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Bio-efficacy of penoxsulam+cyhalofop butyl 6% OD, a new pre-mix herbicide mixture for weed control in direct seeded puddled irrigated rice (*Oryza sativa* L.)

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ABSTRACT

The field experiments were conducted during **kharif** and **rabi** 2014 to study the efficacy of pre-mix herbicide mixture penoxsulam+cyhalofop butyl for weed control in direct seeded puddled rice. The experiment was laid out in randomized block design with eight treatments and three replications. The treatments comprised four different doses of penoxsulam+cyhalofop butyl 6% OD viz., 120, 125, 130 and 135 g a. i./ha, bispyribac sodium 10% SE 25 g a. i./ha, penoxsulam 24 SC 22.5 g a. i./ha, hand weeding twice and weedy check. On 30 days after sowing (DAS) weed flora comprised sedges (53.91%), broad leaf weeds (37.88%) and grasses (8. 2%) and on 60 DAS weed flora constituted sedges (53.15%), broad leaf weeds (BLW) (34.66%) and grasses (12.19%). The dominant weed species present in the experimental field were *Schoenoplectus juncoides* (Roxb.) Palla, *Cyperus iria* L. and *Cyperus difformis* L. among sedges; *Isachne miliaceae* Roth among grasses and *Ludwigia perennis*, *Limnocharis flava* (L.) Buch., *Marsilea quadrifoliata* L. and *Bergia carpensis* L. among broad leaf weeds. Pre-mix herbicide mixture, penoxsulam+cyhalofop butyl was found to be effective in reducing the density and dry weight of weeds at 30, 45 and 60 DAS. Among the doses, higher doses of penoxsulam+cyhalofop butyl (130 and 135 g a. i./ha) were found to be more effective in reducing the dry weight with a weed control efficiency of 97.34 and 98.31%, respectively. Higher growth and better expression of yield attributes were registered for these treatments. Adoption of weed control measures enhanced the grain yield from 4.26 to 8.46 t/ha. All the tested doses of penoxsulam+cyhalofop butyl recorded higher grain yield compared to hand weeding, penoxsulam and bispyribac sodium applied alone. Application of penoxsulam +cyhalofop butyl at its higher dose (135 g a. i./ha) recorded the highest grain yield which was on a par with its lower dose 130 g a. i./ha. The highest gross returns and B : C ratio were also recorded by these treatments. Bispyribac sodium was found to be less effective in reducing the density and dry weight of sedges resulting in lesser yield and B : C ratio compared to penoxsulam in the present study. Hand weeding recorded the lowest gross returns and B : C ratio among the weed control treatments. The study concludes that better broad spectrum control of weeds can be achieved by the post-emergence application of herbicide mixture penoxsulam+cyhalofop butyl on 15 DAS. The selection of herbicide and dose should depend on the target weed species in an area.

Key words : Direct seeded rice, herbicide mixture, penoxsulam+cyhalofop butyl, weed control efficiency, weed density, weed dry matter

INTRODUCTION

Rice, the major cereal crop, which plays a significant role in the food security of India, is grown in an area of 44 million hectares with a production of 104 million tonnes (USDA, 2014). The country has to produce about 130 million tonnes of rice by 2025 to meet the food requirement for the growing population (Hugar *et al.*, 2009). In India, rice is mainly grown by manual transplanting of seedlings into the puddled soil. Puddling and transplanting operations consume significant quantity of water, up to 30% of the total water requirement for rice (Chauhan, 2012). In the future, farmers may have limited availability of water to flood their field because of physical or economic water scarcity. Manual transplanting though ensures better crop stand, better control of weeds and less lodging; it is quite expensive, laborious, time consuming and involves lot of drudgery. Manual transplanting consumes 25% of the total labour requirement for the crop. Because of the decreased availability of water and increased production cost, there has been a shift from manual transplanting to direct seeding in rice. Direct seeding is easier, time and labour saving, which gives equivalent or even higher yield than transplanting (De Datta, 1988).

Weeds are the prime biological constraint in direct seeded rice (DSR) due to the simultaneous emergence of crop and weed and less competitive nature of the germinated seedling. Risk of yield loss from weeds in DSR is greater than in transplanted rice (Rao *et al.*, 2007). Season long weed competition in direct seeded rice may cause yield reduction up to 80% (Sunil *et al.*, 2010). Yield loss in direct seeded rice depends on several factors like season, weed species present, degree of infestation, cultivar used and management practices followed. The success of DSR depends largely on the selection and adoption of effective weed management techniques.

Farmers have to rely largely on herbicides for weed control in DSR because of acute labour shortage and huge wage rates. Herbicides are considered to be the smartest viable option to replace hand weeding compared to other methods of weed control. But the repeated use of a particular herbicide will lead to shift in weed population and development of herbicide resistance in weeds. One of the recent advent ways to overcome the problem of herbicide resistance and shift in weed flora is the use of herbicide mixtures or application of herbicide with different mode of action in sequence.

Herbicides with different mode of action when mixed together bind to different target site in weeds and prevent the probability of target site resistance in susceptible species (Paswan *et al.*, 2012). Simultaneous application of more than one herbicide in a mixture is more effective in controlling diverse weed population giving the crop a better competitive edge. A grassy herbicide in combination with broad leaved weeds killer would take care of both types or grass killer in combination with herbicide that control both sedges and broad leaf weeds will give a wider spectrum of weed control (Mukherjee, 2006). One such post-emergence new herbicide pre-mixture is penoxsulam+cyhalofop butyl, a combination of penoxsulam, a broad spectrum herbicide and cyhalofop butyl, a grass effective herbicide.

Penoxsulam, a post-emergence herbicide, is a member of triazolopyrimidine group inhibiting acetolactate synthase (ALS) enzyme. Cyhalofop butyl is also a post-emergence grass effective herbicide, member of aryloxyphenoxypropionate group inhibiting acetyl CoA carboxylase enzyme. Hence, an investigation was carried out to study the bio-efficacy of penoxsulam+cyhalofop butyl for broad spectrum weed control in direct seeded puddled irrigated rice.

MATERIALS AND METHODS

Field experiments were conducted at farmers' field of Upanniyoor padashekharam, in Kalliyoor panchayat in Thiruvananthapuram district of Kerala, situated at a longitude and latitude of 8.5° N and 76.9° E and 29 m above MSL during **kharif** 2014 (May 2014 to September 2014) and **rabi** 2014 (November 2014 to March 2015). The experiment was conducted in randomized block design with eight treatments viz., penoxsulam+cyhalofop butyl 6% OD applied at 120 , 125 , 130 and 135 g a. i./ha, bispyribac sodium 10% SE at 25 g a. i./ha, penoxsulam 24 SC at 22.5 g a. i./ha, hand weeding twice at 20 and 40 days after sowing (DAS) and weedy check. The treatments were replicated thrice.

The soil was clay loam with pH 4.6, EC 0.2 dS/m, organic carbon 1.6%, available N 602.11 kg/ha, available P 24.64 kg/ha and available K 201 kg/ha, respectively, during **kharif** 2014 and pH 5.5, EC 0.2 dS/m, organic carbon 2.62%, available N 264.42 kg/ha, available P 12.09 kg/ha and available K 72.24 kg/ha, respectively, during **rabi** 2014.

Kanchana (PTB 50), a short duration variety released from Regional Agricultural Research Station, Pattambi, Kerala was used as the test crop. The pre-germinated seeds were sown on 30 May 2014 during **kharif** 2014 and 24 November 2014 during **rabi** 2014. Seed rate adopted was 100 kg/ha. The crop was fertilized with 70 : 35 : 35 kg N : P_2O_5 : K_2O/ha with one-third N and K and half P applied on 15 DAS, one-third N and K and half P on 35th day and remaining one-third N and K on 55th day after sowing corresponding to tillering, active tillering and panicle initiation stage of the crop.

Agronomic management practices were adopted as per Kerala Agricultural University Package of Practices Recommendations (KAU, 2011) for raising the crop. The crop was harvested on 17 September 2014 and 18 March 2015.

The average rainfall received during **kharif** season was 892 mm with 46 rainy days and the mean maximum and minimum temperature recorded was 30.5°C and 24.7°C, respectively, and the average rainfall received during **rabi** was 210 mm with 21 rainy days and the mean maximum and minimum temperature recorded was 30.8°C and 22.8°C, respectively.

The herbicides were applied on 15 DAS as per the treatment schedule. Herbicides were sprayed with the help of hand operated knapsack sprayer fitted with flat fan nozzle at a spray volume of 500 l/ha. In hand weeding treatment, two manual weedings were done on 20 and 40 DAS.

Observations on weed density were recorded with the help of quadrate (0.25 x 0.25 m) placed randomly at two representative sites in each plot at 15, 30 and 45 days after herbicide application (DAHA) corresponding to 30, 45 and 60 DAS of the crop. Weed samples were collected from the same area at 30, 45 and 60 DAS. Weed samples were sun-dried before oven drying at 65°C until constant weight was attained. The data on weed density and weed dry weight were subjected to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Weed control efficiency (WCE) was computed using the dry weight of weeds in control and treated plots. Plant height, tillers per square metre and the yield attributing characters like panicles per square metre, filled grains/panilcle and 1000-grain weight were recorded at harvest. Number of tillers and panicles was recorded by placing a quadrate (0.25 x 0.25 m) at two spots in each plot. Plant height and yield attributing characters were recorded from 10 randomly selected hills. The grain yield was recorded at 14% moisture and expressed in t/ha. Straw obtained from the net plot area was dried to constant weight under sun and then weighed to express the straw yield in t/ha. Economics was worked out based on the cost of labour and input at prevailing rate and minimum support price fixed by the Government of Kerala for the paddy @ Rs. 18/ kg and one rupee/kg for the straw. The data except WCE, total gross returns, cost of cultivation and B : C ratio were subjected to analysis of variance. The data were analyzed separately for the season **kharif** 2014 and **rabi** 2014 using ANOVA and individual year data were subjected to pooled analysis to obtain trend over the seasons.

RESULTS AND DISCUSSION

Weed Flora Composition

Two seasons' study revealed that at 30, 45 and 60 DAS, the major weed flora in the experimental field was *Schoenoplectus juncoides* (Roxb.) Palla (hard stemmed bull rush), *Cyperus iria* L. (rice flat sedge) and *Cyperus difformis* L. (umbrella sedge) among sedges; *Isachne miliaceae* Roth (Isachne), among grasses and *Ludwigia perennis* (water prim rose), *Limnocharis flava* (L.) Buch. (water cabbage), *Marsilea quadrifoliata* L. (airy pepper wort) and *Bergia carpensis* L. among the broad leaf weeds. At 30, 45 and 60 DAS, sedges constituted 53.91, 44.98 and 53.14%, BLW constituted 37.88, 45.56, 34.66% and grasses constituted 8.2, 9.46 and 12.19% of the total weed population. Among the three major groups, sedges was the dominant one followed by BLW and grasses on 30 and 60 DAS, while on 45 DAS, BLW were predominant followed by sedges and grasses. The maximum number of weeds was observed on 45 DAS in weedy check. After 45 DAS, decline in population of sedges and BLW and slight increase in population of grassy weeds were observed (Table 1).

Effect of Treatments on Density of Sedges

Weed control treatments showed significant reduction in the density of sedges at 30, 45 and 60 DAS compared to weedy check (Table 1). Perusal of the data on density of sedges at 30 DAS revealed that the lowest number was observed in penoxsulam+ cyhalofop butyl applied at 125 g a. i./ha which was found to be on a par with its higher doses at 130 and 135 g a. i./ha and penoxsulam at 22.5 g a. i./ha. All doses of combination herbicide were found to be more effective than bispyribac sodium and hand weeding twice in reducing the density of sedges (Table 1). On 45 DAS, penoxsulam+cyhalofop butyl at 135 g a. i./ha recorded significantly lower number of

Table 1. Effect of weed control methods on density of weeds at 30, 45 and 60 DAS in direct seeded rice (Pooled data of **kharif** and **rabi** 2014)

Treatment	Density of sedges (No./m²)			Density of BLW (No./m²)			Density of grasses (No./m²)		
	30	45	60	30	45	60	30	45	60
Penoxsulam+cyhalofop butyl 120 g a. i./ha	8.56 (72.77)	6.31 (39.32)	5.88 (34.07)	8.21 (66.90)	9.24 (84.88)	10.06 (100.70)	3.3 (10.39)	4.18 (16.97)	6.42 (40.72)
Penoxsulam+cyhalofop butyl 125 g a. i./ha	5.72 (32.22)	5.34 (28.02)	6.02 (35.74)	5.96 (35.02)	7.87 (61.44)	8.52 (72.09)	0.95 (0.40)	2.88 (7.79)	3.33 (10.59)
Penoxsulam+cyhalofop butyl 130 g a. i./ha	7.37 (53.82)	5.11 (25.61)	4.75 (22.06)	8.41 (70.23)	8.98 (80.14)	7.73 (59.25)	1.35 (1.32)	3.68 (13.04)	4.66 (21.22)
Penoxsulam+cyhalofop butyl 135 g a. i./ha	6.04 (35.98)	2.94 (8.14)	1.87 (3.00)	4.44 (19.21)	7.39 (54.11)	5.44 (29.09)	2.91 (7.97)	3.26 (10.13)	4.41 (8.95)
Bispyribac sodium 25 g a. i./ha	12.08 (145.43)	13.23 (174.53)	17.38 (301.56)	11.67 (135.69)	7.01 (48.64)	10.14 (102.32)	5.65 (31.42)	7.84 (60.97)	9.12 (82.67)
Penoxsulam 22.5 g a. i./ha	7.23 (51.77)	7.08 (49.63)	8.71 (75.36)	8.04 (64.14)	8.30 (68.39)	7.8 (60.34)	4.14 (16.64)	7.33 (53.23)	7.79 (60.18)
Hand weeding twice at 20 and 40 DAS	13.27 (175.59)	7.19 (51.20)	10.21 (103.74)	15.02 (225.10)	10.26 (104.77)	10.37 (107.12)	1.98 (3.42)	3.13 (9.30)	6.44 (40.97)
Weedy check	23.95 (573.10)	26.43 (698.43)	25.02 (625.50)	20.08 (402.71)	26.61 (707.59)	20.21 (407.94)	9.37 (87.30)	12.14 (146.88)	12.0 (143.5)
C. D. (P=0.05)	1.70	2.01	1.64	1.82	1.84	1.67	0.93	0.54	0.97

BLW–Broadleaf weeds and DAS–Days after sowing. Values in parentheses are transformed values.

sedges compared to other weed control treatments. The other tested doses of penoxsulam+cyhalofop butyl were found to be on a par with penoxsulam alone in reducing the density of sedges. Similarly, on 60 DAS, penoxsulam+cyhalofop butyl 135 g a. i./ha recorded the least number of weeds and showed its superiority over other treatments, while other doses of this combination were found to be statistically on a par in reducing the density of sedges and significantly better than penoxsulam. Das (2008) reported that application of herbicide mixtures resulted in better broad spectrum weed control than the application of components alone. At 45 and 60 DAS, hand weeding and penoxsulam were found to be on a par in reducing the density of sedges and bispyribac sodium was found to be the least effective treatment. Earlier workers have reported the broad spectrum efficiency of bispyribac sodium (Mahajan *et al.*, 2009; Yadav *et al.*, 2009). The difference in opinion can be attributed to the difference in the predominant species present in the experimental location. The most predominant sedge present in the experimental site was *Schoenoplectus juncoides* and two seasons, results showed that, bispyribac sodium failed to control *S. juncoides*.

Effect of Treatments on Density of Broad Leaf Weeds

Statistical analysis of data revealed that density of broad leaf weeds (BLW) was significantly influenced by weed control treatments (Table 1). The lowest density of BLW was observed in plot applied with penoxsulam+ cyhalofop butyl at 135 g a. i./ha which was found to be on a par with 125 g a. i./ha. This was followed by penoxsulam at 22.5 g a. i./ha which was on a par with penoxsulam+cyhalofop butyl at 130 g a. i./ha in reducing the density of BLW at 30 DAS. At 45 and 60 DAS, the lowest density of BLW was observed in bispyribac sodium which was statistically on a par with higher doses of penoxsulam+cyhalofop butyl (135 and 125 g a. i./ha) and penoxsulam 22.5 g a. i./ha. The higher dose of penoxsulam+ cyhalofop butyl recorded significantly lower population of BLW at 60 DAS (Table 1). This was followed by its lower dose 130 g a. i./ha, penoxsulam applied alone and penoxsulam+ cyhalofop butyl at 125 g a. i./ha and all the three were statistically on a par. Observations at three different time intervals revealed that hand weeding was not much effective in reducing the population of BLW compared to herbicide treatments. This result is in agreement with the findings of Raj *et al.* (2013) who opined that manual weeding failed to control weeds than herbicidal treatments because of escape or regeneration of weeds.

Effect of Treatments on Density of Grassy Weeds

Significant differences in the density of grassy weeds were observed due to weed control treatments (Table 1). A gradual increase in the density of grasses was observed as the crop advanced its age. Weedy check recorded the maximum number of grassy weeds during all the three stages of observation. Penoxsulam+ cyhalofop butyl at all doses showed better control of *Isachne miliaceae* than penoxsulam and bispyribac sodium applied alone. Contrary to the control of BLW and sedges, the lower dose (125 g a. i./ha) of penoxsulam+cyhalofop butyl showed the better control of grassy weeds at all the stages of crop growth. This was followed by its higher concentrations (130 and 135 g a. i./ha). Compared to bispyribac sodium, penoxsulam showed better control of *I. miliaceae*, the major grassy weed present in the experimental field. Better efficacy of penoxsulam in DSR was also reported by Nath *et al.* (2014), who stated that penoxsulam at 22.5 and 25 g a. i./ha was more effective in reducing the density of weeds than bispyribac sodium at 20 and 25 g a. i./ha.

Effect of Treatments on Total Weed Density

Pooled data of total density of weeds for two seasons were significantly influenced by the treatments (Table 2). As the age of the crop advanced, an increase in density of weeds was observed in weedy check plots; however, after 60 DAS a decline in population was observed. This might be due to the decline in population of annual weeds viz., sedges and BLW, the predominant weed flora in the experimental area as evident from Table 1. All the four tested doses of combination herbicide were found to be better in reducing the total density of weeds at all the stages of observation compared to hand weeding twice and bispyribac sodium applied alone. At 30 DAS, penoxsulam+ cyhalofop butyl applied at125 g. a. i./ha recorded the lowest total weed density which was found to be on a par with its higher dose of 135 g a. i./ha. The lowest density of weeds observed in these treatments might be due to the better control of sedges, BLW and grassy weeds (Table 1). Penoxsulam applied alone was

Table 2. Effect of weed control treatments on total density of weeds at different growth stages of direct seeded rice (Pooled data of **kharif** and **rabi,** 2014)

Treatment	Total density of weeds (No./m^2)		
	30 DAS	45 DAS	60 DAS
Penoxsulam+cyhalofop butyl 120 g a. i./ha	20.07 (402.30)	19.73 (388.77)	22.35 (499.02)
Penoxsulam+cyhalofop butyl 125 g a. i./ha	12.62 (158.76)	16.08 (258.07)	17.86 (318.48)
Penoxsulam+cyhalofop butyl 130 g a. i./ha	17.12 (292.59)	17.77 (315.27)	17.14 (293.28)
Penoxsulam+cyhalofop butyl 135 g a. i./ha	13.39 (178.79)	13.59 (184.19)	11.72 (137.86)
Bispyribac sodium 25 g a. i./ha	29.47 (867.98)	28.08 (787.99)	36.64 (1341.99)
Penoxsulam 22.5 g a. i./ha	19.41 (376.25)	22.70 (514.79)	24.31 (590.04)
Hand weeding twice at 20 and 40 DAS	30.26 (915.17)	20.58 (423.04)	27.01 (729.04)
Weedy check	53.39 (2849.99)	65.18 (4247.93)	57.23 (3274.77)
C. D. (P=0.05)	2.62	2.94	2.55

Values in parentheses are transformed values.

found to be statistically on par with penoxsulam+cyhalofop butyl at 130 and 120 g a. i./ha. Compared to herbicide treatments, hand weeding was found to be less effective in reducing the density of weeds at 30 DAS. Singh (2008) observed that manual weeding was less effective on some occasions because of escape or regenerations of weeds having many flushes and impractical during adverse weather conditions. At 45 DAS, higher dose of combination herbicide i. e. 135 g a. i./ha recorded the lowest density of weeds which was statistically on a par with its lower doses (130 and 125 g a. i./ha). It was also observed that penoxsulam+cyhalofop butyl applied at 130 g a. i./ha was statistically on a par with its lower dose of 120 g a.i./ha, penoxsulam applied alone and hand weeding. Total density of weeds at 60 DAS indicated that penoxsulam+cyhalofop butyl applied at 135 g a. i./ha was statistically superior in reducing the density of weeds compared to other treatments. This was followed by penoxsulam+cyhalofop butyl at 130 and 125 g a. i./ha and both these treatments were statistically on par. The lower dose of combination herbicide (120 g a. i./ha) was statistically on a par with penoxsulam applied alone. The result is in conformity with the findings of Rahman *et al.* (2012), who opined that proprietary mixture or tank mixture of herbicides with different modes of action appeared to be more effective in widening the weed control spectrum and efficacy. Among the weed control treatments, bispyribac sodium applied at 25 g a. i./ha was found to be least effective in reducing the total density of weeds at 45 and 60 DAS; this might be due to its low efficacy in controlling the density of sedges particularly *Schoenoplectus juncoides* (Table 1). Total density of weeds observed in weedy check (2806.38, 4247.93 and 3274.77) at 30, 45 and 60 DAS, respectively, implied the severity of biological constraint offered by the weeds in DSR and the importance of weed control.

Weed Dry Weight and Weed Control Efficiency

Total dry weight of weeds was significantly influenced by the weed control treatments (Table 3). Weedy check recorded the highest dry weight of weeds at all the three stages of crop growth indicating the severe competition exerted by the weeds for space,

Table 3. Effect of weed control treatments on total weed dry weight and weed control efficiency at different stages of crop growth in direct seeded puddled rice (Pooled data of **kharif** and **rabi** 2014)

Treatment	Total weed dry weight (g/m^2)			Weed control efficiency (%)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
Penoxsulam+cyhalofop butyl 120 g a. i./ha	3.08 (8.98)	3.64 (12.75)	4.32 (18.16)	83.51	95.89	96.61
Penoxsulam+cyhalofop butyl 125 g a. i./ha	2.39 (5.21)	2.89 (7.85)	3.76 (13.64)	90.43	97.47	97.44
Penoxsulam+cyhalofop butyl 130 g a. i./ha	2.86 (7.68)	3.22 (9.86)	3.54 (12.03)	85.90	96.82	97.74
Penoxsulam+cyhalofop butyl 135 g a. i./ha	2.40 (5.26)	2.79 (7.28)	3.09 (9.05)	90.34	97.65	98.31
Bispyribac sodium 25 g a. i./ha	3.23 (9.93)	5.76 (32.68)	7.01 (48.64)	81.77	89.46	90.89
Penoxsulam 22.5 g a. i./ha	2.64 (6.52)	3.85 (14.32)	4.95 (24.00)	88.03	95.38	95.51
Hand weeding twice at 20 and 40 DAS	4.23 (17.39)	4.39 (18.77)	5.75 (32.56)	68.07	93.94	93.91
Weedy check	7.38 (54.46)	17.72 (309.96)	23.13 (534.50)	-	-	-
C. D. (P=0.05)	0.48	0.57	0.82	0.48	0.57	0.82

Values in parentheses are transformed values.

nutrients and light. As the crop advanced its age, considerable increase in dry weight of the weeds was observed in all the treatments. The maximum dry weight of weeds was observed at 60 DAS.

At 30 DAS, the lowest dry weight of weeds was observed in penoxsulam+cyhalofop butyl at 125 g a. i./ha which was on a par with 135 and 130 g a. i./ha and penoxsulam applied alone. It was also observed that penoxsulam was found to be on a par with the lower dose of penoxsulam+cyhalofop butyl (120 g a. i./ha). At 45 and 60 DAS, penoxsulam+cyhalofop butyl at 135 g a. i./ha recorded the lowest dry weight, which was statistically on a par with its lower dose of 125 and 130 g a. i./ha. Similar to 30 DAS, at 45 and 60 DAS penoxsulam applied alone was statistically on a par with the lower dose of penoxsulam+cyhalofop butyl (120 g a. i./ha) in reducing the dry weight of weeds. Juraimi *et al.* (2010) reported that tank mixtures of two or more herbicides provided a broader spectrum of control of weeds compared with their single application. During all the stages of growth where observations were taken, bispyribac sodium was found to less effective in reducing the dry weight compared to hand weeding. This was due to the fact that bispyribac sodium failed to control *S. juncoides* as evident from the data on density of sedges (Table 1). Response of weed flora differed with herbicides because different herbicides worked based on their site specific mode of action (Rahman *et al.*, 2012).

The WCE based on the weed dry weight at different stages of crop growth varied significantly among the weed control treatments (Table 3). At 30 DAS corresponding to 15 DAHA, all the tested herbicides showed higher WCE compared to hand weeding. Penoxsulam+cyhalofop butyl applied at 125 g a. i./ha recorded higher WCE which was closely followed by its higher dose of 135 g a. i./ha and at 45 DAS higher dose (135 g a. i./ha) recorded higher WCE which was closely followed by its lower doses (125, 130 and 120 g a. i./ha). At 60 DAS, higher dose (135 g a. i./ ha) showed higher WCE followed by 130, 125 and 120 g a. i./ha). Pre-mix herbicide mixture at all tested doses showed higher WCE than penoxsulam applied alone at 45 and 60 DAS which may be attributed to the better broad spectrum control of weeds and the efficacy of the combinations in reducing the dry weight of weeds (Tables 2 and 3). Cyhalofop butyl provides post-emergence control of grassy weeds by inhibiting acetyl coenzyme-A carboxylase (ACCase) which is responsible for the biosynthesis of fatty acids, results in the loss of lipids and causes the death of dividing cells at the growing point of the grass. On the other hand, penoxsulam provides broad spectrum control by inhibiting the acetolactate synthase (ALS) enzyme in susceptible species (Rahman *et al.*, 2012). Combination of these two herbicides with different mode of action leads to better weed control efficiency. Among the herbicides, the lowest weed control efficiency was observed in bispyribac sodium sprayed plots. Similar results were also observed by Raj *et al.* (2013) who observed that since the weed flora was dominated by sedges and BLW, penoxsulam recorded higher WCE than bispyribac sodium and when the weed flora was dominated by grassy weeds particularly *Echinochloa*, bispyribac sodium recorded higher WCE than penoxsulam. The result further confirms the fact that the efficiency of the herbicide depends on the composition of weed flora and their abundance.

Growth and Yield Attributes

Plant height was significantly influenced by the treatments (Table 4). Rao (2000) reported that for every unit of weed growth, there would be one unit less of crop growth. In general, all the weed control treatments produced taller plants compared to weedy check. The superiority of weed control treatments might be due to comparatively low competition from weeds. The maximum plant height (96.40 cm) was observed in penoxsulam+cyhalofop butyl applied at 135 g a. i./ha and plants with minimum height (88.63 cm) in weedy check. The severe competition from the weeds might have led to the poor growth of rice plants in weedy check.

Tillering capacity is the index of plant's ability to make use of space and nutrition and reflects on the yield. Treatments had significant influence on the production of tillers also (Table 4). The maximum number of tillers per square metre was observed in hand weeding treatment which was statistically on a par with penoxsulam+cyhalofop butyl at 130 and 135 g a. i./ha and penoxsulam at 22.5 g a. i./ha. More number of tillers observed in these treatments might be due to the better growth of plants resulting from the reduced crop-weed competition at critical stages of crop growth and increased availability of space, light and nutrients and their utilization. Among the herbicidal treatments, bispyribac sodium applied plots recorded the lowest plant height which might be due to phytotoxic physiological effects as reported by Beegum *et al.* (2008).

Panicles/m^2 were also significantly influenced by the weed control treatments (Table 3). The highest number of panicles/m^2 was registered in penoxsulam applied at 22.5 g a. i./ha which was statistically on a par with penoxsulam+cyhalofop butyl at 130, 135 and 125 g a. i./ha and hand weeding twice. As compared to weedy check, the percentage increase in panicles/m^2 in penoxsulam+ cyhalofop butyl at 130 and 135 g a. i./ha, penoxsulam at 22.5 g a. i./ha and hand weeding were in the order of 57.01, 55.84, 58.41 and 53.50, respectively. Being the varietal character, 1000-grain weight was not influenced by the treatments. While filled grains/panicle were significantly influenced by the treatments. The maximum number of filled grains/panicle was recorded in penoxsulam +cyhalofop butyl at 135 g a. i./ha which was statistically on a par with its lower dose (130 g a. i./ha). Comparatively low competition from weeds in these treatments might have allowed the crop to express its full genetic potential. Among the herbicides tested, bispyribac sodium recorded the lowest number of grains/panicle, but it was on a par with penoxsulam+cyhalofop butyl applied at 120 g a. i./ha. The plausible reason for the production of less number of panicles and grains/panicle might be due to the competition from the sedges (Tables 1 and 3) causing considerable reduction in the expression of growth and yield attributes.

Yield and Economics

Weed control treatments significantly influenced the grain yield of direct seeded rice (Table 5). Adoption of weed control measures enhanced the grain yield from 4.26 to 8.46 t/ ha. The percentage increase in grain yield ranged from 42.82 to 49.64, respectively, over weedy check (Table 5). Penoxsulam+cyhalofop butyl applied at 135 g a. i./ha recorded the highest grain yield (8.46 t/ha) which was on a par with its lower dose of 130 g a. i./ha. Increased grain yield observed in these treatments may be attributed to the better control of weeds (Tables 2 and 3) and marked improvement in growth and yield attributes (Table 4). The straw yield was not significantly influenced by the treatments. Penoxsulam+ cyhalofop butyl at 120 g a. i./ha and bispyribac sodium at 25 g a. i./ha recorded higher straw yield compared to other herbicide treatments, this might be the reason for low harvest index in these treatments. The high cost of cultivation and low B : C ratio recorded in hand weeding twice treatment might be due to more labour requirement involved in hand weeding. The gross returns and B : C ratio were found to be more in penoxsulam+cyhalofop butyl applied at 135 and 130 g a. i./ha because of higher grain yield registered in these treatments. Penoxsulam+cyhalofop butyl applied at 120 g a. i./ha and bispyribac sodium registered

Table 4. Effect of weed control treatments on the growth and yield attributes of direct seeded rice (Pooled data of **kharif** and **rabi,** 2014)

Treatment	Plant height (cm)	Tillers/m^2	Panicles/m^2	Filled grains/ panicle	1000-grain weight (g)
Penoxsulam+cyhalofop butyl 120 g a. i./ha	94.93	671	628	83.22	30.95
Penoxsulam+cyhalofop butyl 125 g a. i./ha	93.55	688	658	85.95	31.18
Penoxsulam+cyhalofop butyl 130 g a. i./ha	93.97	713	672	92.47	31.32
Penoxsulam+cyhalofop butyl 135 g a. i./ha	96.40	712	667	93.37	31.35
Bispyribac sodium 25 g a. i./ha	94.23	652	608	78.23	30.23
Penoxsulam 22.5 g a. i./ha	95.98	714	678	84.87	30.90
Hand weeding twice at 20 and 40 DAS	92.73	723	657	80.20	30.82
Weedy check	88.63	510	428	55.47	30.05
C. D. (P=0.05)	1.69	26	32	6.66	NS

NS : Not Significant.

comparatively lower net returns and B : C ratio. The reason was due to the production of comparatively less yield over other herbicide treatments. Weedy check registered the lowest gross returns and B: C ratio. This was due to higher weed competition and lower availability of nutrients to the crop which resulted in lower grain and straw yield. The result is in agreement with the findings of Jacob *et al.* (2014).

Table 5. Effect of weed control treatments on yield, harvest index and economics in direct seeded rice (Pooled data of **kharif** and **rabi** 2014)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	B : C ratio
Penoxsulam+cyhalofop butyl 120 g a. i./ha	7.86	7.37	0.52	65400	148797	2.28
Penoxsulam+cyhalofop butyl 125 g a. i./ha	8.25	7.05	0.54	65525	155461	2.37
Penoxsulam+cyhalofop butyl 130 g a. i./ha	8.42	7.11	0.54	65655	158684	2.42
Penoxsulam+cyhalofop butyl 135 g a. i./ha	8.46	7.19	0.54	65775	159519	2.43
Bispyribac sodium 25 g a. i./ha	7.45	7.25	0.51	64338	141382	2.20
Penoxsulam 22.5 g a. i./ha	7.82	7.14	0.52	64581	147931	2.30
Hand weeding twice at 20 and 40 DAS	7.93	6.87	0.54	68900	149698	2.17
Weedy check	4.26	6.76	0.39	61400	83492	1.38
C. D. (P=0.05)	0.26	NS	-	-	-	-

NS : Not Significant.

CONCLUSION

Based on the two seasons' study results, it can be concluded that herbicidal treatments were more profitable than hand weeding. Post-emergence application of pre-mix herbicide mixture penoxsulam+cyhalofop butyl on 15 DAS at 135 and 130 g a. i./ha provided better control of sedges, BLW and grasses and resulted in increased grain yield, gross returns and B : C ratio. Hence, as an alternative to manual weeding and to overcome the problem of herbicide resistance, penoxsulam+cyhalofop butyl 6% OD at 130 and 135 g a. i./ha can be recommended for broad spectrum weed control in direct seeded puddled rice.

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