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Research Paper

Weed management in wheat as influenced by different rice residue management practices in rice-wheat cropping system

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ABSTRACT

A field experiment was conducted to study the influence of rice residue management practices on weed dynamics and management practices in wheat crop during *rabi* 2019–20 and 2020–21 at Punjab Agricultural University, Ludhiana, Punjab. Results revealed that population and biomass of different weeds at 60 days after sowing was lower under Happy seeder (zero tillage with residue retention) as compared to other rice residue management practices of residue removal, burning and incorporation. Lower population and biomass of *Phalaris minor* was recorded in pinoxaden 50 g a.i./ha treated plots as compared to metsulfuron plus carfentrazone 25 g a.i./ha and weedy plots, but found statistically at par with metribuzin plus clodinafop 270 g a.i./ha. Population and biomass of *Rumex dentatus* and *Medicago denticulata* was recorded lowest in metsulfuron plus carfentrazone 25 g a.i./ha and metribuzin plus clodinafop 270 g a.i./ha treated plots as compared to pinoxaden 50 g a.i./ha and weedy plots. Further, Happy seeder sowing was effective in reducing density and biomass of weeds and resulted in the highest yield. Under *in-situ* residue management wheat fields with complex weed flora, metribuzin plus clodinafop 270 g a.i./ha provided effective weed control in rice–wheat cropping system.

***Key words*:** Broad leaf weeds, Burning, Dicot weeds, Happy Seeder, Grass weeds, Mould board plough, Residue removal

The rice–wheat cropping system is a dominant cropping system of north-western India, particularly Punjab. Rice and wheat are the primary crops of Punjab which covers an area of 31.68 and 35.26 lakh hectares during 2022–23 with production of 205.24 and 148.65 lakh tonnes and average yield of 6.479 and 4.216 t/ha, respectively (Anonymous, 2023–24). Puddled-transplanted rice is the most adapted method accompanied by *in-situ* residue burning after crop harvest, followed by sowing of wheat with conventional tillage. Though, this monoculture of rice-wheat has contributed a lot in making the state self-sufficient in food grains and improving the economic condition but continuous cultivation of rice has resulted into many problems such as rice residue burning, receding water table (Hira *et al*., 2004), less time period between two crops, yield plateau (Ladha *et al*., 2003; Dhillon *et al*., 2010), formation of sub-soil hard pan with a consequent increase in bulk density, multi-nutrient deficiencies, weed infestation and evolution of herbicide resistance (Kaur *et al*., 2022; Dhanda *et al*., 2022) that are threatening the sustainability of rice-wheat cropping system.

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Harvesting of rice is commonly done by combine harvesters ending into stubbles of about 30-40 cm in height and loose straw behind, particularly when these machines are not attached with the spreader. The window for disposal of rice residue is constrained between rice harvest and sowing of *rabi* crops like wheat, potatoes or vegetables. As a result, 80% of the total rice residue produced annually is burnt fully or partially by the farmers in the open fields. Farmers opt for burning because in their opinion, it is a quick and easy way to manage large quantity of crop residue and prepare the field for the next crop well in time (Singh *et al*., 2009). The most effective intervention needed to improve sustainability of rice-wheat cropping system is to switch from burning rice residue *in-situ* to retaining it or incorporating it into field (Mahal *et al*., 2019; Dhillon and Sohu, 2024). Residue incorporation requires additional tillage operations and irrigation to facilitate its decomposition, therefore, residue retention as mulch seems to be the best option. For managing rice residue in the field, Happy Seeder was recommended in 2006 which offers direct drilling of wheat seeds in rice residue without any tillage operation (Sidhu *et al*., 2007).

The shift from conventional tillage to conservational tillage in wheat result into weed flora shift. The emergence of *P. minor* was low under zero tillage than conventional tillage in wheat (Chhokar *et al*., 2009; Franke *et al*., 2007; Gupta and Seth, 2007) but higher for some of the broad-leaf weeds, such as *Rumex dentatus* (Chhokar *et al*., 2007). *Phalaris minor* density is lowered in Happy Seeder sown wheat (Buttar *et al*., 2022; Kaur *et al*., 2024), which affect the weed control practices. In Punjab, *P. minor* has evolved multiple resistance against isoproturon (Malik and Singh, 1995), clodinafop and sulfosulfuron (Heap, 2024). The combined adoption of multiple weed control options, both chemical and non-chemical practices such as residue management (retention or incorporation) will help in effective management of weeds in wheat. Crop residue and tillage practices not only influence the weed growth and population but also influence the herbicide efficacy of pre-emergence herbicides (Kumar and Goh, 2000). Thus, the current study was carried out to assess the effect of different rice residue and weed management practices on weed dynamics and growth, productivity of wheat under rice-wheat cropping system.

MATERIALS AND METHODS

The experiment was conducted during 2019–20 and 2020–21 at student's research farm of Soil Science, Punjab Agricultural University, Ludhiana, (30°90'N and 75°78' E with an average altitude of 247 meter above mean sea level), Punjab. The climate of Ludhiana is typical sub-tropical and semi-arid with four distinct seasons of hot and dry summer in the months of April-June, hot and humid conditions from July-September, cool and dry winters in November-January and mild climate in the months of February-March and October. The daily maximum temperature of 40-45 °C is often recorded during the months of May and June while minimum temperature of 0-4 °C is observed in month of January. The maximum, minimum temperature and rainfall of growing season at experimental field is presented in Figure 1. The soil of experimental site was sandy loam texture with 0.36% organic carbon and pH of 7.40. Available N, P and K in the soil was 189, 15.5 and 65.4 kg/ha, respectively.

The experiment was laid out in a spilt plot design with three replications. The main plot consisted of four methods of rice straw management *viz.* conventional (residue removal followed by conventional tillage), Happy Seeder (zero tillage with residue retention on surface as mulch), mould board plough followed by rotavator (inversion ploughing and pulverising) and burning (residue burning followed by conventional tillage). The harvesting of previous rice crop (PR 122) was done by using combine fitted with super straw management system under all the treatments. In case of Happy Seeder, wheat was sown in standing stubbles having loose straw (surface retention) without any seedbed preparation. Rice straw was removed manually under conventional method while in burning plots, controlled burning of residue was done followed by conventional tillage. In conventional and burning, seedbed for wheat was prepared by ploughings twice followed by planking. Thereafter, seed-cum-fertilizer drill was used for wheat sowing in prepared seed-bed.

Wheat variety '*Unnat* PBW 343' with seed rate of 100 kg/ha was sown as per treatment in rows at 22.5cm row spacing. In sub plots, 4 weed management practices viz; post-emergence application of metribuzin plus clodinafop

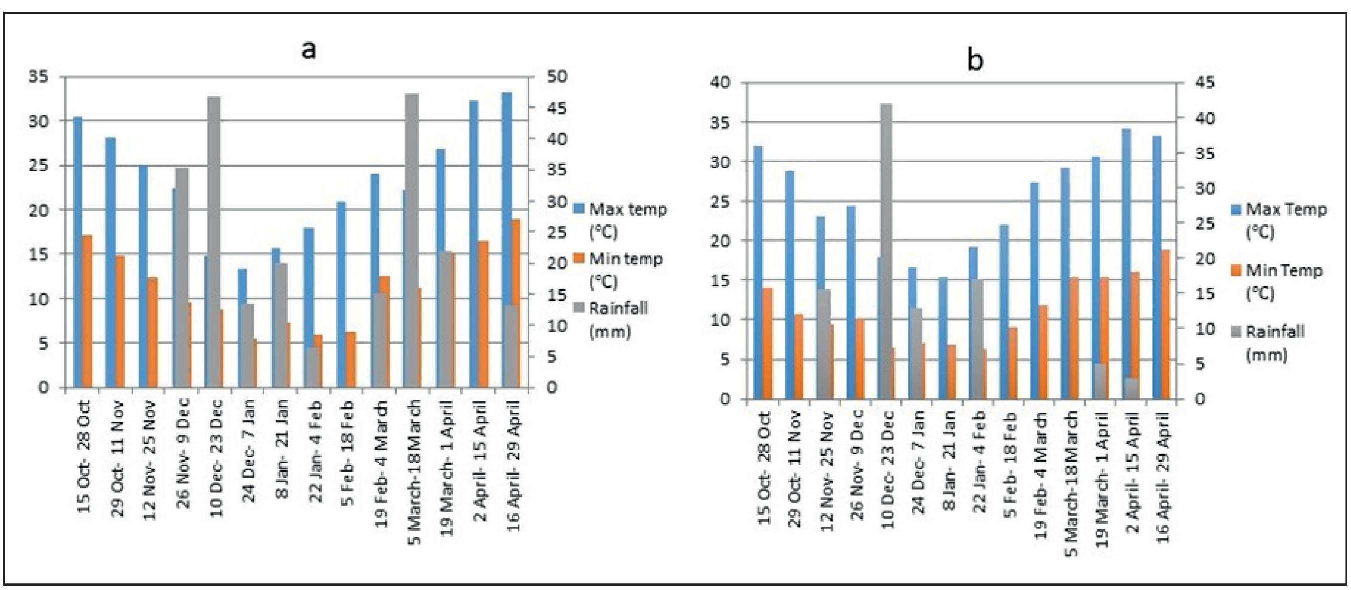


Fig. 1. Meteorological data of experimental site a) 2019–20 and b) 2020–21

270 g a.i./ha, pinoxaden 50 g a.i./ha, metsulfuron plus carfentrazone 25 g a.i./ha and weedy check were applied. Herbicides were sprayed at 35 days after sowing (DAS) in the plots according to the treatments with the ASPEE Knapsack sprayer (battery operated) using flood jet nozzle delivering 350 litres of water/ha. The application of nitrogen, phosphorus and potassium was done at the rate of 125 kg/ha N, 60 kg/ha P_2O_5 and 30 kg/ha K_2O using urea, diammonium phosphate and murate of potash, respectively as per package of practices for *rabi* crops of Punjab (Anonymous, 2023-24). Whole quantity of P and K was applied at sowing while N was applied in two equal splits at 4 and 6 weeks after sowing. In conventional method, the application of urea was done after the irrigation application while in Happy Seeder sown plots, it was applied a day before the irrigation as per recommendations provided in the package of practices for *rabi* crops of Punjab (Anonymous, 2023-24). Application of urea one day before irrigation in Happy Seeder sown plots is mandatory as residue is retained on the soil surface and irrigation water help in dissolution of urea and percolation down to the soil surface through 3-4 inches of residue layer.

A quadrate of 50 cm × 50 cm was placed at two places in each plot to determine the density and biomass of different weeds after 60 DAS of wheat. Weed dry weight was recorded after drying the weed samples at 70±2 °C for 72 hr. Plant height (cm), tiller density (No. m^{-2}) and crop dry matter accumulation (g m^{-2}) were measured at 90 days after sowing of the crop. The grain yield was recorded from net plot at harvest. At 60 DAS, weed control efficiency (WCE) was calculated based on the weed biomass obtained from treatments using formula as given by Mani *et al.* (1973):-

$$\text{WCE (\%)} = (X-Y)/X \times 100$$

Where X is weed biomass of weedy plot in a particular crop residue management method, and Y is weed biomass of treatment for which weed control efficiency is to be worked out.

The crop and weed data were pooled before analysis as experimental error for two years was homogeneous as per Bartlett's test of homogeneity of variance. Data were analyzed as per analysis of variance technique for determining the statistical significance effect of applied treatments. There was no year × treatment interaction effects. However, there was interactive effects of rice residue management methods and weed control treatments on weeds. For observations on weeds, the data of weed population and biomass 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 $p \leq 0.05$ and adjusted with Fisher's protected least significant difference (LSD) test. For comparing difference between treatment means in main plots at same or different level of sub-plots, estimate of standard error (S_d) was calculated by using formula as given by Peterson (1994).

RESULTS AND DISCUSSION

Weed density

Weed flora of the experimental field consisted mainly of *Rumex dentatus* and *Medicago denticulata* amongst broad leaf weeds. Among grasses, only *Phalaris minor* was observed. Amongst rice residue management practices in wheat, Happy seeder proved to be efficient in managing the weeds. Other three rice residue management practices *i.e.* conventional tillage, mould board plough+ rotavator and burning were infested with significantly more dicot/broad leaf and grass/monocot weeds (Table 1 and Figure 2). Weed plants per unit area were lower under Happy Seeder because surface retention of residue leads to physical barrier for the emergence of weed seedlings. Kaur *et al*. (2024); Nandan *et al*. (2018); Chhokar *et al*. (2021) and Nawaz *et al*. (2017) reported that residue retention results in lower weed density as compared to residue removed, which could be due to change in physical and chemical condition in seed environment. The physical effect includes reduction in light and soil surface insulation by mulching.

Population of *R. dentatus* and *M. denticulata* was observed significantly lowered under metsulfuron plus

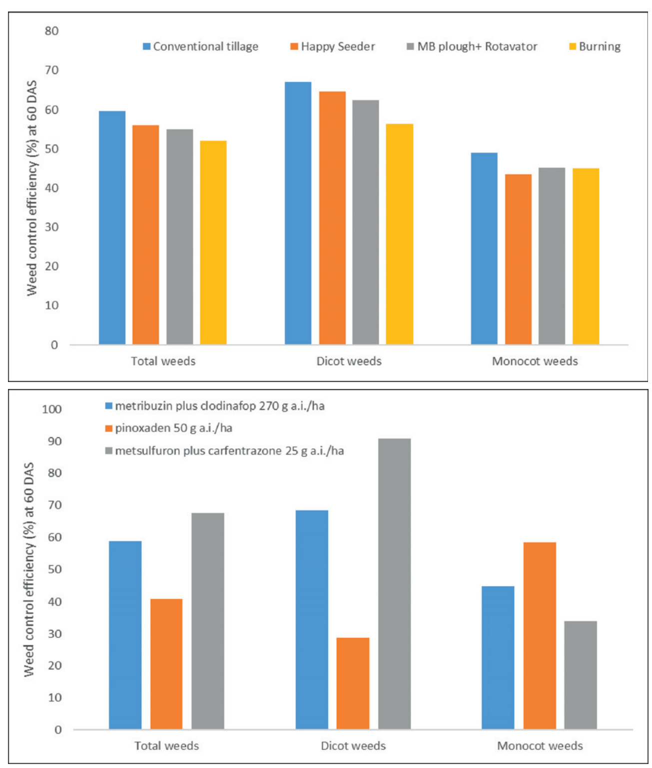


Fig. 2. Effect of rice residue management practices and weed control treatments on weed control efficiency at 60 DAS

Table 1. Interactive effects of rice residue and weed management on weed density at 60 days after sowing (average of 2 years) in wheat

Rice residue management × Weed management treatment	Conventional tillage	Happy Seeder	MB plough+ Rotavator	Burning	Mean
	R. dentatus density (number/m^2)				
metribuzin plus clodinafop 270 g a.i./ha	4.38 (20.88)	4.13 (18.56)	4.70 (26.94)	7.74 (63.25)	5.24 (32.41)
pinoxaden 50 g a.i./ha	11.94 (144.75)	8.27 (69.75)	10.89 (121.75)	12.53 (160.21)	10.91 (124.11)
metsulfuron plus carfentrazone 25 g a.i./ha	2.94 (8.00)	2.91 (10.00)	2.82 (8.75)	2.67 (10.13)	2.83 (63.25)
Weedy check	11.84 (144.67)	8.32 (72.50)	10.56 (117.00)	12.05 (151.25)	10.69 (160.21)
Mean	7.77 (79.57)	5.91 (42.70)	7.24 (68.61)	8.75 (96.21)	
CD (P=0.05) (Rice residue management): 0.41					
CD (P=0.05) (Weed management treatments): 0.60					
CD (P=0.05) (Weed management treatments at same level of Rice residue management): 1.19					
CD (P=0.05) (Rice residue management at same or different level of Weed management treatments): 1.10					
	M. denticulata density (number/m^2)				
metribuzin plus clodinafop 270 g a.i./ha	3.44 (11.76)	2.80 (7.68)	2.92 (8.18)	3.90 (15.14)	3.27 (10.69)
pinoxaden 50 g a.i./ha	3.87 (14.70)	3.48 (11.76)	3.62 (12.47)	4.27 (17.68)	3.81 (14.15)
metsulfuron plus carfentrazone 25 g a.i./ha	1.30 (0.91)	1.49 (1.78)	1.64 (2.16)	1.88 (3.24)	1.57 (2.02)
Weedy check	5.25 (28.47)	4.11 (16.62)	4.17 (17.24)	5.47 (30.12)	4.75 (23.11)
Mean	3.46 (13.96)	2.97 (9.46)	3.09 (10.01)	3.88 (16.54)	
CD (P=0.05) (Rice residue management): 0.18					
CD (P=0.05) (Weed management treatments): 0.23					
CD (P=0.05) (Weed management treatments at same level of Rice residue management): 0.45					
CD (P=0.05) (Rice residue management at same or different level of Weed management treatments): 0.42					
	P. minor density (number/m^2)				
metribuzin plus clodinafop 270 g a.i./ha	3.25 (9.96)	2.84 (7.44)	3.40 (11.33)	3.60 (12.54)	3.27 (10.32)
pinoxaden 50 g a.i./ha	3.05 (8.61)	2.67 (6.58)	2.90 (8.46)	3.18 (9.98)	2.95 (8.41)
metsulfuron plus carfentrazone 25 g a.i./ha	3.73 (13.46)	3.23 (9.81)	3.76 (13.58)	4.23 (17.36)	3.74 (13.55)
Weedy check	4.84 (22.96)	3.68 (13.65)	4.65 (21.27)	4.94 (24.00)	4.53 (20.47)
Mean	3.72 (13.75)	3.10 (9.37)	3.68 (13.66)	3.99 (15.97)	
CD (P=0.05) (Rice residue management): 0.13					
CD (P=0.05) (Weed management treatments): 0.14					
CD (P=0.05) (Weed management treatments at same level of Rice residue management): 0.27					
CD (P=0.05) (Rice residue management at same or different level of Weed management treatments): 0.27					

Weed data was subjected to square root transformation $\sqrt{X+1}$ and means of original values were given in parenthesis.

carfentrazone 25 g a.i./ha as compared to weedy plots and pinoxaden 50 g a.i./ha, but it was found statistically at par with metribuzin plus clodinafop 270 g a.i./ha. This could be due to fact that metsulfuron plus carfentrazone 25 g a.i./ha is effective in controlling broad leaf weeds and metribuzin plus clodinafop 270 g a.i./ha is broad spectrum herbicide that leads to control both broad leaf weeds and grasses effectively. Pinoxaden, being a grass killer herbicide effectively controlled *P. minor*, but was ineffective on broad leaf weeds (Table 1). Thus, population of *P. minor* was significantly lower under pinoxaden 50 g a.i./ha as compared to weedy and plots with application of metsulfuron plus carfentrazone 25 g a.i./ha, while it was found statistically at par with metribuzin plus clodinafop 270 g a.i./ha. The better performance of broad-spectrum herbicide (metribuzin plus clodinafop 270 g a.i./ha) was due to effective control of grass and broad leaf weeds (Table 1 and Figure 2). These results are in conformity with findings of Mathukia *et al*. (2018) and Chaudhary *et al*. (2016).

The interaction effect of rice residue management and weed control treatment on weed density was found to be significant at 60 DAS. Data in Table 1 indicated that density of *R. dentatus, M. denticulata* and *P. minor* recorded under weed control treatment plots of burning was at par with weedy plot under Happy seeder. This indicated that weeds were kept under check with sowing of wheat in residue-retained plots under zero-till conditions. These results are in conformity with those obtained by Buttar *et al*. (2022) and Kaur *et al*. (2024) in which wheat sown with Happy Seeder has less weed pressure than conventional till (residue removed or burnt) plots. It is an established fact that residue retention on the surface act as mulch and suppress weed seedling emergence in addition to moisture and soil conservation.

Dicot weeds: biomass, weed control efficiency and correlation studies

Different rice residue management practices significantly affected the weed biomass of broad leaf weeds. The biomass of different weeds was observed significantly lower under Happy Seeder as compared to conventional tillage, burning and MB plough+ Rotavator. This might be due to lower weed density observed under Happy Seeder plots as compared to other methods of residue management (Table 2). The effect of straw mulching on soil surface under Happy Seeder plots hinders the weed germination by creating physical barrier for weed seedling of broad leaf weed and by reducing the light penetration for grass weeds (Singh *et al*., 2017; Chhokar *et al*., 2007; Kumar *et al*., 2013 and Chhokar *et al*., 2009).

Weed biomass was significantly affected by different weed management practices. Significantly higher biomasses of broad leaf weeds were recorded under weedy plots, which were statistically at par with pinoxaden 50 g a.i./ha. Since pinoxaden is effective only on grass weeds and is ineffective for control of broad leaf weeds, there was more biomass of dicot weeds. Further, significantly lower weed biomass was recorded under metsulfuron plus carfentrazone 25 g a.i./ha, while it was found statistically at par with metribuzin plus clodinafop 270 g a.i./ha. This was due to effective control of broad leaf weeds by premixes of metsulfuron plus carfentrazone 25 g a.i./ha and metribuzin plus clodinafop 270 g a.i./ha as presented in Table 1. The interaction effect of rice residue management and weed control treatment on dicot weed biomass was found to be significant at 60 DAS. The biomass of dicot weeds recorded in herbicide-treated plots in residue burning technique was at par with weedy plot under Happy seeder sowing (Table 2).

There was dominance of dicot weeds in experimental field and premix herbicides such as metribuzin plus clodinafop 270 g a.i./ha and metsulfuron plus carfentrazone 25 g a.i./ha resulted in weed control efficiency of 69% and 91%, respectively with respect to dicot weeds and 59% and 68%, respectively for total weeds (Figure 2b). Further, control efficiency of dicot weeds was 56-67% across residue management techniques. Results showed there was a significant negative correlation (r=-0.82) between dicot weed biomass at 60 DAS and wheat grain yield at harvest (Figure 3a). Further, biomass of dicot weeds explains about 50% of the variation present in the grain yield.

Grassy weeds: biomass, weed control efficiency and correlation studies

Among various rice residue management practices, lower biomass of grass weeds was observed under Happy Seeder as compared to MB plough+ Rotavator, conventional tillage and burning. This might be due to lower weed density noted under Happy Seeder plots (Table 2) as compared to other methods of residue management. Under various weed management practices, higher biomass of grass weeds was recorded under weedy plots, which were statistically at par with metsulfuron plus carfentrazone 25 g a.i./ha. Weed biomass of grasss was recorded significantly lower under pinoxaden 50 g a.i./ha. While, it was found statistically similar to metribuzin plus clodinafop 270 g a.i./ha. This might be due to better control of grass weeds by pinoxaden and broad-spectrum herbicide.

Residue management has negligible effect on weed control efficiency and different post-emergence herbicides resulted in efficient weed control in all residue management methods (Figure 2a). Pinoxaden resulted in the highest

Table 2. Interactive effects of residue management methods and weed management on weed biomass at 60 days after sowing (pooled mean) in wheat

Rice residue management × Weed management treatments	Conventional tillage	Happy Seeder	MB plough+ Rotavator	Burning	Mean
Dicot weed biomass (g/m²) at 60 days after sowing					
metribuzin plus clodinafop 270 g a.i./ha	3.18 (9.11)	2.77 (6.72)	3.23 (9.46)	4.99 (24.16)	3.54 (12.36)
pinoxaden 50 g a.i./ha	5.56 (29.90)	4.21 (16.76)	5.24 (26.50)	5.96 (34.50)	5.24 (26.92)
metsulfuron plus carfentrazone 25 g a.i./ha	1.94 (2.79)	2.07 (3.31)	2.04 (3.20)	2.19 (3.87)	2.06 (3.29)
Weedy check	6.58 (42.29)	5.11 (25.28)	5.98 (34.75)	6.99 (47.36)	6.16 (37.55)
Mean	4.31 (21.02)	3.54 (13.02)	4.12 (18.48)	5.03 (27.61)	
CD (P=0.05) (Rice residue management): 0.13					
CD (P=0.05) (Weed management treatments): 0.11					
CD (P=0.05) (Weed management treatments at same level of Rice residue management): 0.22					
CD (P=0.05) (Rice residue management at same or different level of Weed management treatments): 0.23					
Grass weed biomass (g/m²) at 60 days after sowing					
metribuzin plus clodinafop 270 g a.i./ha	4.00 (15.21)	3.14 (9.17)	3.86 (14.21)	4.36 (18.21)	3.84 (14.20)
pinoxaden 50 g a.i./ha	3.37 (10.54)	2.91 (7.63)	3.42 (11.08)	3.71 (12.96)	3.36 (10.55)
metsulfuron plus carfentrazone 25 g a.i./ha	4.39 (18.38)	3.61 (12.29)	4.24 (17.33)	4.42 (18.88)	4.17 (16.72)
Weedy check	5.43 (28.23)	4.24 (17.17)	5.16 (25.96)	5.57 (30.33)	5.10 (25.57)
Mean	4.30 (18.24)	3.48 (11.56)	4.13 (17.15)	4.40 (20.09)	
CD (P=0.05) (Rice residue management): 0.16					
CD (P=0.05) (Weed management treatments): 0.19					
CD (P=0.05) (Interaction): NS					

Weed data was subjected to square root transformation $\sqrt{X+1}$ and means of original values were given in parenthesis.

weed control efficiency of 58% followed by metribuzin plus clodinafop (broad-spectrum herbicide). Further, biomass of grass weeds was negatively correlated (r=-0.66) with grain yield of wheat, and 25% of the variation in grain yield can be predicted from the biomass of grass weeds (Figure 3b).

Crop growth parameters, yield attributes and grain yield

Different crop growth parameters such as plant height, crop biomass and tiller density at 90 DAS were not significantly affected by rice residue management practices (Table 2). However, crop growth attributes have shown improvement (more plant height, tillers and biomass) in Happy Seeder sown plots. The effective tillers were not significantly affected by the application of various methods of rice residue management, whereas grain per ear was significantly influenced by rice residue management practices. Happy seeder resulted in significantly higher grains per ear as compared to other rice residue management practices. Rice residue management methods significantly affected grain yield of wheat, and significantly higher grain yield was observed in Happy Seeder sown plots as compared to other methods. In Happy Seeder sowing, zero tillage cum residue retention on surface helped in more crop growth and yield attributes (Table 2). Nandan *et al*. (2018); Buttar *et al*. (2022); Naresh *et al*. (2011) and Sidhu *et al*. (2007) observed that the residue retention on soil surface maintains better soil temperature and moisture, that help in larger sink, stronger reproductive phase (due to greater photosynthesis and translocation of photosynthates) and higher grain yield.

Different weed management practices significantly influenced plant height, crop biomass and tiller density at 90 DAS. Crop growth parameters was significantly higher under application of broad-spectrum herbicide, metribuzin plus clodinafop 270 g a.i./ha herbicide, which was due to better control of both broad leaf and grass weeds (Table 3 and Figure 3), that resulted in less crop-weed competition and better crop growth. Application of metribuzin plus clodinafop 270 g a.i./ha herbicide recorded statistically similar

Table 3. Effect of different rice residue management and weed management practices on growth and yield attributes (pooled mean) of wheat

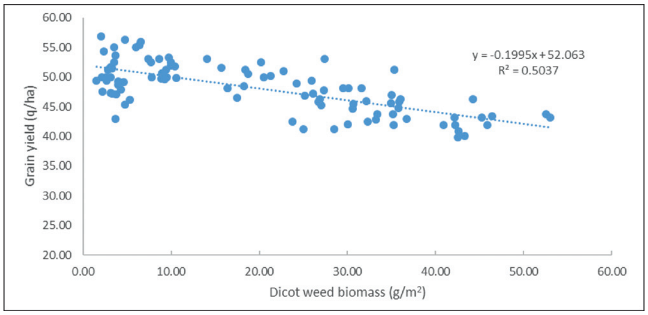
Treatment	Plant height (cm) at 90 DAS	Dry-matter accumulation at 90 DAS (g/m²)	Tiller density at 90 DAS (No./m²)	Effective tiller density (No./m²)	Grains/ spike	Grain yield (t/ha)
Rice residue management						
Conventional tillage	88.16	526.30	385.42	281.35	38.51	4.665
Happy Seeder	93.09	558.53	409.78	297.81	41.71	5.047
Mould Board plough+ Rotavator	91.35	547.14	401.17	281.04	39.44	4.795
Residue Burning + conventional tillage	87.30	520.66	381.16	280.73	38.61	4.721
SEm±	2.76	21.34	16.35	24.77	1.37	0.122
CD (P=0.05)	NS	NS	NS	NS	2.06	0.184
Weed management						
metribuzin plus clodinafop 270 g a.i./ha	95.58	574.79	422.06	308.13	42.68	5.196
pinoxaden 50 g a.i./ha	89.18	532.75	390.30	277.29	38.77	4.705
metsulfuron plus carfentrazone 25 g a.i./ha	92.07	552.14	404.95	292.19	41.00	4.975
Weedy check	83.08	492.95	360.23	263.33	35.82	4.352
SEm±	0.81	6.53	5.06	6.56	0.37	0.040
CD (P=0.05)	2.29	18.47	14.31	18.56	1.05	0.112

Interactions were found non-significant

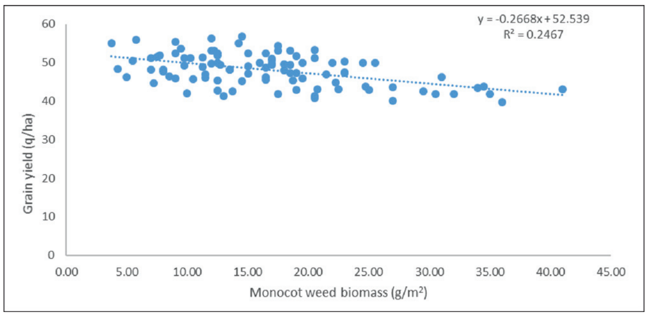
plant height, crop biomass and tiller density to metsulfuron plus carfentrazone 25 g a.i./ha, but significantly higher as compared to pinoxaden 50 g a.i./ha and weedy plots. There was higher population and biomass of broad leaf weeds at experimental site (Table 1 and 2). Pinoxaden, being a grass-killer was ineffective on dicot weeds. On the other hand, both premix herbicides (i.e. metribuzin plus clodinafop 270 g a.i./ha and metsulfuron plus carfentra–zone 25 g a.i./ha) were effective on broad leaf weeds. Application of herbicides resulted in effective weed control, resulted in less crop weed competition and better plant growth as compared to weedy plot.

The number of tillers per unit area were recorded significantly higher under metribuzin plus clodinafop 270 g a.i./ha as compared to metsulfuron plus carfentrazone 25 g a.i./ha, pinoxaden 50 g a.i./ha and weedy plots. This was due to better weed control under metribuzin plus clodinafop 270 g a.i./ha as it was broad spectrum herbicide that resulted in control of both broad leaf and grass weeds (Table 1 and 2), which resulted in better availability of space, sunlight, moisture and nutrient to crop in the absence of weeds. These results are in line with research findings of Tomar and Tomar. (2014) and Monsefi *et al*. (2016). The increased nutrient and water uptake by crop in the absence of crop-weed competition might accelerate photosynthesis, thereby, increasing the supply of carbohydrates, resulted in cell division, multiplication and elongation leading to overall improvement in vegetative growth which favourably influence yield attributes. Weed management practices significantly influenced the grain yield of wheat. Significantly higher seed yield was found under metribuzin plus clodinafop 270 g a.i./ha as compared to pinoxaden 50 g a.i./ha and weedy plots, while statistically at par with metsulfuron plus carfentrazone 25 g a.i./ha. Better crop growth of wheat (Table 2) under metribuzin plus clodinafop 270 g a.i./ha lead to higher effective tillers, grains per panicle (Table 2). Better growth was recorded due to less crop weed competition under herbicide application of metribuzin plus clodinafop 270 g a.i./ha as it was found effective in controlling both broad leaf and grass weeds. Similar weed control by broad-spectrum herbicide had been reported by Yadav and Dixit. (2014); Katara *et al*. (2012) and Mathukia *et al*. (2018).

It is concluded that Happy Seeder sowing of wheat resulted in lower weed biomass and thus,



(a) Correlation of dicot weeds biomass with grain yield



(b) Correlation of grass weed biomass with grain yield

Fig. 3. Correlation of weed biomass at 60 DAS with grain yield of wheat

higher grain yield as compared to residue removal, incorporation and burning methods. Grass and broad leaf/dicot weeds in wheat crop can effectively be controlled with post-emergence application of pinoxaden 50 g a.i./ha and metsulfuron plus carfentrazone 25 g a.i./ha, respectively under residue managed plots in rice-wheat cropping system. Further, post-emergence application of metribuzin plus clodinafop 270 g a.i./ha resuled in effective control of complex weed flora (with both broad leaf weeds and grass weeds) under different residue management methods.

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