting the crop. Moreover, combination of herbicides could be better option to control broad spectrum of weeds, save time and reduce cost of cultivation.

Penoxsulam 1.02% w/w (1.0% w/v) + cyhalofop-butyl 5.1% w/w (5.0% w/v) is a new ready-mix PoE herbicide for broad spectrum weed control in transplanted rice (Kailkhura *et al*. 2015, Singh *et al*. 2016, Hossain and Malik 2017). Although recommended herbicides penoxsulam and bispyribac-sodium provide effective control of *Echinochloa* along with few broad-leaf weeds and sedges, but increasing infestation of other aerobic grassy weeds such as *Leptochloa chinensis*, *Eragrostis* sp.) in rice fields particularly in situations of water scarcity calls for better weed management strategy. Hence, a read-mix combination of penoxsulam + cyhalofop was evaluated for control of broad spectrum of weeds in transplanted rice, along with its evaluation at farmers' fields, and residual carry over in soil, rice straw and grains.

MATERIALS AND METHODS

On-station experiment

Bio-efficacy studies: A field experiment was conducted to evaluate the efficacy of penoxsulam 1.02% w/w (1.0%w/v) + cyhalofop-butyl 5.1% w/w (5.0% w/v) for weed control during *Kharif* 2010 and *Kharif* 2011, and its phyto-toxicity on rice crop *Kharif* 2010 to 2012 as well as residual phyto-toxicity on wheat crop during *Rabi* 2010-11 to 2012-13, residue analysis in *Kharif* 2017 at CCS HAU Regional Research Station, Karnal and multi-location adaptive trials at farmers' fields in *Kharif* 2017. The soil of the experimental field was clay loam in texture, low in available nitrogen, medium in P_2O_5 and high in available K_2O with slightly alkaline reaction (pH 8.2). The treatments included penoxsulam + cyhalofop 105, 120, 135, 150 g/ha at 15-20 DAT, penoxsulam 22.5 g/ha at 8-12 DAT, cyhalofop-butyl 80 g/ha at 18-20 DAT, bispyribac-sodium 20 g/ha at 10-14 DAT, pretilachlor 750 g/ha at 0-3 DAT (pre-emergence as sand mixed broadcast), butachlor 1500 g/ha at 0-3 DAT along with weed free and weedy checks. The experiment was laid out in randomized block design with three replications. Rice cultivar HKR 47 was transplanted (35 days old seedlings) done on 5 July, 2010 and 20 July 2011, at a spacing of 20 x 15 cm in a plot size of 6.1 x 2.4 m. The post-emergence (PoE) herbicides were applied as spray using knap-sack sprayer fitted with flat fan nozzle in a spray volume of 300 litre/ha, and the pre-emergence (PE) herbicides as sand mix broadcast using 150 kg sand/ha. Soil in the field was kept under saturated condition during spray application and re-irrigated after 24 hours of spray. Crop was raised as per the recommendations of the CCS HAU and harvested on 19 October, 2010 and 30 October, 2011. Density and dry weight of weeds were recorded at 60 days after transplanting (DAT), and yield attributes and yield at were recorded maturity. Crop injury in respect of phyto-toxicity symptoms (yellowing, chlorosis, stunting or scorching) under different treatments was also recorded by visual rating (0-100%) at 15, 30 and 45 days after herbicide application (DAA). Since there was no crop injury on rice crop, data pertaining to this observation are not presented herein.

Phyto-toxicity studies: A field experiment was conducted to study the phyto-toxicity of penoxsulam + cyhalofop-butyl on transplanted rice at CCS HAU Regional Research Station, Karnal during *Kharif* 2010 to 2012. The treatments included penoxsulam + cyhalofop 150, 300 and 600 g/ha at 15-20 DAT along with untreated check with three replications. During *Kharif* 2010, 35 days old nursery of rice cv. '*HKR-47*'

was transplanted on 5 July. During 2011, 42 days old nursery of rice cv. '*HKR 47*' was transplanted on 20 July. During 2012, 36 days old nursery of rice cv. '*HKR 47*' was transplanted on 12 July. The transplanting was done at a spacing of 20 x 15 cm in a plot size of 6.1 x 2.4 m. Herbicides spray and other agronomic practices were the same as mentioned in previous section. The crop harvested on 19 October, 2010, 30 October, 2011 and 23 October 2012. Observations (from 10 plants/plot) on crop phytotoxicity in terms of vein clearing, epinasty, hyponasty, wilting and injury to leaf tips and leaf surface were recorded at 1, 3, 5, 7, 10, 15 and 30 days after herbicide application, on 0-10 scale with 0= no phytotoxicty and 10= compete mortality.

Maintaining the same plots, sowing of wheat crop was done at row spacing of 20 cm on 19 November 2010 (*DBW 17*), 25 November 2011 (*DPW 621-50*) and 20 November 2012 (*DPW 621-50*), using seed rate of 100-112.5 kg/ha. Crop was raised as per package of practices of the CCS HAU. Observations (from 10 plants/ plot) on crop phytotoxicity for rice were recorded at 15 and 30 DAS.

Residue studies: Residual studies in soil, straw and grains of rice were conducted during 2017 when technical grade herbicide with testing protocol was made available by the manufacturing company. For residual studies, a field experiment was laid out at CCS HAU Regional Research Station, Karnal during *Kharif* 2017. The treatments included penoxsulam + cyhalofop-butyl at 135 (X), 270 g/ha (2X) and untreated check. One month old seedlings of rice cultivar '*HKR-47*' were transplanted on 13 July at a spacing of 20 x 15 cm in a plot size of 16 x 6 m. Crop was raised as per the recommendations of the CCS HAU and harvested on 20 October. Samples of grain, straw and soil were collected at harvest for residue estimation. After validation of analytical method, the sample of soil, straw and grains of rice after harvest were analysed for residues of penoxsulam and cyhalofop on HPLC and of cyhalofop-butyl on GC-MS/MS. The limits of detection of herbicides and the MRL standards are given below.

MRL standards are given below.	
Limit of detection (LOD):	0.005 ug/g (for penoxsulam on HPLC) 0.001 ug/g (for cyhalofop on GC-MS/MS)
Limit of quantification (LOQ):	0.01 ug/g (for penoxsulam on HPLC) 0.005 ug/g (for cyhalofop on GC-MS/MS)
MRL in rice grain:	0.02 ug/g (US Environment Protection Agency, 2004) 0.02 ug/g (European Food Safety Authority, 2013)
MRL in rice straw:	0.5 ug/g (US Environment Protection Agency, 2004) 0.02 ug/g (European Food Safety Authority, 2013)

On-farm adaptive trials

To assess the performance of the herbicide on large scale in real field situations, adaptive trials at farmers' fields were conducted during *Kharif* 2017 with commercial formulation of penoxsulam+ cyhalofop-butyl made available by the company. Adaptive trials were conducted at 12 locations at farmers' fields in Karnal, Kurukshetra and Panipat districts during *Kharif* 2017. The fields were infested with complex weed flora. Penoxsulam + cyhalofop 135 g/ha at 15-20 DAT was evaluated in comparison to the check herbicide bispyribac-sodium 25 g/ha at 15-25 DAT. Herbicides were applied as spray in 300 litre water/ ha. The area under each treatment was 0.2 ha at each site.

Statistical analysis

Before statistical analysis, the data on density of weeds was subjected to square root $(\sqrt{x+1})$ transformation to improve the homogeneity of the variance. The data were subjected to the analysis of variance (ANOVA) separately for each year. The significant treatment effect was judged with the help of 'F' test at the 5% level of significance. The 'OPSTAT' software of CCS Haryana Agricultural University, Hisar, India was used for statistical analysis (Sheoran *et al*. 1998).

RESULTS AND DISCUSSION

On-station experiments

Effect on weeds: During 2010, penoxsulam + cyhalofop 135 g/ha resulted in significantly lower density of grassy weeds (0.0- 3.3/m^2) than its lower doses (105 and 120 g/ha) and further reduction in density of grassy weeds with its higher dose (150 g/ ha) was not significant over 135 g /ha (**Table 1**). It resulted in density of grassy weeds lower than penoxsulam 22.5 g/ha, cyhalofop 80 g/ha, pretilachlor 750 g/ha, bispyribac-sodium 20 g/ha, but was at par with butachlor 1500 g/ha. However, this dose (135 g/ha) was inferior to weed free check in respect of density of grassy weeds.

During 2011, density of *Echinochloa* under penoxsulam + cyhalofop 135 g/ha was lower than its lower doses and at par with its higher dose (**Table 1**). Penoxsulam + cyhalofop 135 g/ha resulted in density of *Echinochloa* at par with penoxsulam 22.5 g/ha, butachlor 1500 g/ha and weed free check, and lower than other treatments. Density of other grassy weeds (*Leptochloa chinenesis* and *Eragrostis* sp.) under penoxsulam + cyhalofop 135 g/ha was lower than penoxsulam + cyhalofop 105 g/ha but at par with its other doses. Penoxsulam + cyhalofop 135 g/ha

resulted in density of aerobic grassy weeds at par with cyhalofop 80 g/ha, pretilachlor 750 g/ha and butachlor 1500 g/ha and weed free check, and lower than all other treatments.

During 2010, penoxsulam + cyhalofop 135 g/ha resulted in density of broadleaf weeds (BLW) (36.7/ m^2) at par with all its other doses; penoxsulam 22.5 g/ ha, bispyribac-sodium 20 g/ha, pretilachlor 750 g/ha and butachlor 1500 g/ha (**Table 1**). Penoxsulam + cyhalofop 135 g/ha was superior to cyhalofop 80 g/ ha and weedy check, but was inferior to weed free conditions in respect of density of BLW. During 2011, penoxsulam + cyhalofop 135 g/ha resulted in density of BLW (30.7/m^2) lower than its lower doses (105 and 120 g/ha); and at par with its higher dose as well as with penoxsulam 22.5 g/ha and butachlor 1500 g/ ha (**Table 1**). Penoxsulam + cyhalofop 135 g/ha was superior to cyhalofop 80 g/ha, bispyribac-sodium, pretilachlor and weedy check in respect of density of BLW. However, it was inferior to weed free check in controlling the weeds.

The data of sedge were recorded in 2011 (**Table 1**). Penoxsulam + cyhalofop 135 g/ha provided almost complete control of sedges and registered superiority over cyhalofop 80 g/ha and weedy check and was at par with all other treatments in respect of density of sedges.

Dry weight of weeds: During 2010, application of penoxsulam + cyhalofop 135 g/ha resulted in significantly lower dry weight of grassy weeds (26.3 g/m^2) than its lower doses (105 and 120 g/ha) and at par with its higher dose of 150 g/ha (**Table 2**). It also resulted in significantly lower dry weight of grassy weeds than cyhalofop 80 g/ha and weedy check.

During 2011, dry weight of *Echinochloa* under penoxsulam + cyhalofop 135 g/ha was lower than its lower doses (105 and 120 g/ha) (**Table 2**). However, penoxsulam + cyhalofop 6% OD 135 g/ha was at par with its higher dose (150 g/ha) and with penoxsulam 22.5 g/ha, butachlor 1500 g/ha and weed free check in reducing dry weight of *Echinochloa*. Dry weight of aerobic grassy weeds under penoxsulam + cyhalofop 135 g/ha was also lower than penoxsulam + cyhalofop 105 g/ha but at par with its other doses as well as with cyhalofop 80 g/ha, pretilachlor 750 g/ ha and butachlor 1500 g/ha and weed free check, but lower than bispyribac-sodium 20 g/ha and weedy check.

During 2010, penoxsulam + cyhalofop 135 g/ha caused significant reduction in dry weight of broadleaf weeds (4.7 g/m^2) over than its lower doses but was at par with its higher dose. During 2011, penoxsulam + cyhalofop 135 g/ha was superior to its dose of 105 g/ha but at par with other doses. Penoxsulam + cyhalofop 135 g/ha was also superior to cyhalofop 80 g/ha and weedy check in respect of dry weight of BLW, in both years. Penoxsulam + cyhalofop 135 g/ha provided almost complete control of sedges, was markedly superior to cyhalofop 80 g/ ha and weedy check in respect of dry weight of sedges during 2011 (**Table 2**).

Penoxsulam (Yadav *et al.* 2008) and bispyribac-sodium (Yadav *et al.* 2009) applied as PoE have already been reported very effective against *E.*

Table 1. Effect of penoxsulam + cyhalofop on density of weeds (no./m^2) in transplanted rice during *Kharif* 2010 and 2011

Treatment	2010		2011					
	Echino-chloa spp.	BLW	*Echino-chloa* spp.	Other grassy weeds	BLW	*Cyperus difformis*	*Fimbristylis miliaceae*	Total sedges
Penoxsulam + cyhalofop (105 g/ha) 15-20 DAT	4.99(24.0)	7.11(50.7)	2.92(8.0)	1.8(2.7)	8.0(64.0)	1.0(0)	1.4(1.3)	1.4(1.3)
Penoxsulam + cyhalofop (120 g/ha) 5-20 DAT	4.18(16.7)	6.44(42.0)	2.49(5.3)	1.2(0.7)	7.4(54.0)	1.0(0)	1.0(0.0)	1.0(0)
Penoxsulam + cyhalofop (135 g/ha) 5-20 DAT	2.04(3.3)	6.07(36.7)	1.00 (0)	1.0(0)	5.6(30.7)	1.0(0)	1.0(0.0)	1.0(0)
Penoxsulam + cyhalofop (150 g/ha) 5-20 DAT	1.66(2.0)	6.00(35.3)	1.00(0)	1.0(0)	5.6(30.0)	1.0(0)	1.0(0.0)	1.0(0)
Penoxsulam (22.5 g/ha) 8-12 DAT	3.19(9.3)	6.28(38.7)	1.41(1.3)	2.3(4.7)	6.1(36.0)	1.0(0)	1.0(0.0)	1.0(0)
Cyhalofop (80 g/ha) 18-20 DAT	6.68(44.7)	10.1(103.3)	3.57(12.7)	1.0(0)	8.9(78.7)	4.2(17.3)	2.5(6.7)	5.0(24.0)
Bispyribac-sodium (20 g/ha) 10-14 DAT	4.68(21.3)	6.98(48.0)	2.32(5.3)	1.8(2.7)	7.5(56.0)	1.4(1.3)	1.0(0.0)	1.4(1.3)
Bispyribac-sodium (25 g/ha) 15-25 DAT	2.75(6.7)	6.43(41.3)	1.00(0)	1.8(2.7)	6.6(42.7)	1.0(0)	1.2(0.7)	1.2(0.7)
Pretilachlor (750 g/ha) 0-3 DAT	3.29(10.0)	6.36(40.0)	2.33(5.3)	1.0(0)	7.4(54.0)	1.0(0)	1.0(0.0)	1.0(0)
Butachlor (1500 g/ha) 0-3 DAT	1.66(2.0)	5.60(30.7)	1.66(2.0)	1.0(0)	5.7(32.0)	1.0(0)	1.0(0.0)	1.0(0)
Weed free	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.0(0)	1.0(0)	1.0(0)	1.0(0.0)	1.0(0)
Weedy check	7.37(54.0)	9.67(92.7)	4.72(21.3)	2.4(5.3)	10.1(102.0)	4.6(20.7)	2.8(8.7)	5.5(29.3)
LSD (p=0.05)	1.03	1.67	1.25	0.62	1.44	0.59	1.03	0.75

Original figures given in parenthesis were subjected to square root transformation ($\sqrt{x+1}$); Efore statistical analysis; DAT - Days after transplanting; BLW - broad-leaf weeds

crusgalli and *E. colona,* few broad-leaf weeds and sedges, but not against other grasses such as *Leptochloa, Eragrostis, Dactyloctenium etc*. Application of cyhalofop 80 g/ha alone proved less effective in reducing density and dry weight of complex weed flora, than combined application of penoxsulam + cyhalofop 135 g/ha in transplanted rice (Singh *et al.* 2016). Kailkhura *et al.* (2015) and Hossain and Malik (2017) also found effective control of complex weed flora in transplanted rice with premix application of penoxsulam + cyhalofop 135 g/ ha. However, Menon *et al.* (2016) reported poor efficacy of this herbicide combination against *Ludwigia parviflora.*

Effect on crop: There was no significant effect of herbicide treatments on the plant height and panicle length of the crop during both the years (**Table 3**). Penoxsulam + cyhalofop 135 g/ha resulted in similar number of effective tillers/ mrl (49.0 in 2010 and 53.3 in 2011) to be at par with all other treatments except being higher than penoxsulam + cyhalofop 105 g/ha (51.5 in 2011), cyhalofop 80 g/ha (33.8.0 in 2010 and 49.8 in 2011) and weedy check (27.0 in 2010 and 32.5 in 2011). The grain yield under penoxsulam + cyhalofop 135 g/ha (5.46 t/ha in 2010 and 5.53 t/ha in 2011) was significantly higher than its lower doses (105 and 120 g/ha) and at par with higher dose (150 g/ha) during both the years, indicating it to be the optimum dose. Penoxsulam + cyhalofop 135 g/ha also resulted in grain yields similar to penoxsulam 22.5 g/ha, pretilachlor 750 g/ha, butachlor 1500 g/ha and weed free check; but higher than cyhalofop 80 g/ ha, bispyribac-sodium 20 g/ha and weedy check during both the years. These results are in agreement with earlier findings from different locations (Kailkhura *et al.* 2015, Singh *et al.* 2016, Hossain and Malik 2017). Weeds growing throughout the crop season reduced the grain yield to the extent of 68.8% and 45.8% during 2010 and 2011, respectively.

Table 2. Effect of penoxsulam + cyhalofop on dry-weight of weeds (g/m^2) in transplanted rice during *Kharif* 2010 and 2011

Treatment	Dose (g/ha)	Time (DAT)	2010		2011			
			Grassy weeds	BLW*	*Echinochloa* spp	Other grasses	BLW	Sedges
Penoxsulam + cyhalofop	105	15-20	140.0	9.5	59.8	2.5	3.1	0.7
Penoxsulam + cyhalofop	120	15-20	72.6	7.3	39.4	0.7	2.5	0.0
Penoxsulam + cyhalofop	135	15-20	26.3	4.7	0.0	0.0	1.1	0.0
Penoxsulam + cyhalofop	150	15-20	28.6	4.2	0.0	0.0	1.4	0.0
Penoxsulam	22.5	8-12	35.5	4.1	16.5	6.0	1.5	0.0
Cyhalofop	80	18-20	316.3	10.1	162.1	0.0	7.0	11.3
Bispyribac-sodium	20	10-14	46.6	7.7	35.9	2.8	3.9	0.5
Bispyribac-sodium	25	15-25	29.9	5.9	0.0	2.7	2.3	0.3
Pretilachlor	750	0-3	51.1	7.1	37.3	0.0	0.9	0.0
Butachlor	1500	0-3	17.3	3.9	14.8	0.0	0.4	0.0
Weed free			0.0	0.0	0.0	0.0	0.0	0.0
Weedy check			433.5	10.3	311.0	6.1	7.5	13.9
LSD (p=0.05)			35.8	3.0	35.0	1.9	1.6	2.9

*BLW, broad-leaf weeds

Table 3. Effect of penoxsulam + cyhalofop on plant height, yield attributes and grain yield of transplanted rice during *Kharif* 2010 and 2011

Treatment	Dose (g/ha)	Time (DAT)	Plant height (cm)		Effective tillers/ mrl		Panicle length (cm)		Grain yield (t/ha)	
			2010	2011	2010	2011	2010	2011	2010	2011
Penoxsulam + cyhalofop	105	15-20	114.9	95.8	46.5	51.5	22.1	20.2	4.63	4.89
Penoxsulam + cyhalofop	120	15-20	114.8	95.7	49.0	53.3	22.4	20.0	4.86	5.15
Penoxsulam + cyhalofop	135	15-20	115.5	93.8	53.3	58.0	22.3	20.5	5.46	5.53
Penoxsulam + cyhalofop	150	15-20	115.5	95.5	52.7	57.3	22.5	20.5	5.44	5.58
Penoxsulam	22.5	8-12	115.4	94.3	52.0	57.2	22.3	20.3	5.22	5.42
Cyhalofop	80	18-20	114.5	94.1	33.8	49.8	21.7	19.9	3.44	5.07
Bispyribac-sodium	20	10-14	115.9	94.9	50.3	53.7	21.9	20.1	5.14	5.23
Bispyribac-sodium	25	15-25	115.4	95.3	53.0	56.5	22.1	20.3	5.32	5.41
Pretilachlor	750	0-3	114.7	96.1	50.7	54.0	22.0	20.0	5.19	5.27
Butachlor	1500	0-3	115.7	94.5	54.5	58.2	22.6	20.2	5.53	5.46
Weed free			119.9	94.3	56.8	60.0	22.2	20.1	5.77	5.60
Weedy check			113.4	94.0	27.0	32.5	21.5	19.7	1.80	3.03
LSD (p=0.05)			NS	NS	6.9	6.1	NS	NS	0.32	0.32

The grain yield and yield attributing characters were lower during 2010 as compared to 2011 owing to high infestation of weeds during 2010.

Economics: Penoxsulam + cyhalofop 135 g/ha provided net returns of ` 24945-29325/ha, which was almost similar/ higher than recommended post-em herbicide penoxsulam 22.5 g/ha (` 23756-29368/ha). Penoxsulam + cyhalofop 135 g/ha offered B-C ratio of 1.80-1.91, which was also almost similar to penoxsulam (**Table 4**). Singh *et al.* (2016) also reported improvement in grain yield, net returns and B-C ratio with this combination in transplanted rice.

Phyto-toxicity studies: There was no phyto-toxicity of penoxsulam + cyhalofop even up to 600 g/ha on transplanted rice at 1, 3, 5, 7, 10, 15 and 30 days after application (DAA) of the herbicide during *Kharif* 2010 to 2012 or on the succeeding wheat crop during *Rabi* seasons of 2010-11 to 2012-13

Residue studies: Residues of penoxsulam+ cyhalofop applied at 135 and 270 g/ha were below detectable level in soil, straw and grains of rice at harvest during 2017 which indicated its safety to the human/animal health and the environment.

On- farm adaptive trials: Penoxsulam + cyhalofop 135 g/ha provided 92-97% control of weeds and resulted in average grain yield of 4.13 t/ha as compared to 85-92% weed control and grain yield of 3.83 t/ha in check herbicide bispyribac-sodium 25 g/ha (**Table 5**). Penoxsulam + cyhalofop 6%OD 135 g/ha increased the gross monetary returns by ` 9665/ha with additional cost of ` 1200/ha, thus giving a net gain of ` 8465/ha due to increase in productivity (**Table 6**).

Table 4. Effect of penoxsulam + cyhalofop on economics of transplanted rice during *Kharif* 2010 and 2011

Treatment	Dose (g/ha)	Time (DAT)	Variable cost (x10^3 `/ha)		Gross returns (x10^3 `/ha)		Net returns (x10^3 `/ha)		B:C ratio	
			2010	2011	2010	2011	2010	2011	2010	2011
Penoxsulam + cyhalofop	105	15-20	30.65	31.45	47.71	54.33	17.06	22.89	1.56	1.73
Penoxsulam + cyhalofop	120	15-20	30.96	31.76	50.04	57.22	19.07	25.46	1.62	1.80
Penoxsulam + cyhalofop	135	15-20	31.27	32.07	56.22	61.39	24.94	29.32	1.80	1.91
Penoxsulam + cyhalofop	150	15-20	31.58	32.38	56.07	61.90	24.49	29.52	1.78	1.91
Penoxsulam	22.5	8-12	30.03	30.83	53.79	60.19	23.76	29.37	1.79	1.95
Cyhalofop	80	18-20	29.72	30.52	35.41	56.29	5.69	25.77	1.19	1.84
Bispyribac-sodium	20	10-14	29.72	30.52	52.92	58.01	23.20	27.49	1.78	1.90
Bispyribac-sodium	25	15-25	30.03	30.83	54.75	60.09	24.72	29.27	1.82	1.95
Pretilachlor	750	0-3	29.07	29.84	53.45	58.54	24.38	28.70	1.84	1.96
Butachlor	1500	0-3	29.02	29.79	56.99	60.62	27.97	30.82	1.96	2.03
Weed free			34.85	37.44	59.45	62.22	24.60	24.77	1.71	1.66
Weedy check			28.13	28.85	18.53	33.69	-9.60	4.84	0.66	1.17

Table 5. Performance of penxsulam + cyhalofop-butyl against weeds in transplanted rice in adaptive trials conducted at farmers' fields in *Kharif* 2017

District	Location	Variety	Weed control (%)		Grain yield (t/ha)	
			Penxsulam + cyhalofop 135 g/ha	Bispyribac-sodium 25 g/ha	Penxsulam + cyhalofop 135 g/ha	Bispyribac-sodium 25 g/ha
Karnal	Uchana-1	CSR-30	95	90	3.52	3.25
Karnal	Uchana-2	CSR-30	96	91	3.46	3.24
Karnal	Tikri	HKR 47	97	90	6.81	6.43
Karnal	Shindarpur	PB 1121	94	92	4.02	3.86
Karnal	Uchani-1	PB 1121	95	90	4.15	3.82
Karnal	Uchani-2	CSR -30	95	90	2.95	2.86
Karnal	Popra	PB 1121	94	86	3.82	3.42
Karnal	Kunjpura	PB 1121	93	85	3.64	3.35
Karnal	Panhari	HKR 47	95	90	6.72	6.34
Kuruksetra	Darala	CSR-30	94	89	2.92	2.73
Panipat	Ishrana	PB 1121	95	88	3.82	3.45
Panipat	Dhurana	PB 1121	92	85	3.75	3.22
Average			94.6	88.8	4.13	3.83

Table 6. Net gains from use of penoxsulam + cyhalofop in adaptive trials conducted at farmers' fields in *Kharif* 2017

Variety	No. of locations	Average grain yield (t/ha)		Increase in grain yield over check herbicide (t/ha)	Total monetary gain over check herbicide (`/ha)	Additional cost of test herbicide over check (`/ha)	Net monetary gain (`/ha)
		Penxsulam + cyhalofop (135 g/ha)	Check herbicide (bispyribac-sodium 25 g/ha)				
Basmati rice (*CSR-30*)	4	3.21	3.02	0.19	7600	1200	6400
Basmati rice (*Pusa basmati 1121*)	6	3.87	3.52	0.35	12250	1200	11050
Coarse grain rice (*HKR 47*)	2	6.77	6.39	0.38	6042	1200	4842
Average		4.13	3.83	0.30	9665	1200	8465

The present investigation suggests that penoxsulam + cyhalofop (ready-mix) 135 g/ha applied at 15-20 DAT in a spray volume of 300 litre water/ha could be alternative option for effective and economic control of complex weed flora and attain significant improvement in grain yield of transplanted rice.

REFERENCES

Duary B, Teja KC, Roy Chowdhury S and Mallick RB. 2015. Weed growth and productivity of wet season transplanted rice as influenced by sole and sequential application of herbicides. *International Journal of Bio-Resource, Environment and Agricultural Sciences* **1**(4): 187–192.

Economic Survey. 2015-16. Ministry of Finance, Govt. of India. http://indiabudget.nic.in/budget2016-17/es2014-15/echapter-vol2.pdf (accessed 17.12.2017), Vol-II, pp. 100.

Fageria NK. 2007. Yield physiology of rice. *Journal of Plant Nutrition* **30**: 843–879.

Hossain A and Malik GC. 2017. Herbicide combinations for control of complex weed flora in transplanted rice in lateritic belt of West Bengal. *Indian Journal of Weed Science* **49**(3): 276–278.

Jason AB, Timothy W, Eric PW, Nathan WB and Dustin LH. 2007. Rice cultivars response to penoxsulam. *Weed Technology* **21**: 961–965.

Kailkhura S, Pratap T, Singh VP, Guru SK and Singh SP. 2015. Herbicide combinations for control of complex weed flora in transplanted rice. *Indian Journal of Weed Science* **47**(4): 414–416.

Manhas SS, Singh G, Singh D and Khajuria V. 2012. Effect of tank-mixed herbicides on weeds and transplanted rice (*Oryza sativa* L.). *Annals of Agricultural Research New Series* **33**(1&2): 25–31.

Menon MV, Bridgit TK and Girija T. 2016. Efficacy of herbicide combinations for weed management in transplanted rice. *Journal of Tropical Agriculture* **54**(2): 204–208.

Mishra JS, Dixit A and Varshney JG. 2007. Efficacy of penoxsulam on weeds and transplanted rice (*Oryza sativa*). *Indian Journal of Weed Science* **39**(1): 24–27.

Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS. 1998. Statistical Software Package for Agricultural Research Workers. Recent advances in information theory, statistics & computer applications by DS Hooda and RC Hasija. CCS HAU, Hisar. pp 139–143.

Singh VP, Singh SP, Pratap T, Joshi V, Kumar A, Tripathi N, Banga A and Bisht N.2016. Efficacy of ready mix of penoxsulam and cyhalofop-butyl for weed control in transplanted rice. *The Ecoscan* **10**(1&2): 217–221.

Yadav DB, Yadav A and Punia SS. 2008. Efficacy of penoxsulam against weeds in transplanted rice. *Indian Journal of Weed Science* **40**(3&4): 142–146.

Yadav DB, Yadav A and Punia SS. 2009. Evaluation of bispyribac-sodium for weed control in transplanted rice. *Indian Journal of Weed Science* **41**(1&2): 23–27.