



## RESEARCH ARTICLE

# Wheat productivity response to preceding rice residue-retention and integrated weed management

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### ABSTRACT

The sustainability of happy seeder (HS) sown wheat with preceding rice residue retention needs optimization of row spacing and integrated weed management. In this context, a study was conducted during *Rabi* seasons of 2020-21 and 2021-22 at Punjab Agricultural University, Ludhiana, India. The objective was to evaluate and identify the best option to realize higher wheat productivity and better weed management in wheat sown with happy seeder (HS) using varying row spacings in combination with retained preceding rice residues and integrated weed management treatments. The tested treatments include: wheat sown with happy seeder at row spacings (HS row spacing) of 18.25, 20.0 and 22.5 cm and weed control treatments including: unsprayed check, pre-plant application (PPA) of pyroxasulfone 127.5 g/ha, pendimethalin 1125 g/ha PPA, pendimethalin + metribuzin 962.5 g/ha PPA and post-emergence application (PoE) of metribuzin + clodinafop 270 g/ha. HS row spacing of 18.25 cm recorded *P. minor* density reduction of 16.7, 17.8% and 26.1, 27.1% and broad-leaved weeds density reduction of 22.1, 15.9% and 31.1, 27.8% at harvest, over HS row spacing of 20.0 and 22.5 cm, in 2020-21 and 2021-22, respectively. An increase in wheat grain yield of 24.9, 28.6% and 10.7, 16.3% was recorded with HS row spacing of 18.25 than HS row spacing of 20.0 and 22.5 cm during 2020-21 and 2021-22, respectively. Lower weed density (74.4%) and higher grain yield (82.9%) were recorded with metribuzin + clodinafop 270 g/ha compared to unsprayed check. Pendimethalin plus metribuzin 962.5 g/ha PPA by mixing with urea has provided greater control of diverse weed flora in wheat.

**Keywords:** Happy Seeder, Herbicide, Pendimethalin + metribuzin, Metribuzin + clodinafop, Rice residues, Wheat

### INTRODUCTION

The rice-wheat cropping system is very important for the food security in the country due to its approximately 69% contribution to total government food procurement. The rice-wheat cropping system produces a large amount (7-10 t/ha) of crop residues. Total surplus residue in India was about 141 Mt/year and out of these 82 Mt of surplus was from cereals, 44 Mt was from rice and 24.5 Mt was from wheat crop (Kaur *et al.* 2022). Approximately 80% of rice crop residue produced yearly is being burnt within 20-25 days during late October and early November in the north western part of India. Residue burning results in loss of lot of nutrients, organic matter and causes air pollution problems which affect the human health (Gupta *et al.* 2004). Thus, farmers have to manage the huge tonnage of rice residue within a shorter window period of 15-20 days to sow the wheat crop in the stipulated time frame. Happy seeder technology provides the ability to drill wheat seeds directly into loose paddy residues (Sidhu *et al.* 2015). It does not

mix the stubbles into the soil rather retains the paddy stubbles (12-18 inches) on the soil surface and sow wheat at a depth of 2-3 inches, thereby reducing weed germination by 60-70% (Sidhu *et al.* 2007) as compared to conventional sowing method.

In rice-wheat cropping system, another major issue is weeds in wheat crop (Kaur *et al.* 2022). The yield losses due to weeds in this system are higher as compared to other cropping systems (Singh *et al.* 2005). Among all the different weeds, *Phalaris minor* is an important and troublesome grass weed of wheat. Moreover, *P. minor* has evolved resistance against ALS- and ACCase-inhibitors. The pre-emergence herbicides are effective against resistant *Phalaris* but their application in residue-retained wheat fields is a big challenge due to presence of heavy straw load on the soil surface. Post-emergence herbicides often fail to provide satisfactory control because the presence of paddy straw restricts their absorption by weeds. Multiple herbicide resistant population of *P. minor* is sensitive to pendimethalin (Chhokar *et al.* 2008). Metribuzin + clodinafop and pyroxasulfone provided effective weed control due to longer persistence of herbicide in the soil (Singh 2015) which ultimately helped to provide congenial

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environment to wheat for proper growth and development. Herbicides alone are unable to contain weeds despite their continuous use for longer periods. Thus, there is a need for development of integrated weed management (IWM) approaches for long-term management of weeds in wheat.

Optimal row spacing is also a common cultural approach for weed management and used to enhance the wheat productivity by optimizing tillering (Thind *et al.* 2019). Narrow row spacing can be exploited as a useful weed management tool as it smothers the weed flora (Marin and Weiner 2014; Ramesh *et al.* 2017). Earlier sowing with happy seeder at 22.5 cm row spacing was recommended by Punjab Agricultural University, Ludhiana. In this study, evaluation was done to identify the best row spacing and integrated weed management options to realize higher wheat productivity with effective management of herbicide resistant *P. minor* and other weeds in wheat sown with happy seeder while preceding rice residues are retained.

## MATERIALS AND METHODS

The experiment was carried out at Research Farm, Punjab Agricultural University, Ludhiana (30° 54½N latitude and 75° 48½E longitude), India during 2020-21 and 2021-22. The area is characterized by sub-tropical semi-arid climate with very dry and hot summer during April to June, hot and humid monsoon during July to September, very cold winter during December-January and mild climate during February, March and October. Maximum temperature reaches above 47°C during summer months, while minimum temperature below 4°C accompanied by frost spells is quite common during the winter months of December and January. Average annual rainfall ranges between 500-750 mm. The soil of the experimental site was sandy loam in texture, normal in pH (6.7), normal in EC (0.14 dS/m), low in organic carbon (0.33%), low in available nitrogen (198 kg/ha), medium in available phosphorus (20.5 kg/ha), and medium in available potassium (157.5 kg/ha).

The field experiment was conducted in split plot design with three replications. Wheat sown with happy seeder at row spacings (HS row spacing) of 18.25, 20.0 and 22.5 cm in main plots and weed control treatments *i.e.*, unsprayed check, pre-plant application (PPA) of pyroxasulfone 127.5 g/ha, pendimethalin 1125 g/ha PPA, pendimethalin 35% + metribuzin 3.5% (pendimethalin + metribuzin) 962.5 g/ha PPA and post-emergence application (PoE) of metsulfuron 42% + clodinafop 12% (metribuzin + clodinafop) 270 g/ha in sub plots. Pre-plant herbicides were mixed with basal dose of urea (87.5

kg/ha) and broadcasted uniformly before sowing of wheat with happy seeder in the respective plots. After the harvesting of paddy crop, its residue (7.0 t/ha) were spread uniformly in the field. Wheat variety *PBW 725* was sown with 112.5 kg/ha seed on 3<sup>rd</sup> November 2020 and 15<sup>th</sup> November 2021. The recommended dose of 62.5 kg P/ha and 125 kg N/ha were applied. Full dose of phosphorus was applied at sowing time, while 87.5 kg/ha urea was applied (broadcast) before the sowing and remaining dose of nitrogen was applied in two equal splits, just before the first and second irrigation. The crop was harvested when the grains became hard and straw turned dry and brittle. During harvesting, bundles from each net plot were weighed to record the biological yield. After threshing, the grain yield obtained from each net plot was adjusted at 14% grain moisture. Straw yield from each plot was calculated by subtracting grain yield from biological yield.

For weeds data, weeds were counted as species-wise from two spots/plot with a quadrat of 0.5 m × 0.5 m at 60 DAS and at harvest. Weed biomass samples were cut at the collar portion of the plant, collected, sun dried and then dried in hot air oven at 60±2°C till constant weight was achieved. Weeds were separated out group-wise *i.e.*, grass and broad-leaved weeds. The weed control efficiency was calculated and expressed in percentage:

$$\text{Weed control efficiency} = \frac{\text{Weed biomass of unsprayed check} - \text{Weed biomass of treatment}}{\text{Weed biomass of unsprayed check}} \times 100$$

Leaf area index (LAI) at 60 DAS was recorded by using the Sun Scan Canopy Analyzer. Number of tillers were counted from the middle rows from the two randomly selected spots of 1m row length in each plot and later converted to tillers/m<sup>2</sup>. Plant height was recorded from the 10 randomly selected plants from each treatment from base of plant to base of the fully opened leaves. The length of main ear was measured from the base to tip of floret excluding awns, and the averaged value of ear length was taken and from these ears, number of grains/ear was counted.

Data was analyzed using the GLM procedure in SAS 9.3 to evaluate differences between treatments; means were compared using Tukey's test for pair-wise comparison at p=0.05 (SAS 2011). LSD values were calculated to compare interaction means. Further, some interaction effects were interpreted by slicing out the effect of one factor in SAS. Weed density and biomass data were square-root-transformed before performing ANOVA because of high variance.

## RESULTS AND DISCUSSION

### Effect on weeds

*Phalaris minor* was the dominant grass weed in the experimental field. At 60 DAS, HS row spacing of 18.25 cm resulted in lower *P. minor* and broad-leaved weed density as compared to 20.0 cm and 22.5 cm during both the years of study (Table 1). HS row spacing of 18.25 cm recorded reduction of 16.7 and 17.8% & 26.1 and 27.1% in *P. minor* density and 22.1 and 15.9% and 31.1 and 27.8% in broad-leaved weeds than HS row spacing of 20.0 and 22.5 cm at harvest, in 2020-21 and 2021-22, respectively. It might be due to the fact that there was more number of crop plants per unit area in closer rows than the wider rows of 22.5 cm (Jamil *et al.* 2003) and wheat in narrow row spacing suppressed weeds more effectively as compared to wider row spacing (Brar and Walia 2010; Devi *et al.* 2018; Kaur *et al.* 2022).

Among the weed control treatments, at 60 DAS, metribuzin + clodinafop at 270 g/ha recorded significantly less mean *P. minor* and broad-leaved weed density being a broad-spectrum herbicide than pyroxasulfone 127.5 g/ha, pendimethalin + metribuzin at 962.5 g/ha, pendimethalin at 1125 g/ha and unsprayed check (Table 1). Similarly at harvest, there was reduction of 89.5 and 86.0% *P. minor* and broad-leaved weed density with metribuzin + clodinafop, 83.2 and 45.5% with pyroxasulfone, 73.6 and 69.2% with pendimethalin + metribuzin, 69.4 and 51.6% with pendimethalin than unsprayed check, respectively, when averaged both years. Kaur *et al.* (2017) reported earlier that pendimethalin + metribuzin resulted in a reduction of weed density of both grasses and broad-leaved weeds in wheat.

The interactive effect of happy seeder row spacing and weed control treatment on weed control at 60 DAS was significant in 2020-21 (Table 2). With an increase in wheat row spacing from 18.25 to 22.5 cm, *P. minor* density also increased at 60 DAS. The combination of pendimethalin + metribuzin with HS row spacing of 18.25 cm recorded statistically at par *P. minor* density with pyroxasulfone with HS row spacing of 20.0 cm and 22.5 cm. This indicated the greater suppression in weed density at 60 DAS with pre-mix pendimethalin + metribuzin or pyroxasulfone along with wheat narrow row spacing.

Weed biomass of *P. minor* and broad-leaved weeds was less with happy seeder sown spacing of 18.25 cm as compared to HS sown spacing of 20.0 cm and 22.5 cm at 60 DAS (Table 3). Similarly at harvest, HS sown row spacing of 18.25 cm resulted in reduction of biomass of *P. minor* (12.2 and 44.3%) and broad-leaved weeds (19.0 and 29.2%) than HS sown row spacing of 20.0 cm and 22.5 cm. Narrow row spacing provided the smothering effect which inhibits the weed germination and growth by reducing incoming radiant energy resulted in lesser biomass production of weeds as compared to wider spacing (Amare 2014; Mahajan and Brar 2002).

Among weed control treatments, metribuzin + clodinafop at 270 g/ha recorded less *P. minor* biomass in both years as compared to pyroxasulfone at 127.5 g/ha, pendimethalin + metribuzin at 962.5 g/ha, pendimethalin at 1125 g/ha as pre-plant. At harvest, higher reduction in *P. minor* and broad-leaved weed biomass was recorded with metribuzin + clodinafop, pyroxasulfone, pendimethalin + metribuzin and pendimethalin during both years confirming the findings of Qazizada *et al.* (2022) and

**Table 1. Effect of happy seeder sown wheat row spacing and weed control treatments on density of *Phalaris minor* and broad-leaved weeds in wheat at 60 days after seeding (DAS) and at harvest during 2020-21 and 2021-22.**

Treatment	<i>Phalaris minor</i> * (no./m <sup>2</sup> )				Broad-leaved weeds* (no./m <sup>2</sup> )			
	60 DAS		at harvest		60 DAS		at harvest	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
<i>Happy seeder sown wheat row spacing (HS)</i>								
18.25 cm	3.70(17.3)	3.16(11.5)	3.98(18.4)	3.24(12.9)	5.17(31.4)	3.46(13.9)	5.74(37.3)	4.03(17.4)
20.0 cm	4.17(20.9)	3.44(13.5)	4.35(22.1)	3.62(15.7)	5.79(38.7)	4.00(17.7)	6.54(47.9)	4.41(20.7)
22.5 cm	4.15(21.7)	3.67(15.2)	4.59(24.9)	3.90(17.7)	6.13(43.6)	4.31(20.1)	6.99(54.1)	4.79(24.1)
LSD (p=0.05)	0.20	0.21	0.12	0.26	0.59	0.13	0.23	0.18
<i>Weed control (WC)</i>								
Unsprayed check	7.56(57.3)	6.36(39.6)	7.71(59.6)	6.42(41.3)	9.12(83.4)	5.82(34.0)	9.89(98.3)	6.09(37.2)
Pyroxasulfone 127.5 g/ha	3.08(9.6)	2.52(5.6)	3.20(10.3)	2.55(6.7)	6.49(42.4)	4.50(20.3)	7.07(50.2)	4.85(23.7)
Pendimethalin + metribuzin 962.5 g/ha	3.64(13.3)	3.20(9.3)	3.82(14.7)	3.42(11.9)	4.40(19.9)	3.33(11.2)	5.15(26.9)	3.84(14.9)
Pendimethalin 1125 g/ha	4.05(16.4)	3.46(11.1)	4.13(17.1)	3.70(13.8)	6.13(37.8)	4.07(16.7)	6.78(46.2)	4.4(19.4)
Metribuzin + clodinafop 270 g/ha	1.71(3.2)	1.57(1.6)	2.68(7.2)	1.84(3.4)	2.34(5.9)	1.9(3.9)	3.24(10.7)	2.85(8.3)
LSD (p=0.05)	0.26	0.33	0.15	0.22	0.48	0.18	0.18	0.22
<i>Interaction (HS x WC)</i>								
LSD (p=0.05)	S	NS	NS	NS	NS	NS	NS	NS

\*Figures in parentheses are original means. Data were subjected to square root transformation

Ahirwal *et al.* (2020). Pendimethalin alone could not provide adequate control of *P. minor* but its mixture with other herbicides was very effective against *P. minor* and other weeds (Bayat and Zargar 2021). The interactive effect of happy seeder spacings and weed control treatments on weed biomass at 60 DAS and at harvest were not significant.

The highest *P. minor* weed control efficiency (WCE) (69.1 and 68.7%) and broad-leaved weeds WCE (61.5 and 52.8%) was recorded with HS sown row spacing of 18.25 cm during 2020-21 and 2021-22. Among weed control treatments, the highest WCE was recorded against *P. minor* and broad-

leaved weeds with metribuzin + clodinafop (88.65 and 83.7%) closely followed by pyroxasulfone (82.8 and 42.1%), pendimethalin + metribuzin (72.0 and 66.3%) and pendimethalin (67.8 and 50.2%) over unsprayed check (Table 3).

**Effect on wheat**

Happy seeder sown spacing of 18.25 cm produced higher grain yield (5.57 and 5.13 t/ha) than HS row spacing of 20.0 cm (5.03 and 4.13 t/ha) and 22.5 cm (4.46 and 3.99 t/ha) during 2020-21 and 2021-22, respectively. An increase of 24.9 & 28.6% and 12.8 & 10.5% grain yield was recorded in HS

**Table 2. Interaction effect of happy seeder sown wheat row spacing and weed control treatments on *Phalaris minor* density (no./m<sup>2</sup>) in wheat at 60 DAS (2020-21)**

Treatment	<i>Phalaris minor</i> density* (no./m <sup>2</sup> )				
	Weed control (WC)				
	Unsprayed check	Pyroxasulfone 127.5 g/ha	Pendimethalin + metribuzin 962.5 g/ha	Pendimethalin 1125 g/ha	Metribuzin + clodinafop 270 g/ha
Happy seeder sown wheat row spacing (HS)					
18.25 cm	6.98 (48.7)	2.88 (8.3)	3.46 (12.0)	3.95 (15.7)	1.24 (1.7)
20.0 cm	7.72 (59.7)	3.11 (9.7)	3.64 (13.0)	4.08 (16.7)	2.35 (5.7)
22.5 cm	7.97 (63.7)	3.26 (10.7)	3.86 (15.0)	4.12 (17.0)	1.52 (2.3)
LSD (p=0.05)	HS = 0.20 WC= 0.26 HS × WC = 0.44				

\*Figures in parentheses are original means. Data were subjected to square root transformation

**Table 3. Effect of happy seeder sown wheat row spacing and weed control treatments on dry biomass of *Phalaris minor* and broad-leaved weeds in wheat and weed control efficiency during 2020-21 and 2021-22**

Treatment	<i>Phalaris minor</i> biomass* (g/m <sup>2</sup> )				Broad-leaved weeds biomass* (g/m <sup>2</sup> )				Weed control efficiency (%)			
	60 DAS		at harvest		60 DAS		at harvest		<i>P. minor</i> at harvest		Broad-leaved weeds at harvest	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
	<i>Happy seeder sown wheat row spacing (HS)</i>											
18.25 cm	2.22 (5.3)	2.27 (5.2)	5.45 (34.8)	4.47 (24.6)	2.52 (8.2)	1.49 (2.6)	6.66 (51.0)	4.72 (23.8)	69.1	68.7	61.5	52.8
20.0 cm	2.41 (5.8)	2.44 (6.0)	5.69 (37.4)	4.99 (29.8)	2.97 (10.8)	1.75 (3.5)	7.64 (65.6)	5.14 (28.2)	67.1	62.0	51.1	44.0
22.5 cm	2.40 (6.0)	2.58 (6.8)	6.90 (56.3)	5.37 (33.6)	3.25 (13.0)	1.88 (3.9)	8.17 (74.4)	5.54 (32.1)	50.0	95.4	44.5	36.3
LSD (p=0.05)	0.16	0.13	1.05	0.36	0.33	0.08	0.29	0.29	-	-	-	-
<i>Weed control (WC)</i>												
Unsprayed check	4.20 (16.9)	4.31 (17.7)	10.25 (112.5)	8.85 (78.5)	5.35 (28.9)	2.69 (7.3)	11.55 (134.1)	7.09 (50.4)	0.0	0.0	0.0	0.0
Pyroxasulfone 127.5 g/ha	1.83 (2.6)	1.84 (2.5)	4.47 (20.4)	3.51 (12.7)	2.92 (8.6)	1.91 (3.7)	8.40 (70.9)	5.62 (31.7)	81.9	83.8	47.1	37.1
Pendimethalin + metribuzin 962.5 g/ha	2.09 (3.5)	2.26 (4.2)	5.50 (30.5)	4.71 (22.6)	2.37 (5.9)	1.41 (2.0)	5.97 (36.3)	4.50 (20.4)	72.9	71.2	72.9	59.5
Pendimethalin 1125 g/ha	2.26 (4.5)	2.43 (5.0)	5.84 (34.6)	5.1 (26.2)	2.91 (8.7)	1.71 (3.0)	7.96 (63.9)	5.11 (26.2)	69.2	66.6	52.3	48.0
Metribuzin + clodinafop 270 g/ha	1.33 (0.9)	1.29 (0.7)	4.00 (16.2)	2.54 (6.5)	1.02 (1.2)	0.79 (0.7)	3.57 (13.1)	3.35 (11.5)	85.6	91.7	90.2	77.2
LSD (p=0.05)	0.20	0.21	1.21	0.3	0.38	0.09	0.36	0.24	-	-	-	-
<i>Interaction (HS x WC)</i>												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-

\*Figures in parentheses are original means. Data were subjected to square root transformation



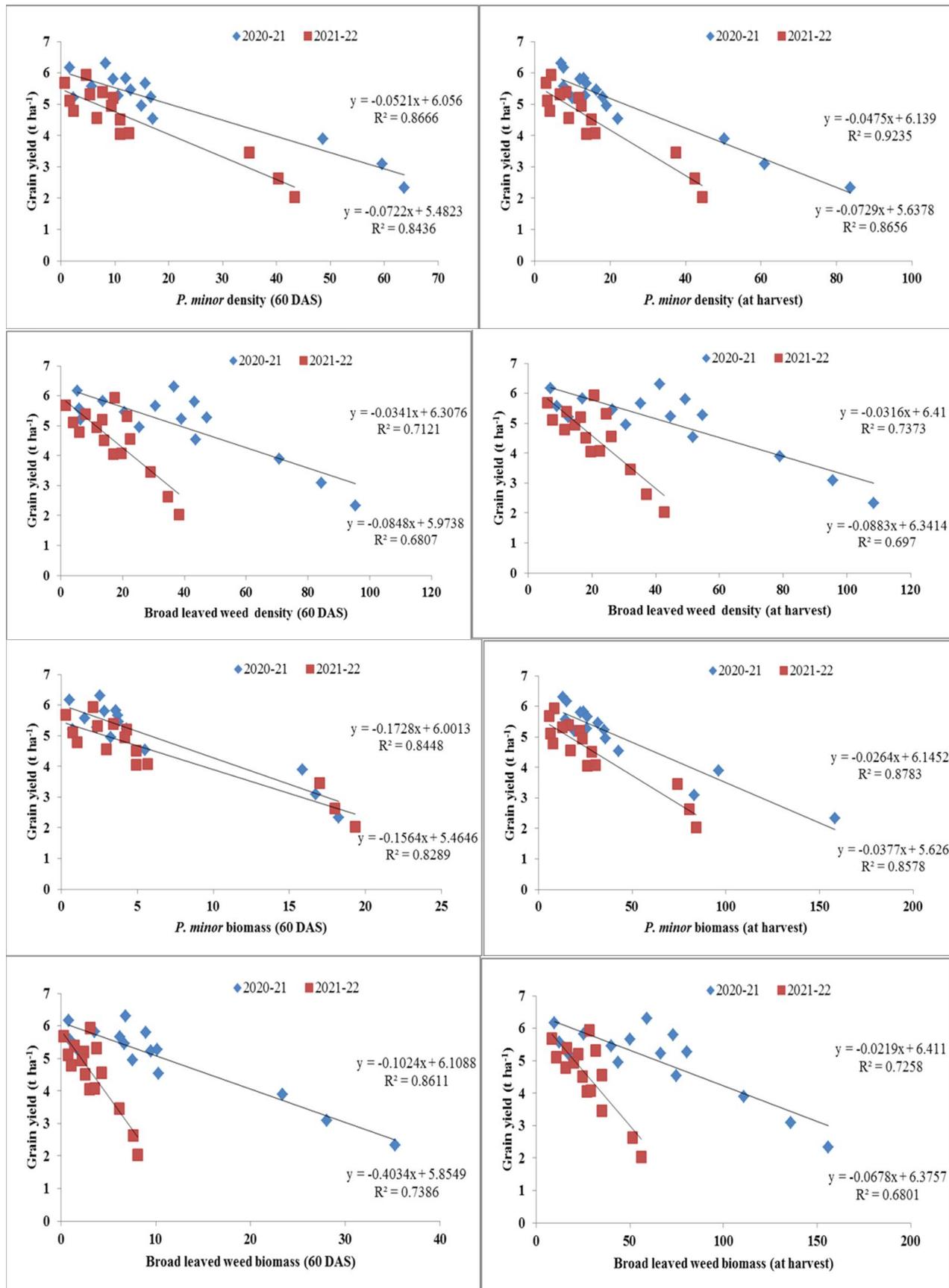


Figure 1. Relationship between grain yield and *Phalaris minor* and broad-leaved weed density (no./m<sup>2</sup>) and biomass (g/m<sup>2</sup>) in wheat

grain yield reduced linearly with an increase in *P. minor* density at 60 DAS and at harvest (**Figure 1**). *P. minor* infestation at 60 DAS caused 86.7 and 84.4% variation in grain yield during 2020-21 and 2021-22, respectively. Similarly, *P. minor* density accounted for 92.4 and 86.6% reduction at harvest during 2020-21 and 2021-22, respectively. Similarly, broad-leaved weed density caused 71.2 and 68.1% and 73.7 and 69.7% variation in grain yield of wheat at 60 DAS and at harvest during 2020-21 and 2021-22, respectively. *P. minor* biomass caused 84.5 and 82.9% and 87.8 and 85.8% variation in grain yield at 60 DAS and at harvest, during 2020-21 and 2021-22, respectively. Similarly, total broad-leaved weed biomass accounted for 86.1 and 73.9% and 72.6 and 68.0% variation in grain yield at 60 DAS and at harvest during 2020-21 and 2021-22, respectively (**Figure 1**).

### Conclusion

Happy seeder sown wheat at 18.25 cm row to row spacing recorded less weed density and biomass, higher wheat yield attributes and grain yield than happy seeder sown wheat with 20.0 and 22.5 cm spacing. Pyroxasulfone 127.5 g/ha, pendimethalin 1125 g/ha or pendimethalin + metribuzin (pre-mix) 962.5 g/ha PPA by mixing with urea provided good control of diverse weed flora in wheat. Integration of narrow spacing (18.25 cm) with the above effective herbicides improved weed control and wheat productivity.

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