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Herbicide mixtures effect on weed seed bank in direct-seeded rice

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ABSTRACT

To study the effect of post-emergence applied herbicide mixtures, *viz*. bispyribac-sodium + metamifop and penoxsulam + cyhalofop-butyl on soil weed seed bank, weed seed bank assay were carried out at College of Agriculture Vellayani, Thiruvananthapuram during rainy season 2014 and winter season 2014-15. Weed seed bank assay results revealed a significant reduction in the emergence of sedges, broad-leaved weeds (BLW) and grasses from the soil treated with herbicide mixtures compared to individual application of bispyribac-sodium at 25 g/ha and penoxsulam at 22.5 g/ha. The results also revealed that penoxsulam + cyhalofop-butyl was more effective in reducing the weed seed bank than bispyribac sodium + metamifop. The higher doses of penoxsulam + cyhalofop-butyl (135, 130 and 125 g/ha) were found to be more effective than its lower dose of 120 g/ha. Among the tested doses of bipyribac-sodium + metamifop, its higher doses (90 and 80 g/ha) performed better than lower doses (60 and 70 g/ha) in reducing the soil weed seed bank. Hence, post-emergence application of penoxsulam + cyhalofop-butyl either at 125 or 130 or 135 g/ha or bispyribac-sodium + metamifop at 80 or 90 g/ha at 15 DAS (days after sowing) can be recommended for the effective management of weed seed bank in wet direct-seeded rice.

INTRODUCTION

Weed seed bank is the reserve of viable weed seeds present in the soil surface and scattered in the soil profile. Weed seed bank is the main reason for the continued presence of weeds in the agricultural field (Cousens and Mortimer 1995) and it is an indicator of weed population in soil (Dhawan 2007). Annual fluctuations of climatic factors significantly influence the weed seed bank (Harbuck *et al.* 2009). Steinmann and Klingebiel (2004) opined that weed seed bank has impact on the distribution of annual and perennial weeds over the years and it affects the spread of weed community. Weed seed characteristics such as high output, efficient dispersal, longevity and seed dormancy, produce large seed banks in the soil (Pereira *et al.* 2013). Understanding the dynamics of soil seed bank can help in the development of integrated weed management programmes and also help to predict the degree to which the crop-weed competition affects the crop yield and quality (Menalled 2008). Accurate forecast of potential weed seedling density would allow the farmers to implement control measures more effectively thus avoiding inappropriate and over use of herbicides (Mobli and Hassannejad 2013).

Weed seed bank can be manipulated by altering seedling recruitment, seedling mortality, seed viability and fecundity. Manual weeding and herbicidal use reduce the weed population by increasing seedling mortality (Pandey and Pingali1996). Barberi *et al.* (1998) reported that herbicides reduced the weed density and number of weed seeds entering the seed bank. Buhler *et al.* (2001) pointed out that when weeds were controlled by cultivation only, the seed bank was approximately 25 times greater than where herbicides in conjunction with cultivation practices were adopted for weed control. Jain *et al.* (2006) reported that continuous use of clodinafop *fb* 2,4-D and isoproturon + 2,4-D for control of weeds in wheat field significantly reduced the number of weed seeds in the seed bank over weedy check. Walia and Brar (2006) also reported that herbicide treatments significantly reduced the seed bank of *Phalaris minor* in wheat field. According to Islam (2012), herbicide application influenced the seed number and species composition of the seed bank.

The main objective of any weed management programme should be to deplete the weed seed bank and enable the rice crop to be competitive either by delaying the weed emergence or suppressing the weed emergence and growth. With this background the present study was formulated to find out the effect of herbicide mixtures, *viz*. bispyribac-sodium + metamifop and penoxsulam + cyhalofop-butyl on soil weed seed bank.

MATERIALS AND METHODS

Field experiments were conducted during the first (rainy season 2014) and second (winter 2014-15) crop seasons at Upaniyoor padashekaram, in Kalliyoor Panchayat, Nemom block, Thiruvananthapuram district, Kerala, India. The experimental site was situated at 8° 26.762' N latitude and 77° 0.136' E longitude and 29 m above mean sea level (MSL) with humid tropical climate. The soil was sandy clay loam, acidic in reaction, high in organic carbon and medium in N, P and K status. The average annual rainfall received during the period of experimentation was 875.5 mm during first crop season and 203.4 mm during second crop season. The mean maximum and minimum temperature recorded during first and second crop seasons were 30.1 ºC and 24.4 ºC and 30.8 ºC and 22.6 ºC, respectively.

For the first and second crop, the field was ploughed thrice with a power tiller and uniformly levelled. The experiment was laid out in a randomized block design with twelve treatments and three replications. Raised bunds of 20 cm height and channels of 30 cm width were taken around each plot and 60 cm wide channels were taken along the length of each block between the replications. The treatments were bispyribac-sodium + metamifop at 60 g/ha, bispyribac-sodium + metamifop at 70 g/ha, bispyribac-sodium + metamifop at 80 g/ha, bispyribac-sodium + metamifop at 90 g/ha, penoxsulam + cyhalofop-butyl at 120 g/ha, penoxsulam + cyhalofop-butyl at 125 g/ha, penoxsulam + cyhalofop-butyl at 130 g/ha, penoxsulam + cyhalofop-butyl at 135 g/ha, bispyribac-sodium applied alone 25 g/ha, penoxsulam applied alone 22.5 g/ha, hand weeding twice and weedy check. The herbicides were applied at 15 DAS using knapsack sprayer fitted with flat-fan nozzle. The spray fluid used for the study was 500 L/ha. The rice variety '*Kanchana*', a short duration variety released from Regional Agricultural Research Station, Pattambi, Kerala Agricultural University was used under the study. The crop was fertilized with 70:35:35 kg/ha N, P and K, with one third N and K and half P applied on 15 DAS (days after sowing), one third N and K and half P on 35th day and remaining one third N and K on 55th day of sowing.

Weed seed bank in the soil was estimated before and after the first and second crop by the seedling emergence method suggested by Luschei (2003) in a completely randomized block design with twelve treatments in with three replications. Weed seed bank assay was conducted under net house condition at College of Agriculture Vellayani.

Composite soil samples were collected from each plot before the crop and after the harvest of first and second crop using a soil auger at a depth of 15 cm. From the composite samples one kg soil was weighed accurately and transferred and spread evenly in plastic trays under net house condition. The soil was kept at adequate moisture level. The emerging weeds were counted up to 70 days at fortnightly interval and categorized into sedges, broad-leaved weeds and grasses. The data generated were statistically analyzed using analysis of variance technique (ANOVA) and difference between the treatments means were compared at 5% probability level.

RESULTS AND DISCUSSION

Weed flora composition

Weed seed bank assay results revealed that three major groups of weeds, *viz*. sedges, broad-leaved weeds (BLW) and grasses were present in the experimental field. Among the three, BLW were the predominant weed flora followed by sedges and grasses (**Table 1** and **2**).

Effect of herbicides mixtures on the emergence of sedges

Weed seed bank assay carried out before the first and second crop season revealed that there was no significant difference among the treatments in the number of sedges emerged from the soil.

Weed control treatments registered a significant reduction in the emergence of sedges from the soil seed bank after the first and second crop season (**Table 1** and **2**). Among the herbicide mixtures, penoxsulam + cyhalofop-butyl was found to be better than bispyribac-sodium + metamifop in reducing the weed seed bank of sedges. In both the experiments, penoxsulam + cyhalofop-butyl 135 g/ha recorded the lowest count of sedges emerged from the soil.Weed seed bank observations indicated that, compared to weedy check, population of sedges was reduced by 60.40 and 88.70%, respectively after the first and second crop season; however, compared to hand weeding, the percentage reduction was 45.44 and 67.60%, respectively. Compared to penoxsulam applied alone at 22.5 g/ha, the percentage reduction in the count of sedges by the application of penoxsulam + cyhalofop-butyl at 135 g/ha was 34.44 and 63.24, respectively and compared to bispyribac-sodium applied alone at 25 g/ha the percentage reduction was 36.46 and 70.94, respectively after the first and second crop seasons. Raj and Syriac (2015) reported that post-emergence application of penoxsulam + cyhalofop-butyl 135 g/ha significantly reduced the density of sedges. This might be the plausible reason for the reduction in the weed seed bank of sedges in this treatment. Singh *et al.* (2012) reported that the main source of weed seeds in the seed bank is the local matured weeds that set seed.

Effect of herbicides mixtures on the emergence of broad-leaved weeds

Weed seed bank assay carried out before the first and second crop season revealed that there was no significant difference among the treatments in the number of BLW emerged from the soil (**Table 1** and **2**).

As compared to weedy check there was significant reduction in the emergence of BLW from the soil seed bank in all the herbicide treatments and hand weeding treatment. Penoxsulam + cyhalofop-butyl 135 g/ha recorded the lowest population of BLW after the first crop season. However, penoxsulam + cyhalofop-butyl 125 g/ha recorded the lowest population after the second crop season and was on par with its higher dose of 135 g/ha. (**Table 2**). Both these treatments were statistically on par with bispyribac-sodium + metamifop 80 and 90 g/ha. It has been observed that, as compared to hand weeding, the treatments bispyribac-sodium + metamifop 80 and 90 g/ha reduced the emergence of BLW by 42.25 and 39.05% and 72.80 and 86.22%, respectively after the first and second crop seasons. Compared to penoxsulam applied alone at 22.5 g/ha, bispyribac-sodium + metamifop 80 and 90 g/ha recorded a reduction in the emergence of BLW by 30.82 and 26.98 and 13.23 and 56.03%, respectively. Compared to bispyribac-sodium applied alone at 22.5 g/ha, these treatments reduced the emergence of BLW by 29.53 and 25.62% and 68.61 and 38.06%, respectively after first and second crop seasons.

As compared to hand weeding, penoxsualm + cyhalofop-butyl 125 and 135 g/ha reduced the emergence of BLW by 23.40 and 48.36% and 91.87 and 85.0%, respectively after the first and second crop season. Compared to penoxsulam 22.5 g/ha, the percentage reduction of BLW was 8.23 and 38.13 and 74.04 and 52.14, respectively and compared to bispyribac-sodium 25 g/ha the percentage reduction was 6.52 and 36.98 and 81.47 and 65.83, respectively. Higher population of BLW in the weedy check might have enhanced the seed rain from mature weeds, as the weeds were not controlled and allowed to grow throughout the season. Roberts (1982) reported that weedy field may contain large amount of viable weed seeds; similarly, Sheibani and Ghadiri (2012) reported that weedy plots had the highest number of weed seeds in 0-15 cm depth.

Effect of herbicide mixtures on the emergence of grasses

Similar to sedges and BLW, a significant reduction in the emergence of grasses was also observed in the herbicide treated pots and hand weeding treatment as compared to weedy check (**Table 1** and **2**). Weed seed bank assay carried out after the first and second crop season indicated that penoxsulam + cyhalofop-butyl 125 g/ha recorded the lowest emergence of grasses among the treatments. After the first and second crop seasons, penoxsulam + cyhalofop-butyl 125 g/ha reduced the grass

Table 1. Emergence of broad leaf weeds, grasses and sedges (no./kg soil in 70 days) as influenced by weed management treatments before and after the first crop

Treatment	BLW		Grasses		Sedges	
	Before the first crop	After the first crop	Before the first crop	After the first crop	Before the first crop	After the first crop
Bispyripac-sodium + metamifop 60 g/ha	237.0(15.0)	215.3(14.7)	19.3(4.32)	15.3(3.97)	107.0(10.3)	68.3(8.28)
Bispyripac-sodium + metamifop 70 g/ha	315.3(17.6)	195.0(14.0)	14.0(3.78)	9.7(3.15)	177.3(13.3)	73.7(8.58)
Bispyripac-sodium + metamifop 80 g/ha	246.0(15.7)	151.3(12.3)	25.3(5.05)	18.0(4.22)	145.0(12.0)	63.7(7.99)
Bispyripac-sodium + metamifop 90 g/ha	257.7(16.0)	159.7(12.6)	30.7(5.54)	13.3(3.64)	160.0(12.6)	51.3(7.18)
Penoxsulam + cyhalofop-butyl 120 g/ha	190.0(13.7)	215.0(14.7)	18.0(4.14)	12.0(3.45)	93.0(9.6)	45.3(6.76)
Penoxsulam + cyhalofop-butyl 125 g/ha	301.0(17.3)	200.7(14.2)	13.3(3.70)	4.3(2.11)	180.7(13.4)	57.3(7.60)
Penoxsulam + cyhalofop-butyl 130 g/ha	310.0(17.6)	199.0(14.1)	22.0(4.65)	9.3(3.08)	160.0(12.6)	52.7(7.28)
Penoxsulam + cyhalofop-butyl 135 g/ha	229.7(14.8)	135.3(11.6)	28.7(5.36)	9.7(3.18)	175.7(13.1)	41.3(6.46)
Bispyribac-sodium 25 g/ha	236.3(17.2)	214.7(14.7)	16.7(4.14)	20.3(4.54)	146.7(12.0)	65.0(8.09)
Penoxsulam 22.5 g/ha	255.3(15.9)	218.7(14.7)	9.7(3.16)	12.0(3.53)	151.7(12.2)	63.0(7.92)
Hand weeding twice at 20 and 40 DAS	294.7(17.2)	262.0(16.2)	15.7(4.02)	9.7(3.19)	169.3(13.0)	75.7(8.69)
Weedy check	320.0(17.9)	314.0(17.8)	22.0(4.63)	33.0(5.69)	159.7(12.6)	104.3(10.23)
LSD (p=0.05)	NS	1.279	NS	1.250	NS	1.188

Values in parentheses are transformed values $\sqrt{x+0.5}$, NS- non-significant

Table 2. Emergence of broad leaf weeds, grasses and sedges (no./kg soil in 70 days) as influenced by weed management treatments before and after the second crop

Treatment	BLW		Grasses		Sedges	
	Before the second crop	After the second crop	Before the second crop	After the second crop	Before the second crop	After the second crop
Bispyripac-sodium+ metamifop 60 g/ha	231.0(14.8)	48.0(6.94)	22.3(4.54)	13.0(3.54)	73.3(8.58)	29.0(5.29)
Bispyripac-sodium+ metamifop 70 g/ha	254.3(15.9)	42.7(6.18)	27.7(5.28)	10.0(3.22)	117.3(10.8)	20.3(4.49)
Bispyripac-sodium + metamifop 80 g/ha	181.0(13.4)	22.3(3.43)	22.7(4.73)	13.3(3.70)	82.0(8.91)	17.0(4.02)
Bispyripac-sodium + metamifop 90 g/ha	191.7(13.5)	27.3(4.65)	28.3(5.35)	17.0(4.13)	71.3(8.25)	17 .0(4.12)
Penoxsulam + cyhalofop-butyl 120 g/ha	210.3(14.4)	27.3(4.65)	15.3(3.80)	12.0(3.10)	63.7(7.97)	11.3(3.42)
Penoxsulam + cyhalofop-butyl 125 g/ha	349.7(18.6)	6.67(2.62)	8.7(2.88)	5.0(2.23)	101.3(10.1)	14.0(3.80)
Penoxsulam + cyhalofop -butyl 130 g/ha	327.0(18.0)	21.0(4.54)	12.7(3.56)	10.3(3.2)	92.7(9.62)	14.3(3.84)
Penoxsulam + cyhalofop-butyl 135 g/ha	267.0(15.9)	12.3(2.75)	19.3(4.44)	14.7(3.85)	86.7(9.24)	9.3(3.09)
Bispyribac-sodium 25 g/ha	305.3(17.5)	36.0(6.02)	29.3(5.30)	32.3(5.72)	69.3(8.33)	32.0(5.68)
Penoxsulam 22.5 g/ha	294.7(17.2)	25.7(5.11)	10.0(3.20)	17.3(4.21)	86.3(9.24)	25.3(4.84)
Hand weeding twice at 20 and 40 DAS	353.7(18.7)	82.0(9.07)	14.3(3.83)	14.7(3.88)	81.0(8.97)	28.7(5.31)
Weedy check	295.7(17.1)	136.0(11.6)	19.7(4.39)	52.0(7.25)	91.0(9.55)	82.3(9.09)
LSD (p=0.05)	NS	2.907	NS	1.616	NS	1.710

Values in parentheses are transformed values $\sqrt{x+0.5}$, NS- non-significant

population by 55.67 and 65.99%, respectively as compared to hand weeding. While compared to bispyribac-sodium applied alone at 25 g/ha, the percentage reduction in the grass population was 78.82 and 84.52, respectively and compared to penoxsulam applied alone at 22.5 g/ha, the percentage reduction was 64.17 and 71.10, respectively. Sheibani and Ghadiri (2012) opined that herbicide application indirectly affects the weed seed bank by reducing the number of seed producing plants.

Effect on total weed population

Data on the total weed population after the first and second crop season revealed that non-herbicide treatments, *viz*. weedy check and hand weeding recorded the highest emergence of weeds and were significantly inferior in reducing the size of the weed seed bank. Buhler *et al.* (2001) pointed out that when weeds were controlled by cultivation only, the seed bank was approximately 25 times greater than where herbicides in conjunction with cultivation practices were adopted for weed control. Many researchers have the opinion that absence of herbicides has resulted in increased weed seed bank (Hyvonen and Salonen 2002). Among the treatments, penoxsulam + cyhalofop-butyl 135 g/ha recorded the lowest weed seed bank after the first crop season. Compared to weedy check, the percentage reduction was 58.69 and compared to hand weeding, the percentage reduction was 46.36. Compared to individual application of penoxsulam 22.5 g/ha and bispyribac-sodium 25 g/ha, the percentage reduction was 36.57 and 37.90, respectively (**Table 3**).

Weed seed bank assay after the second crop season revealed that penoxsulam + cyhalofop- butyl 125 g/ha recorded the lowest weed population and was at par with its higher doses of 135 and 130 g/ha. These treatments reduced the weed seed bank by 94.41, 90.28 and 89.43%, respectively. The reduction in the emergence of weeds in treatments penoxsulam + cyhalofop-butyl 125 and 135 g/ha as compared to hand weeding were 79.48 and 71.03%, respectively. Compared to bispyribac-sodium 25 g/ha the percentage reduction was 74.38 and 63.81%, respectively and compared to penoxsulam 22.5 g/ha, the reduction was 62.37 and 46.85%, respectively. Voll *et al*. (1996) reported that application of herbicides can lead to exhaustion of the weed seed bank and similarly Carmona (1992) observed that application of certain chemicals contributed to an accelerated decay rate of seeds in the soil. Among the different doses of bispyribac-sodium + metamifop tested, its highest dose (90 g/ha) was better than other three doses in reducing the weed seed bank. This was mainly because of the better efficacy in controlling the sedges, BLW and grasses, the major group of weeds present in the soil as reported by Raj and Syriac (2016). Schweizer and Zimdahl (1984) reported that the number of weed seeds in continuous corn dropped by approximately 70% after three years of herbicide application and inter row cultivation. Several researchers (Walia and Brar 2006, Konstantinovic and Blagojevic 2014) have reported that herbicide use reduced the weed seed bank considerably.

It can be concluded that the application of herbicide mixtures, *viz*. penoxsulam + cyhalofop-butyl and bispyribac-sodium + metamifop were more effective in depleting the weed seed bank, than the individual application of bispyribac-sodium and penoxsulam. The results also revealed that penoxsulam + cyhalofop-butyl was better than bispyribac-sodium + metamifop in depleting the weed seed bank in direct-seeded rice.

Table 3. Effect of herbicide mixtures on the emergence of total number of weeds (no./kg soil in 70 days) from the soil seed bank during the first and second crop season

Treatment	Total no. of weeds		Total no. of weeds	
	Before the first crop	After the first crop	Before the second crop	After the second crop
Bispyripac-sodium + metamifop 60 g/ha	363.7(18.92)	299.0(17.30)	326.7(17.98)	91.3 (9.57)
Bispyripac-sodium + metamifop 70 g/ha	506.7(22.35)	278.3(16.70)	399.3(19.96)	73.0(8.38)
Bispyripac-sodium + metamifop 80 g/ha	416.3(20.40)	233.0(15.28)	285.7(16.86)	52.7(7.22)
Bispyripac-sodium + metamifop 90 g/ha	448.3(21.18)	224.3(14.99)	291.3(16.68)	45.3(6.76)
Penoxsulam + cyhalofop butyl 120 g/ha	301.0(17.31)	272.3(16.52)	289.3(16.94)	50.7(6.70)
Penoxsulam + cyhalofop-butyl 125 g/ha	495.0(22.22)	262.3(16.21)	459.7(21.40)	25.7(5.10)
Penoxsulam + cyhalofop-butyl 130 g/ha	492.0(22.17)	261.0(16.17)	432.3(20.73)	45.7(6.72)
Penoxsulam + cyhalofop-butyl 135 g/ha	434.0(20.57)	186.3(13.67)	373.3(18.94)	36.3(5.82)
Bispyribac-sodium 25 g/ha	399.7(19.74)	300.0(17.33)	404.0(20.10)	100.3(10.3)
Penoxsulam 22.5 g/ha	416.7(20.35)	293.7(17.13)	391.0(19.78)	68.3(8.21)
Hand weeding twice at 20 and 40 DAS	479.7(21.91)	347.3(18.63)	449.0(21.06)	125.3(11.18)
Weedy check	501.7(22.40)	451.0(21.26)	406.3(20.11)	270.3(16.44)
LSD (p=0.05)	NS	1.133	NS	2.507

Values in parentheses are transformed values $\sqrt{x+0.5}$, NS- non-significant

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