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RESEARCH ARTICLE

Weed seed bank and dynamics in wheat as affected by sowing time and rice residue management methods

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ABSTRACT

Field studies were carried out to evaluate the effect of sowing time and residue management methods of preceding rice varieties (with different residue load) on weed seed bank and density in wheat during *Rabi* 2019-20 and 2020-21 in Punjab. Experiment was conducted in split plot design keeping combinations of 2 preceding rice varieties with different residue loads and 2 sowing times in main plots and 4 residue management methods in sub-plots with 3 replications. Results revealed that weed population and biomass at 30 days after sowing was higher in fields with low residue load (6.96-7.89 t/ha of PR 126) as compared to high residue load (10.25-11.44 t/ha of PR 122). Population and biomass of *Medicago denticulata* was lower in 15th November sown wheat in contrast to other broad-leaf weeds. Lower density of *Phalaris minor* was recorded under early sown wheat (25th October). Weed density and biomass was lower under happy seeder as compared to other residue management methods. In mould board plough + rotavator treatment, weed seed per unit area was lower in 0-5 cm soil layer but it was higher at 10-15 cm soil depth as compared to other residue management methods. Crop growth parameters (plant height, tillers density and biomass) were not influenced by rice residue load and wheat planting time. Grain yield was recorded highest under early sown wheat as compared to late sown wheat. Grain yield was recorded highest under Happy Seeder as compared to other residue management system during second year. However, grain yield was recorded similar under all residue management methods during first year. The results suggested that grass weeds were less in 25th October sown wheat but 15th November sown crop has less broad-leaf weeds.

Keywords: Early sown wheat, Happy Seeder, Mould board plough, Residue burning, Residue removal, Rice varieties

INTRODUCTION

Rice-wheat is the dominant cropping system of Punjab and plays an important role in satisfying growing food demand. In Punjab, rice and wheat are grown on an area of 31.45 and 35.26 lakh hectares during 2021 and 2022 with production of 203.71 and 148.65 lakh tonnes and average yield of 64.78 and 42.16 quintals per hectare, respectively (Anonymous 2023). 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), formation of sub-soil hard pan with a consequent increase in bulk density, multi-nutrient deficiencies, weed infestation and evolution of herbicide resistance (Singh *et al.* 2016) that are threatening the sustainability of rice-wheat cropping system.

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The combine harvesting of rice leaves stubbles of about 30-40 cm in height and spreads most of the straw in the field (Prasad *et al.* 1999). Burning of residue results in emission of harmful gases and poses a health hazard besides depleting soil health. Various solutions have been proposed to utilize crop residues such as incorporation, retention, baling and use in different industries. Beside this, long duration varieties of rice vacate the fields very late and cause delay in sowing of wheat beside leaving large residue load. The shift from conventional tillage to conservational tillage in wheat resulted in weed flora shift. In wheat, emergence of *Phalaris minor* was lower under zero tillage than conventional tillage (Chhokar *et al.* 2009) but some of the broad-leaf weeds, such as *Rumex dentatus* emerged in higher number in former (Chhokar *et al.* 2007). Further, more than 60% of weed seeds were concentrated in 0-7.5 cm soil layer in conventional/zero tillage (Hasam *et al.* 2021). Crop residue and tillage practices not only influence weed growth and population but also influence the efficacy of pre-emergence herbicides (Kaur *et al.* 2021). In Punjab, *P. minor* has evolved resistance against isoproturon (Malik and Singh 1995), clodinafop and sulfosulfuron

(Chokkar and Malik 2002). The combined adoption of multiple weed control options, both chemical and non-chemical practices such as change in tillage practices, residue management (retention or incorporation) will help in effective management of weeds in wheat. It was hypothesized that weed density and biomass will be affected by rice residue load and wheat planting time under different residue management methods. An experiment was conducted to study weed seed bank dynamics as affected by different residue loads, sowing time and residue management methods.

MATERIALS AND METHODS

Two years field study was conducted during 2019-20 and 2020-21 at student's research farm of Agronomy, Punjab Agricultural University, Ludhiana (Punjab). The maximum temperature in February-March was higher by 1ºC during 2020-21 than 2019-20. The soil of experimental site was sandy loam texture with 0.35% organic carbon and pH of 7.79. Available N, P and K content in the soil were 210, 32.75, 183.50 kg/ha, respectively. The experiment was conducted in spilt plot design with three replications. The main-plot consisted of 4 combinations of 2 preceding rice varieties and 2 wheat sowing time. The variety '*PR 122*' (with residue load of 10.25 and 11.44 t/ha during 2019-20 and 2020-21, respectively) and '*PR 126*' (with residue load 7.89 and 6.96 t/ha during 2019-20 and 2020-21, respectively) were cultivated in the previous summer season (June-October months). In winter season (October to April), wheat was sown at two different times *i.e.* 25th October and 15th November. In sub-plots, four methods of rice residue management, *viz.* conventional (residue removal followed by conventional tillage), Happy Seeder, mould board plough followed by rotavator and burning were allocated for the study. The harvesting of previous rice crop was done by using combine fitted with super straw management system. Under conventional method, rice straw was removed manually and controlled burning was done in burning plots. In Happy Seeder sowing method, wheat was sown in standing stubbles having loose straw without any seedbed preparation. 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 in rows at 22.5 cm row spacing. The application of nitrogen, phosphorus and potassium was done at the rate of 125 kg/ha N, 60 kg/ha P and 30 kg/ha K using urea, diammonium phosphate and murate of potash, respectively. Whole quantity of P and K was applied as basal dose at sowing while N was top dressed in two equal splits at 4 and 6 weeks after sowing. In conventional method, urea was applied after irrigation application while it was applied a day before irrigation in Happy Seeder.

A quadrate of 50 × 50 cm was placed at two places in each plot to determine the density and biomass of different weeds after 30 days of sowing (DAS). Weed dry weight was recorded after drying the weed samples at 70°C for 48 hr. Weed seed bank study was done by adopting germination method described by Espeland *et al.* (2010). Soil samples were taken from each sub-plot with the help of auger core sampler from 0-5, 5-10 and 10-15 cm soil depth one day before and after rice residue management. To separate weed seeds from the soil, the soil samples were washed with a 0.2 mm sieve cloth. Seed samples were transferred to Petri plates lined with wet filter papers in laboratory. Weed seed germination was recorded at a weekly interval, until no germination occurred in the dishes. Germination tests were performed at 25-30°C temperatures and sufficient conditions of moisture were maintained in the plates. The data was converted into viable m^2 seeds. 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. Data were analyzed as per analysis of variance technique for determining the statistical significance effect of applied treatments. 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 $p<0.05$ and adjusted with Fisher's protected least significant difference (LSD) test.

RESULTS AND DISCUSSION

Weed seed bank

Seed bank of *M. denticulata, R. dentatus,* and *P. minor* were observed at 0-5 cm, 5-10 cm and 10-15 cm depth of soil before residue management (**Figure 1**). Weed seed bank was not significantly influenced by different rice residue load and wheat planting time during both the years. The numbers of seeds per unit area decreases with increase in soil depth. Seed bank of *M. denticulata, R. dentatus* and *P. minor* was more at 0-5 cm soil depth as compared to 5-10 cm and 10-15 cm soil profile. Similar results were reported by Chokkar *et al.* (2009).

After residue management, three broad-leaf weeds namely *M. denticulata, A. arvensis, R. dentatus,* and one grass *P. minor* were observed in the weed seed bank study at 0-5 cm, 5-10 cm and 10-15 cm depth of soil after residue management (**Figure 2**). The seeds of different weeds were lower under mould board plough + rotavator at 0-5 cm (surface soil layer) as compared to other systems. However, at 10-15 cm soil depth, mould board plough + rotavator results in significantly higher weed seeds as compared to other residue management system during both the crop seasons. This could be due to inversion of soil by mould board plough, results in dormant seed at surface. This might be due to burial of viable seed at lower soil depth. Intensive tillage brought the weed seeds to the shallow depth thus exposing them to fluctuating temperature and sunlight, which enhanced the emergence of weed seeds. At 5-10 cm soil depth, seed bank of different weeds was statistically at par during both the crop seasons. Under no-till (Happy Seeder) conditions, much of weed seeds were located near the soil surface and number of weed seeds were declined with increase in depth (Yenish *et al.* 1992).

Weed density at 30 DAS

Weed flora of the experimental field consisted mainly of broad-leaf weeds *Medicago denticulata, Anagallis arvensis, Rumex dentatus, Coronopus didymus* and *Melilotus indica.* Among grasses, only *Phalaris minor* was observed. Weed density of all broad-leaf weeds and grass weed were significantly influenced by rice residue load during 2019-20 (**Table 1**). Higher weed population per unit area was recorded under lesser residue load (*PR 126*) as compared to higher residue load of '*PR 122*' in the first year. This might be due to fact that high residue load acts as a physical barrier for weeds, which hinders their emergence. Similarly, less weed emergence under higher residue load was reported by Kumar *et al.* (2013). A lower number of weeds was observed under high residue load of *PR 122* during 2020-21; however, the differences between weed densities under two residue loads were non-significant.

Planting time of wheat had significant effect on density of *M. denticulata* during both the years (**Table 1**). It was observed that significantly higher number of plants of *M. denticulata* per unit area was recorded under early sown wheat (25th October) as compared to late sown (15th November) wheat during both the years. In contrast, other broad-leaf weeds like *R. dentatus, A. arvensis, C. didymus, M. indica* and grass weed *P. minor* were recorded significantly lower when wheat was sown on 25th October during both the years. *Medicago denticulata* can germinate over temperature range of 10-20°C (Kumar *et al.* 2013) and temperature during end-October were favourable for growth and germination of *M. denticulata*. However, other weeds may require lower temperature for their germination and growth as compared to *M. denticulata*. This might be due to the fact that *P. minor* germinates at cooler temperature which was achieved on 15th November. Similarly, Singh *et al.* (2019) observed that *P. minor* density was maximum in wheat sown on 15th November.

Table 1. Effect of different rice residue load, wheat planting time and rice residue management methods on weed density (no./m^2) at 30 DAS

Treatment	*M. denticulata*		*M. indica*		*R. dentatus*		*A. arvensis*		*C. didymus*		*P. minor*	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Preceding crop variety												
PR122	11.10	13.32	2.62	3.52	4.28	4.97	5.66	8.35	2.24	2.53	3.21	8.52
	(126)	(184)	(9)	(15)	(22)	(26)	(46)	(83)	(6)	(6)	(14)	(75)
PR126	12.42	14.83	3.07	3.19	6.15	4.20	7.46	10.40	3.36 (11)	2.92	3.99	9.00
	(164)	(227)	(12)	(11)	(40)	(18)	(57)	(87)		(8)	(15)	(83)
LSD (p=0.05)	0.67	NS	0.15	NS	0.58	NS	0.74	NS	0.42	NS	0.43	NS
Date of sowing of wheat												
25-Oct	13.84	16.23	1.50	2.04	3.83	4.10	5.01	8.19	1.73	2.32	2.36	7.69
	(196)	(266)	(2)	(4)	(16)	(17)	(35)	(70)	(3)	(5)	(7)	(59)
15-Nov	9.68 (94)	11.92	4.19	4.67	6.60	5.08	8.12	10.56	3.87 (15)	3.13	4.83	9.83
		(146)	(19)	(22)	(45)	(28)	(68)	(112)		(9)	(23)	(99)
LSD (p=0.05)	0.67	1.59	0.15	0.37	0.58	0.58	0.74	0.49	0.42	0.45	0.43	0.51
Rice residue management system												
Residue removal	12.64	14.04	3.36	3.43	5.58	5.20	6.98	9.77	2.96 (10)	2.99	3.86	9.09
	(164)	(204)	(14)	(14)	(33)	(27)	(58)	(97)		(8)	(17)	(83)
Happy seeder	9.71 (96)	12.69	1.65	2.63	3.98	2.86	5.37	8.28	2.35	2.16	3.14	7.41
		(168)	(3)	(8)	(19)	(8)	(36)	(72)	(6)	(4)	(11)	(55)
MB plough + Rotavator	11.53	13.97	2.40	3.00	4.87	4.54	6.15	8.83	2.58	2.66	3.45	8.50
	(140)	(200)	(6)	(10)	(26)	(21)	(45)	(81)	(7)	(7)	(13)	(72)
Residue burning	13.15	15.61	3.98	4.34	6.44	5.74	7.74	10.61	3.32 (12)	3.08	3.94	10.05
	(181)	(251)	(18)	(20)	(44)	(33)	(67)	(114)		(9)	(18)	(106)
LSD (p=0.05)	0.96	1.48	0.23	0.54	0.74	0.53	0.69	0.52	0.31	0.42	0.38	0.89

Interactions between treatments in main, main×sub plots were found non-significant during 2019-20 while interaction between treatments in main plots was found significant during 2020-21. Weed data is subjected to square root transformation ($\sqrt{x+1}$). and means of original values are given in parentheses

Residue management practices significantly influenced the density of broad-leaf weeds as well as grass weed during both the years. During 2019-20, significantly lower weed population was observed under Happy Seeder as compared to other management methods such as mould board plough+ rotavator, conventional tillage and burning (**Table 1**). This might be due to mulching effect of straw on soil surface under Happy Seeder plots as compared to other plots in which there is no residue on surface. Residue at the surface hinders the weed germination by creating physical barrier for emergence of seedling of broad leaf weeds and by reducing the light penetration for grass weeds. These results were in front line with Chhokar *et al.* (2021). However, during 2020-21, significantly lower density of different weeds was recorded under Happy Seeder as compared to conventional tillage and burning, but it was found statistically similar with mould board plough+ rotavator. *Phalaris minor* density was lowered in Happy Seeder sown wheat (Saini and Walia 2010). Further, residue incorporation by mould board plough+ rotavator resulted in significantly lower weed population than burning during both the years. These results are supported by findings of Khankhane *et al.* (2009).

The interaction between date of sowing and rice residue load on weed density was significant and differential during second year. On 25th October sown wheat, there was significant effect of rice residue load on population of *M. denticulata* and *P. minor* (**Table 2**) and population was lower under high residue load of '*PR 122*' but in late sown (15th November) wheat, effect of residue load on weed emergence was not visible. This could be due to the rainfall received in early-November which resulted in faster decomposition of residue. The density of *A. arvensis* was affected by residue load and it was less under high residue load under both sowing time of wheat.

Weed biomass at 30 DAS

Rice residue load significantly influenced biomass of broad-leaf weeds in first year however, the differences were non-significant during second year (**Table 3**). The biomass of broad leaf weeds was significantly lower when wheat was sown on 15th November as compared to 25th October. This might be due to fact that the major weed at experimental site was *M. denticulata* and higher weed density of *M. denticulata* was recorded at 25th October which results in higher biomass. In contrast, biomass of *P. minor* was lower when wheat was sown on 25th October as compared to 15th November. This could be due to more density of *P. minor* when wheat is sown on 15th November. Similar results were reported by Mahajan and Brar (2002) that wheat sown in November has more problem of *P. minor* because of decline in temperature.

Different rice residue management practices significantly affected the weed biomass during both years. During 2019-20, lower biomass of weeds was observed under Happy Seeder as compared to mould board plough+ rotavator, conventional tillage and burning. However, Happy Seeder was found statistically at par with mould board plough + rotavator but significantly better than conventional tillage and burning, during 2020-21. This could be due to lower weed population per unit area under Happy Seeder as compared to conventional tillage and burning. Also, retention of rice residue reduced biomass of weeds by suppressing weed population due to physical barrier and also by allelochemical released from rice residue mulch, which inhibit weed seed germination.

Table 3. Effect of different rice residue load, wheat planting time and rice residue management methods on weed biomass (g/m^2) at 30 DAS during 2019-20 and 2020-21

Treatment	Broad-leaf weeds		Grass weeds	
	2019-20	2020-21	2019-20	2020-21
Preceding crop variety				
PR122	3.88 (15)	6.32 (40)	2.01 (4)	3.19 (13)
PR126	4.32 (19)	6.47 (42)	2.31 (4)	4.01 (15)
LSD (p=0.05)	0.22	NS	0.2	0.25
Date of sowing of wheat				
25-Oct	4.79 (23)	7.45 (55)	1.59 (2)	3.07 (12)
15-Nov	3.41 (11)	5.34 (29)	2.73 (7)	4.18 (15)
LSD (p=0.05)	0.22	0.63	0.2	0.25
Rice residue management				
Residue removal	4.36 (19)	6.47 (43)	2.29 (5)	4.12 (17)
Happy Seeder	3.46 (10)	5.67 (33)	1.93 (3)	2.27 (5)
MB plough+ rotavator	3.75 (13)	6.27 (40)	2.09 (4)	4.10 (17)
Residue burning	4.56 (21)	7.17 (52)	2.34 (5)	4.25 (18)
LSD (p=0.05)	0.32	0.63	0.18	0.23

Interactions between main, main×sub plots are found non-significant during 2019-20

Weed data is subjected to square root transformation ($\sqrt{x+1}$). and means of original values are given in parentheses

Table 2. Interactive effect of rice residue load and date of sowing on weed density (no./m^2) at 30 DAS during 2020-21

Sowing time	*PR122*	*PR126*	*PR122*	*PR126*	*PR122*	*PR126*
	M. denticulata		*A. arvensis*		*P. minor*	
25-Oct	15.47 (241)	16.57 (275)	6.80 (47)	9.60 (92)	7.40 (54)	9.00 (84)
15-Nov	11.48 (128)	12.36 (164)	9.90 (98)	11.20 (126)	9.90 (101)	9.71 (97)
LSD (p=0.05)	0.88		0.69		0.71	

Weed data is subjected to square root transformation ($\sqrt{x+1}$) and means of original values are given in parentheses

Table 4. Effect of different rice residue load, wheat planting time, rice residue management and weed management methods on growth parameters and grain yield of wheat

Treatment	Plant height (cm) at 90 DAS		Tiller density (no./m²) at 90 DAS		Crop biomass (g/m²) at 90 DAS		Grain yield (t/ha)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Preceding crop variety								
PR122	83.25	76.65	482.31	477.78	588.47	563.56	5.06	4.68
PR126	82.41	73.76	470.56	472.32	572.35	552.85	4.87	4.64
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Date of sowing of wheat								
25-Oct	83.26	76.59	496.9	480.78	580.71	563.88	5.12	5.00
15-Nov	82.41	73.82	455.96	469.32	580.11	552.53	4.80	4.32
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.23	0.27
Rice residue management								
Residue removal	82.97	75.26	465.44	465.79	580.67	558.42	4.95	4.52
Happy Seeder	83.44	75.78	498	501.54	581.06	558.33	5.09	5.00
MB plough + rotavator	82.88	75.64	492.95	486.52	580.81	558.72	4.93	4.63
Residue burning	82.13	74.14	449.33	446.36	579.11	557.33	4.89	4.48
LSD (p=0.05)	NS	NS	40.27	31.33	NS	NS	NS	0.20

Crop growth parameters and yield

Plant height and crop biomass were not affected by rice residue load, wheat planting time and rice residue management system during both crop seasons (**Table 4**). Different loads of rice residue and wheat planting time did not influence the tiller density of wheat during both years. The rice residue management methods recorded significantly higher tiller density as compared to conventional method, and the lowest being under burning. The data were in agreement with the findings of Singh *et al.* (2011) who also observed higher tiller mortality of wheat under no mulch conditions. Rice residue load did not significantly affect the grain yield during both years. Wheat planting time significantly affected the grain yield of wheat during both years. The grain yield was 7.35 and 15.63 % higher when wheat was sown on 25th October as compared to 15th November sown wheat during 2019-20 and 2020-21, respectively. This could be due to better crop growth during early sowing of wheat. The poor germination and growth of weeds favoured crop growth and resulted in higher grain yield under early sown conditions. These results are in front line with Singh *et al.* (2019).

The methods of rice straw management did not significantly affect the grain yield of wheat, during 2019-20. Similarly, Bhattacharyya *et al.* (2008) found the non-significant change in grain yield of wheat under zero tillage as compared to conventional method. The temperature was higher during grain filling and maturity time during 2020-21. Plots with residue retention (Happy Seeder) lead to significantly higher grain yield as compared to conventional method. Residue retention as mulch helps in protecting crop from terminal heat stress. Wheat grain yield was 7.87, 10.56 and 12.14 % higher in Happy Seeder plot as compared to mould board plough *fb* rotavator, residue removal and burning, respectively. Crop residue management is one of the vital issues for sustainability in north-western Indian states, and its *in-situ* management (residue retention or incorporation) may result in improving soil fertility along with effective weed control and sustainable productivity of rice-wheat cropping system.

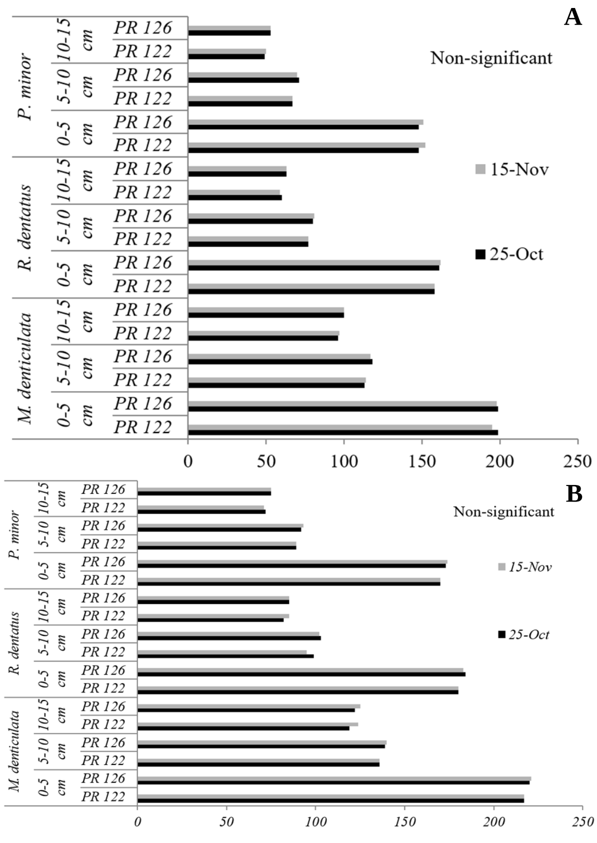

Figure 1. Weed seed bank no./m² before residue management methods as affected by preceding rice varieties and sowing time; a and b graph indicate weed seed bank before residue management during 2019-20 and 2020-21, respectively; NS: Treatment means are non-significant at p<0.05.

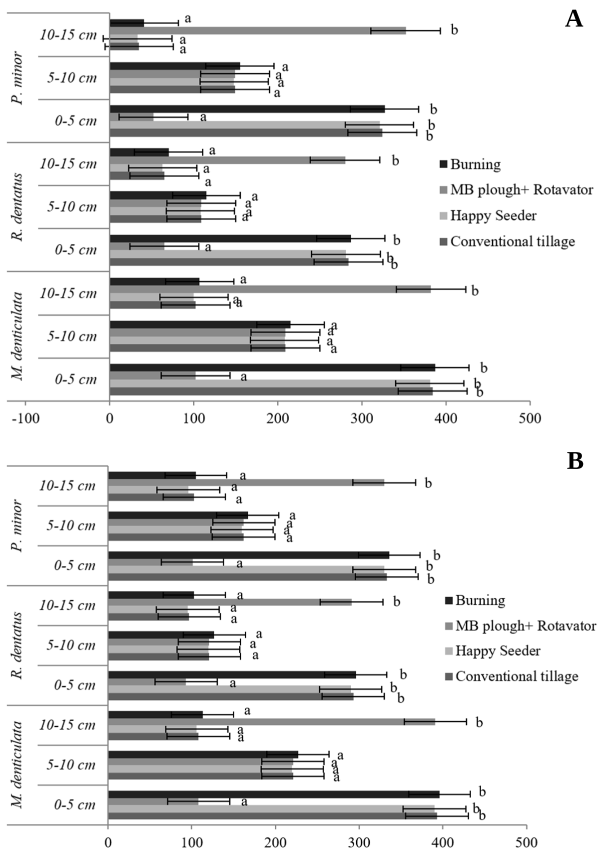

Figure 2. Weed seed bank no./m² as affected by residue management methods; a and b graph indicate weed seed bank after management during 2019-20 and 2020-21, respectively; Mean values not connected by the same letter are significantly different according to $p<0.05$. Vertical error bars depict standard error of mean.

It was concluded that weed population and biomass was more in plots with lesser residue load of '*PR 126*' as compared to '*PR 122*'. Residue incorporation with mould board plough resulted in a smaller number of weed seed bank in the 0-5 cm soil layer. *Medicago denticulata* density was more in 25th October sown wheat than in 15th November sown wheat however, *Phalaris minor* density was less in early sowing of wheat sown on 25th October.

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