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Herbicide weed management effect on weed dynamics, crop growth and yield in direct-seeded rice

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ABSTRACT

Effect of herbicide combinations were evaluated in Raipur (Chhattisgarh) on crop growth, weed suppression and rice yield in direct-seeded rice (DSR) system during 2014 and 2015. Results revealed that combination of pyrazosulfuron + pretilachlor provided wide spectrum weed control at 15 + 600 g/ha to 30 + 1200 g/ha (61.6 - 81.5%), which was comparable to two hand weeding at 15 and 30 days after sowing. Weed control efficiency was recorded to the tune of 40.0 - 89.9%, with highest in two hand weeding (84.6 - 89.9%) and lowest in pendimethalin and lowest dose of pyrazosulfuron + pretilachlor in 2014 (40.0%) and pyrazosulfuron alone in 2015 (48.5%). The crop growth parameters (tillers, total dry matter/hill and leaf area index), yield attributes (panicle length, panicle weight, filled grains/panicle) and grain yield were recorded highest in two hand weeding (2.69 t/ha in 2014 and 5.87 t/ha in 2015) followed by pyrazosulfuron + pretilachlor at 15 + 600, 16.88 + 675 and 30 + 1200 g/ha. However, the least rice grain yield was recorded under weedy plot (1.45 t/ha in 2014 and 2.17 t/ha in 2015). The results suggested that pyrazosulfuron + pretilachlor at 15 + 600, 16.88 + 675 and 30 + 1200 g/ha were the best broad spectrum effective herbicide in order to minimize the diverse weed flora in DSR system.

INTRODUCTION

Rice (*Oryza sativa* L.) is predominantly grown by transplanting seedlings, this practice consumes about 150 ha-cm of water and engagement of labour for transplanting and weeding (Mahajan and Chauhan 2016). Manual transplanting is labour cumbersome and scarcity of labour during peak season force to shifting of crop establishment methods from transplanting to direct-seeded rice (DSR) (Choudhary 2017, Choudhary *et al.* 2017). It has several advantages such as requirement of 35-57% less water and 67% less labour over transplanting rice. Apart from these, DSR requires less use of machine, and have lesser methane emissions (Chauhan *et al.* 2012). However, weeds are major biological constraint in DSR, mainly due to absence of impounding of water at crop emergence, hence, production and weed management are crucial for increasing the productivity of rice (Chauhan 2012). The extent of yield reduction of rice due to weeds has been estimated up to 95% in India (Naresh *et al.* 2011), 71-96% in the Philippines (Chauhan and Johnson 2011) and 33-80% in Pakistan (Khaliq *et al.* 2012). Manual weeding is considered to be the best, but due to labour scarcity and escalating wages, the fields left un-weeded at critical growth stages. In this condition, herbicides have been considered to be an alternative to hand weeding in DSR rice (Singh *et al.* 2006).

It is suggested to use pre-emergence herbicides in DSR to prevent the simultaneous emergence of weeds with rice crop and to favour the crop to establish under relatively weed free condition (Baloch *et al.* 2005). Although the application window is narrow for pre-emergence herbicides. However, the efficacy of pre-emergence herbicides can vary from molecule to molecule and the operating environmental condition (Mahajan and Chauhan 2013). Therefore, farmers need chemicals having high efficiency, no phyto-toxicity to rice. Since, area under DSR is rapidly increasing and weeds are the major constraints, generation of data on the effect of herbicide under DSR system is essential. Considering the above fact, the present experiment was done to assess the relative bio-efficacy of pre-mix herbicide molecule pyrazosulfuron + pretilachlor for broad spectrum weed control.

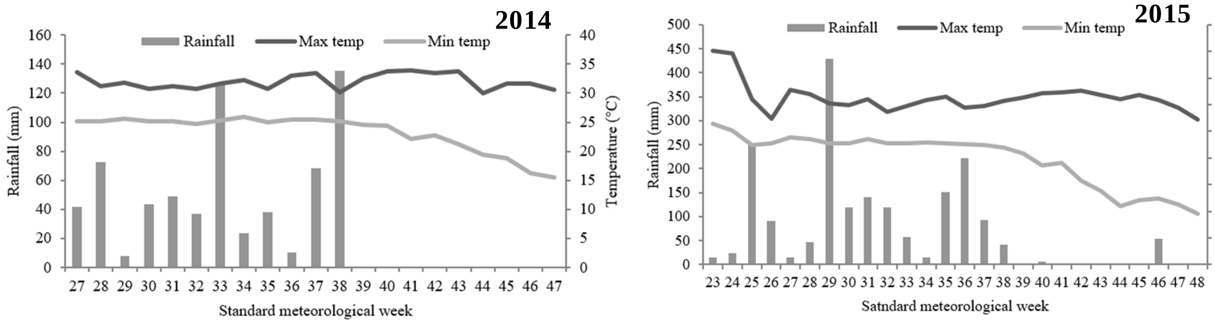

Figure 1. Maximum and minimum temperature, and rainfall during the growing season 2014 and 2015

MATERIALS AND METHODS

Two years field study was conducted during 2014 and 2015 at research farm of the ICAR-National Institute of Biotic Stress Management, Raipur (Chhattisgarh). The study area receives average annual rainfall of 1200-1400 mm, with temperature ranged from 12 °C in December to 45 °C in May (**Figure 1**). The soil of the experimental site was loamy texture with 0.34% organic matter, and pH of 6.8. Available N, P and K content in the soil was 217.3, 15.8 and 323.0 kg/ha, respectively. Rice *cv* '*Swarna*' (145 days duration) seeds of 80 kg/ha were sown with hand in rows at 20 × 10 cm planting geometry during both the years. Crop was subjected to 80:60:40 kg N, P_2O_5 and K_2O/ha, P_2O_5 and K_2O were supplied at basal and N was applied with three splits (50% basal, 25% at tillering, and 25% at panicle initiation). The experiment was laid out in a randomized block design with three replications. The details of the treatments and their scheduling are given in **Table 1**. The required amount of herbicides was sprayed using 375 l/ha of water with knapsack sprayer fitted with a flat fan nozzle.

At sampling time (45 and 75 days after sowing; DAS), a quadrate of 50 × 50 cm was placed at two places in each plot to determine the density and dry weight of different weeds. Weed dry weight was recorded after drying the weed samples at 70 °C for 48 h. Weed control efficiency was calculated based on the data recorded at 45 and 75 DAS in rice as per standard formula.

Plant height (cm), tillers/hill, total dry matter (g/hill^2), and leaf area index were measured at flowering stage of the crop. Panicle/m^2, panicle length (cm), filled grains/panicle, panicle weight (g), chaffy grains/panicle, grain and straw yield (kg/ha), and harvest index was recorded just before harvesting. The grain and straw yield was recorded from 5 m^2 area, and rice grain yield was expressed at 14% moisture content. Data were analysed using the PROC GLM in SAS version 9.2 to evaluate the difference between the treatments. Weed density and dry weight were square root transformed, before analysis. However, for better understanding, original values are given in parenthesis. While the ANOVA indicated significant treatment effects, means were separated at $p<0.05$ and adjusted with Fisher's protected least significant difference (LSD) test.

RESULTS AND DISCUSSION

Weed flora

Weed flora of experimental plots were comprised of broad-leaved weeds (BLW) like *Eclipta alba, Eclipta prostrata, Trianthema portulacastrum, Portulaca oleracea, Commelina communis, Commelina benghalensis, Ludwigia parviflora, Parthenium hysterophorus, Physalis minima, Alternanthera sessilis* and *Ageratum conyzoides;* grasses like *Echinochloa colona, Echinochloa crusgalli, Cynodon dactylon, Leptochloa chinensis, Digitaria sanguinalis, Eleusine indica, Dactyloctenium aegyptium,* and *Eragrostis tenella,* and sedges like *Cyperus iria, Cyperus compressus, Cyperus halapan, Fimbristylis miliacea* and *Fimbristylis dichotoma.*

Weed dynamics at 45 and 75 DAS

The effect of weed control treatment and years has significant ($p<0.05$) effect on BLW, grasses and sedges density (**Table 1**). Among the weeds, the BLW density ranged from 23–207/m^2 in 2014 and 17–147/m^2 in 2015 at 45 DAS and 83–323/m^2 in 2014 and 11–208/m^2 in 2015 at 75 DAS. The highest BLW was recorded in weedy plots, whereas lowest density obtained in two hand weeding at 15 and 30 DAS. Similarly, the densities of grasses and sedges followed the trend of BLW and were recorded 23–71/m^2 and 7–96/m^2, respectively in 2014, and 5-53/m^2 and 12-96/m^2, respectively in 2015 at 45 DAS and it was further increased to 44-117/m^2 and 28-77/m^2, respectively in 2014, and 3-99/m^2 and 8-121/m^2, respectively in 2015 at 75 DAS. The weedy check plots had the highest and two hand weeding at 15 and

30 DAS recorded with lowest weed densities. It was measured that among the ready mix of pyrazosulfuron + pretilachlor at 16.88 + 675 g/ha and its higher doses considerably controlled the BLW and grasses, whereas sedges were suppressed in pyrazosulfuron + pretilachlor at 15 + 500 g/ha onwards during both the years. Pyrazosulfuron at 15 g/ha was reasonably effective in controlling BLW during both the years, but pendimethalin and pretilachlor were less effective against BLW.

The total weed density followed the trend of individual group of weeds and it was observed in the range of 51-331/m^2 in 2014 and 36-339/m^2 in 2015 at 45 DAS and 157-517/m^2 in 2014 and 21-428/m^2 in 2015 at 75 DAS (**Table 1**). The lowest total weed density was recorded in two hand weeding at 15 and 30 DAS, whereas, the highest total weed density obtained in weedy check plots during both the sampling time and years. Among the herbicides, the plots treated with pyrazosulfuron + pretilachlor at 15 + 600 g/ha to 30 + 1200 g/ha have almost comparable weed density in 2014 and 2015. Between the years, the total weed density was considerably more in 2014 than 2015. The lonely applied herbicides also performed superior but combination of pyrazosulfuron + pretilachlor at 15+600 g/ha onwards outperformed than others. The weed severity increases in DSR mainly due to the absence of impounding water, dry tillage, and alternate wetting and drying during growth period encourage the multiple flush of weeds (Chauhan 2012, Khaliq *et al.* 2014). It was also noticed that the emergence of some of the weeds, such as *Celosia argentea, Physalis minima* and *Phyllanthus niruri* was delayed in DSR system. Previous study also revealed that grasses and BLW were major problem in DSR system and this further led to shift in weed flora towards difficult-to-control weeds (Singh *et al.* 2006).

Weed dry weight and weed control efficiency at 45 and 75 DAS

The weed dry weight was significantly influenced by weed control treatments and years, it was measured that the weed dry weight ranged from 9.5-63.1 g/m^2 in 2014 and 6.5- 64.9 g/m^2 in 2015 at 45 DAS and 39.4-111.9 g/m^2 in 2014 and 5.1-101.4 g/m^2 in 2015 at 75 DAS (**Table 2**). The highest weed dry weight recorded in weedy plots, whereas two hand weeding at 15 and 30 DAS recorded with minimum. Among the herbicides, pyrazosulfuron + pretilachlor at 30 + 1200 g/ha measured lowest weed dry weight but lower dose of pyrazosulfuron + pretilachlor from 15 + 600 and 16.88 + 675 g/ha also registered the lower weed dry weight during both the years. In 2015, the performance of pyrazosulfuron + pretilachlor at 13.13 + 525 g/ha was also better than

Table 1. Effect of weed management practices on broadleaf weeds, grasses, sedges and total weed density at 45 and 75 DAS in direct seeded rice in 2014 and 2015

Treatment	Broad-leaf weeds		Grasses		Sedges		Total weed density (no./m^2)	
	2014	2015	2014	2015	2014	2015	2014	2015
45 DAS								
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	11(115)	6(39)	7(53)	4(20)	5(29)	4(16)	14(196)	9(75)
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	8(63)	5(27)	5(29)	4(19)	4(15)	4(13)	10(107)	8(59)
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	7(47)	5(25)	6(32)	5(21)	4(17)	3(11)	10(96)	8(57)
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	7(51)	5(25)	5(24)	4(19)	5(24)	4(12)	10(99)	8(56)
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	7(47)	8(67)	7(49)	7(55)	5(24)	6(37)	11(120)	13(159)
Pretilachlor (600 g/ha) 3 DAS	11(115)	8(69)	6(35)	7(52)	4(17)	5(24)	13(167)	12(145)
Pendimethalin (1500 g/ha) 3 DAS	12(155)	7(47)	5(29)	7(47)	6(26)	6(33)	15(220)	11(127)
Two hand weeding 15 and 30 DAS	5(23)	4(17)	5(23)	3(7)	2(5)	4(12)	7(51)	6(36)
Weedy check un-weeded	14(207)	12(147)	8(71)	10(96)	7(53)	10(96)	18(331)	18(339)
LSD (p=0.05)	0.99	0.89	1.07	1.40	0.60	1.54	1.05	1.25
75 DAS								
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	11(233)	8(57)	9(80)	6(31)	7(52)	5(27)	19(365)	11(115)
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	10(109)	4(20)	7(51)	4(16)	6(39)	4(17)	14(199)	7(53)
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	10(96)	4(20)	7(44)	4(17)	5(29)	4(16)	13(169)	7(53)
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	11(112)	4(17)	7(44)	3(11)	6(39)	4(17)	14(195)	7(45)
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	10(101)	8(64)	9(84)	8(60)	6(41)	6(31)	15(227)	12(155)
Pretilachlor (600 g/ha) 3 DAS	14(199)	10(109)	7(53)	7(48)	7(44)	6(37)	17(296)	14(195)
Pendimethalin (1500 g/ha) 3 DAS	16(245)	11(112)	7(47)	6(36)	8(57)	7(56)	19(329)	14(204)
Two hand weeding 15 and 30 DAS	9(83)	3(11)	7(47)	2(3)	5(28)	3(8)	13(157)	5(21)
Weedy check un-weeded	18(323)	14(208)	11(117)	10(99)	9(77)	11(121)	23(517)	21(428)
LSD (p=0.05)	1.08	1.18	1.23	0.96	1.50	1.16	1.28	1.32

LSD, least significant difference at the 5% level of significance; DAS - Days after sowing; the figures in the parentheses were original values the lonely applied herbicides and all the herbicides applied plots had lower weed dry weight than weedy plot. Pendimethalin alone was less effective than the other herbicides in 2014, whereas, pyrazosulfuron alone was less effective among herbicides in 2015 but all the herbicides were better than weedy plot during both the years.

The weed control efficiency was largely depended on weed dry weight but influenced largely by weed control treatments and years (**Table 2**). The highest weed control efficiency was obtained with two hand weeding at 15 and 30 DAS (84.6% in 2014 and 89.9% in 2015) at 45 DAS, whereas, at 75 DAS, it was 64.5% in 2014 and 90.2% in 2015 followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha (65.9 and 81.5%, respectively at 45 DAS). Plots treated with pyrazosulfuron + pretilachlor at various doses were almost comparable to each other (61.6 - 65.9%) except to pyrazosulfuron + pretilachlor at 13.13 + 625 g/ha in 2014. Plots treated with pyrazosulfuron + pretilachlor from lowest to highest dose had difference of only 5.9% in 2015, but in 2014, gap was wider with 15.9%. It clearly indicated that the performance of pyrazosulfuron + pretilachlor was better in 2015 than 2014. It was visualized (**Table 2)** that weed control efficiency in 2014 at 75 DAS was decreased from the initial sampling at 45 DAS, this was due to poor control of weeds, which suppressed the crop and weeds become more dominant. In contrary to this, in 2015, the weed control efficiency at 75 DAS increased from 45 DAS, mainly due to better weed suppression at 45 DAS, which encouraged the plants for early canopy closure/ coverage, led to increased weed control efficiency. The better weed control during 2015 was recorded due to timely sowing of crop and herbicide application, which are prerequisite to obtain the better efficacy. In 2014, crops were sown late and coincide with rain events, led to reduction in efficacy of herbicides resulted in poor control of weeds and it further reduced as advancement of crop growth. Previous study reported that sequential application of pre-emergence herbicides followed by post-emergence or tank mixture of two herbicides are more effective against wide spectrum of weed flora. Combining of other herbicide widens the spectrum of weed control (Singh *et al.* 2010). Pre-mix of pyrazosulfuron + pretilachlor increased broad spectrum weed control (grasses, BLW and sedges).

The weed density and dry weight data derived from the study suggest that the application of pretlachlor effectively control grasses and to some extent BLW, but its efficacy was poor on sedges. Pyrazosulfuron applied plots had lesser BLW and sedges, than the grasses. The pre-mix of pyrazosulfuron + pretilachlor had additive effect on controlling wide range of weeds and effective against grasses, broad-leaf and sedges. These findings are also supported by earlier findings which found that combination of compatible herbicides with different mode of action provides wide spectrum weed control (Mahajan and Chauhan 2013, Awan *et al.* 2015).

Crop growth parameters

Plant biometric parameters such as plant height, tillers/hill, total dry matter (g/hill), and leaf area index were significantly ($p<0.05$) influenced by weed control treatments and years (**Table 3**). The rice plants were taller in weedy plots in 2014 and pendimethalin applied plots in 2015, whereas no specific trend was recorded during both the years. The highest tillers/hill, total dry matter/hill and leaf area index was measured in two hand weeding at 15 and 30 DAS followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha during 2014 and 2015. Although application of pyrazosulfuron + pretilachlor

Table 2. Effect of weed management practices on weed dry weight and weed control efficiency at 45 and 75 DAS in direct seeded rice in 2014 and 2015

Treatment	Total weed dry weight (g/m^2) at 45 DAS		Total weed dry weight (g/m^2) at 75 DAS		Weed control efficiency (%) at 45 DAS		Weed control efficiency (%) at 75 DAS	
	2014	2015	2014	2015	2014	2015	2014	2015
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	6.1(37.2)	4.0(16.0)	9.6(92.6)	5.8(33.1)	40.0	75.6	16.7	64.4
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	5.0(24.2)	3.8(13.9)	7.5(56.3)	4.0(15.5)	61.6	78.8	49.4	80.7
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	4.8(22.7)	3.8(13.8)	7.1(50.3)	4.1(16.7)	63.8	78.6	54.6	79.4
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	4.7(21.5)	3.5(12.0)	7.3(53.0)	3.5(12.2)	65.9	81.5	52.4	83.6
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	5.0(24.7)	5.8(33.2)	8.0(64.3)	6.5(41.3)	60.7	48.5	41.9	55.9
Pretilachlor (600 g/ha) 3 DAS	5.7(32.3)	5.2(27.0)	8.9(78.3)	7.0 (48.8)	48.1	57.8	29.0	48.7
Pendimethalin (1500 g/ha) 3 DAS	6.1(37.3)	4.7(21.6)	8.7(75.7)	6.9(47.8)	40.4	66.6	31.6	50.4
Two hand weeding 15 and 30 DAS	3.2(9.5)	2.6(6.5)	6.3(39.4)	2.4(5.1)	84.6	89.9	64.5	90.2
Weedy check un-weeded	8.0(63.1)	8.1(64.9)	10.6(112)	10.1(101)	-	-	-	-
LSD (p=0.05)	0.69	0.65	0.78	0.96				

LSD, least significant difference at the 5% level of significance; DAS - Days after sowing; the figures in the parentheses were original values

Table 3. Effect of weed management practices on crop growth parameters in direct-seeded rice in 2014 and 2015

Treatment	Plant height (cm)		Tillers/hill		Total dry matter (g/hill)		Leaf area index	
	2014	2015	2014	2015	2014	2015	2014	2015
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	82.7	98.8	4.5	6.0	15.0	16.8	1.67	2.48
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	80.3	96.5	4.8	6.6	16.1	17.9	2.28	2.56
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	80.3	97.4	5.5	6.5	16.7	18.2	2.30	2.53
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	85.0	100.4	6.1	7.1	16.8	18.2	2.45	2.57
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	78.0	100.6	4.7	5.8	16.2	15.2	2.18	2.37
Pretilachlor (600 g/ha) 3 DAS	81.3	94.8	4.2	5.3	15.7	15.3	1.89	2.31
Pendimethalin (1500 g/ha) 3 DAS	82.0	100.9	4.1	5.1	15.0	16.3	1.77	2.22
Two hand weeding 15 and 30 DAS	85.7	94.5	6.5	7.5	18.3	19.1	2.50	2.68
Weedy check un-weeded	94.3	88.8	3.3	4.4	13.5	13.4	1.67	1.87
LSD (p=0.05)	5.60	7.84	0.95	1.02	1.12	1.16	0.10	0.12

LSD, least significant difference at the 5% level of significance; DAS - Days after sowing; the figures in the parentheses were original values

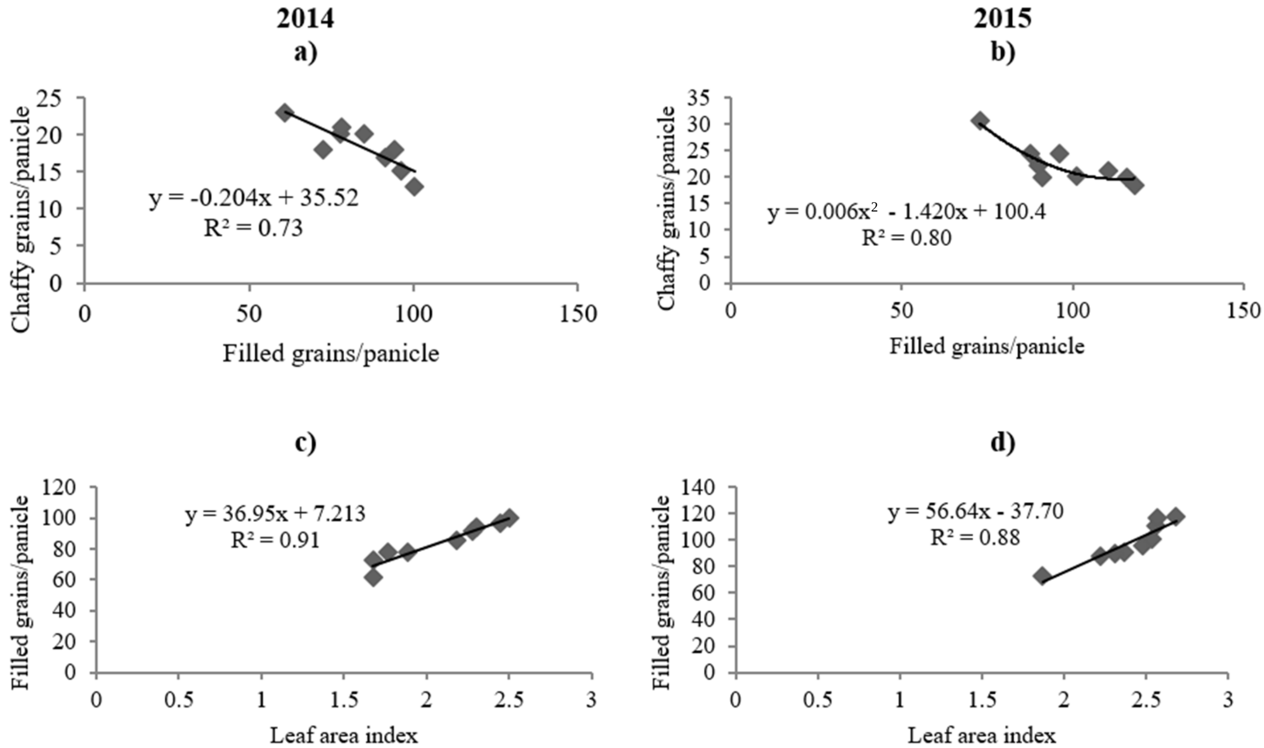

Figure 2. The relationship between filled grains and chaffy grains (a and b), and leaf area index and filled grains/panicle (c and d)

at all the doses improved the crop growth parameters, yet their effect was less pertinent in comparison to two hand weeding at 15 and 30 DAS. In this condition, rice plant may take up optimum water and nutrients led to better crop growth parameters such as plant height, tillers/hill, total dry matter and leaf area index resulting in higher grain yield. Our finding were corroborated with Bloach *et al.* (2005). It was noticed that appropriate use of herbicides not only reduce the weed density and dry weight but also have some additive effect on the crops. Plots treated with pyrazosulfuron + pretilachlor had noticed with taller plants, more tillers/hills, higher total dry matter accumulation/hills and longer and wider leaves led to more leaf area index, which might reduced the further growth and development of weeds. Similarly, in our study it was also noticed that more panicles/m^2, longer and heavier panicles, more numbers of filled grain, and lesser chaffy grains/panicle in rice were measured, which led to higher rice grain yield. Similar reports are also reported by Kumar and Ladha (2011), Khaliq *et al.* (2012), Singh *et al.* (2016). There was strong negative linear relationship between filled grains and chaffy grains in 2014 with R^2=0.73 (**Figure 2a**), and quadratic relationship in 2015 with R^2=0.80 (**Figure 2b**). However, positive linear relationship was established during 2014 and 2015 between leaf area index and filled grains/panicle with R^2=0.91 and 88, respectively (**Figure 2c** and **d**).

Yield attributes

Yield attributes such as panicle length, number of filled grains/panicle, panicle weight and chaffy grains/panicle were influenced by weed management during both the years. It was measured that panicles were longer, more number of filled grains/panicle, heavier panicles and fewer chaffy grains were observed in two hand weeding at 15 and 30 DAS followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha (**Table 4**). However, shorter panicles, less filled grains/panicle, lighter panicles and more number of chaffy grains/panicle were noticed in weedy plots. Although pyrazosulfuron + pretilachlor at 15 + 600 g/ha and at 16.88 + 675 g/ha improved these parameters, yet their effect were less pertinent in comparison to two hand weeding at 15 and 30 DAS. The trends were similar during both the years, but, better yield attributes were measured in 2015.

Grain and straw yield

Rice grain yield was significantly (p<0.05) affected by the weed control treatments in both the years (**Table 5**). The highest grain yield 2.69 t/ha in 2014 and 5.87 t/ha in 2015 was recorded in two hand weeding at 15 and 30 DAS followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha (2.45 and 5.28 t/ha, respectively). The lowest rice grain yield was recorded in weedy plot (1.45 and 2.17 t/ha, respectively). The grain yield in pyrazosulfuron + pretilachlor at 15 + 600 and 16.88 + 675 g/ha was comparable to each other. It was noticed that in 2015 the rice grain yield under pyrazosulfuron + pretilachlor at 15 + 600 g/ha was statistically comparable to two hand weeding at 15 and 30 DAS. It was also recorded that application of single herbicide also improved the grain yield and followed the trend with highest to lowest pyrazosulfuron> pretilachlor>pendimethalin during both the years. In the study, weeds in the weedy plots reduced grain yield by 46.0 to 63.1%. This was corroborated by Singh *et al.* (2007) and Chauhan *et al.* (2012). It was reported that there was >90% of yield loss in DSR (Chauhan and Johnson 2011). Rice grain yield and weed dry weight at 75 DAS had noticed with negative linear relationship during both the years with coefficient of determination of 0.93 in 2014 and 0.97 in 2015 (**Figure 3a** and **b**). Straw yield was significantly (p<0.05) influenced under weed control treatments during both the years (**Table 5**). The highest straw yield was recorded with two hand weeding at 15 and 30 DAS (4.07 and 8.71 t/ha, respectively) followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha in 2014 and pyrazosulfuron + pretilachlor at 16.88 + 675 g/ha in

Table 4. Effect of weed management practices on yield attributing parameters in direct-seeded rice in 2014 and 2015

Treatment	Panicle length (cm)		Filled grains/panicle		Panicle weight (g/panicle)		Chaffy grains/panicle	
	2014	2015	2014	2015	2014	2015	2014	2015
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	20.1	21.4	72.3	96.2	1.8	2.2	18.0	24.4
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	21.2	21.8	91.7	110.7	2.2	2.4	17.0	21.1
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	21.6	21.3	94.0	100.9	2.2	2.2	18.0	20.2
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	21.4	21.8	96.3	116.1	2.3	2.4	15.0	20.1
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	20.6	21.1	85.0	91.2	1.7	2.1	20.0	20.0
Pretilachlor (600 g/ha) 3 DAS	20.5	21.0	77.7	89.9	1.6	2.0	20.0	22.1
Pendimethalin (1500 g/ha) 3 DAS	20.8	20.2	78.0	87.9	1.6	1.7	21.0	24.4
Two hand weeding 15 and 30 DAS	22.6	21.9	100.3	118.0	2.4	2.4	13.0	18.3
Weedy check un-weeded	19.6	19.4	61.0	72.7	1.3	1.6	23.0	30.7
LSD (p=0.05)	0.83	1.00	12.23	18.39	0.30	0.37	4.56	7.74

LSD, least significant difference at the 5% level of significance; DAS - Days after sowing; the figures in the parentheses were original values

Table 5. Effect of weed management practices on grain and straw yield and harvest index in direct seeded rice in 2014 and 2015

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Harvest index	
	2014	2015	2014	2015	2014	2015
Pyrazosulfuron + pretilachlor (13.13+525 g/ha) 6 DAS	1.68	4.86	2.62	7.63	0.391	0.389
Pyrazosulfuron + pretilachlor (15+600 g/ha) 6 DAS	2.22	5.24	3.43	8.28	0.394	0.387
Pyrazosulfuron + pretilachlor (16.88+675 g/ha) 6 DAS	2.28	4.89	3.49	8.41	0.395	0.366
Pyrazosulfuron + pretilachlor (30+1200 g/ha) 6 DAS	2.45	5.28	3.74	8.01	0.396	0.398
Pyrazosulfuron-ethyl (15 g/ha) 3 DAS	2.11	4.48	3.23	6.91	0.395	0.393
Pretilachlor (600 g/ha) 3 DAS	2.05	4.31	3.15	6.82	0.395	0.389
Pendimethalin (1500 g/ha) 3 DAS	1.85	4.06	2.84	6.37	0.394	0.388
Two hand weeding 15 and 30 DAS	2.69	5.87	4.07	8.71	0.398	0.400
Weedy check un-weeded	1.45	2.17	2.21	5.15	0.396	0.298
LSD (p=0.05)	0.19	0.96	0.27	1.05	NS	0.051

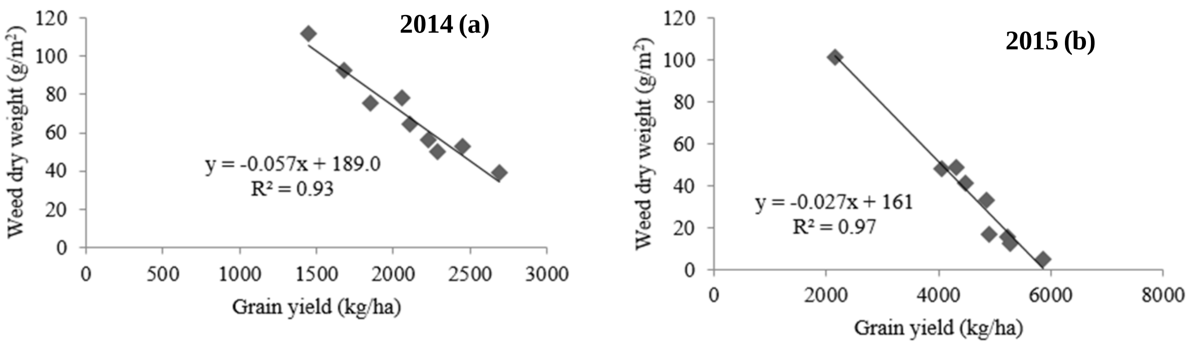

Figure 3. The relationship between grain yield and weed dry weight at 75 DAS (a and b)

2015. The lowest straw yield was recorded in weedy plots (2.21 and 5.15 t/ha, respectively). In DSR, weed control at initial 30 to 45 days are very crucial, owing to slow growth of plants and poor canopy coverage by the crop (Mahajan and Chauhan 2013).

The harvest index was ranged from 0.391-0.398 during 2014, which was statistically comparable, whereas, in 2015 (**Table 5**), it was recorded significantly higher in two hand weeding at 15 and 30 DAS (0.40) followed by pyrazosulfuron + pretilachlor at 30 + 1200 g/ha. The lowest harvest index was recorded in weedy check plot (0.298).

It was concluded that in order to obtain the optimum rice grain yield in DSR system, growers may use two hand weeding at 15 and 30 DAS as per the availability of labours, or the ready-mix of pyrazosulfuron + pretilachlor at 15 + 600 g/ha at 6 days after sowing in order to control the wide spectrum of weeds in the DSR system.

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