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EFFECTS OF SOWING DATES AND MULCHING ON GROWTH AND YIELD OF WHEAT AND WEEDS (*PHALARIS MINOR* RETZ.)

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Abstract

Weed infestation, particularly *Phalaris minor* Retz. is a serious threat for increasing wheat productivity in Indo-Gangetic Plains of India. The primary objective of this research was to study the effect of sowing dates and mulching on the growth of wheat and weeds. In general, early sowing (November-25) exhibited less growth of *P. minor*, but increased weed biomass and lower wheat yields than the delayed (December-10) sowing date. Application of paddy straw, jute mat, and black polythene mulches positively increased the height, tiller count, yield of wheat; and drastically reduced weed infestation, especially the growth of *P. minor*. Moreover, under no weed management, delayed sowing increased the wheat yield, over earlier sowing. It was concluded that organic mulches can sustainably manage the weed infestation, particularly *P. minor* and increase the wheat yield.

Introduction

In India, wheat is a staple cereal grown in an area of 30.22 million ha with an annual production and productivity of 98.38 Mt and 3.0 t/ha, respectively (GoI 2017). In fact, it is an important source of nutrition for about 40% of the population (Joshi *et al*. 2010). To fulfill the demand of the burgeoning Indian population, it is estimated that by 2051 A.D., wheat production needs to increase by 110–120 M tons. By that time, however, it is expected that the area under wheat production would decrease by 5–6 M ha. Thus, average wheat productivity needs to increase up to 5 t/ha to feed the population (Sharma *et al*. 2013).

Exacerbating weed problem accounts for 20–40 per cent reduction in wheat yield (Sharma 2009). Among weeds, *Phalaris minor* predominates in wheat-growing regions of Indian subcontinent (Singh 2007) and has potential to reduce yield by 80 per cent (Singh *et al*. 1999). Therefore, for sustaining the wheat grain production, weed management is very essential. Herbicides, while effective, are not widely used by farmers, specially in eastern Indo-Gangetic Plains of Uttar Pradesh, due to technological and socio-economic constraints (Singh 2011).

Keeping the above fact in view, 'sowing date' and 'mulching' were tested as potential non-chemical approach for weed management. In fact, altering the sowing dates influences the weed communities (Milberg *et al*. 2001), and provides a competitive advantage in yielding the crop (Singh *et al*. 1995, Singh and Saini 2008). Furthermore, greater interests have developed recently in the utilization of mulch for crop production. Organic mulch materials, such as paddy straw, carpet waste and jute mat are abundantly available in the eastern Uttar Pradesh. Indeed, 95 per cent of global jute is produced in India, Bangladesh, China, Nepal and Thailand (Maity *et al*. 2012). Organic mulching improves the physical, chemical, biological properties of soil (Kasirajan and Ngouajio 2012), and also controls weeds (Singh and Saini 2008, Anzalone *et al*. 2010), pests

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and diseases (Hu *et al.* 1995) besides its positive influence on crop yield (Singh and Saini 2008, Anzalone *et al.* 2010). Though, nowadays plastic mulches are used in large volume in commercial crop production (Bhardwaj 2013). The plastic mulch materials, such as poly vinyl chloride or polyethylene films, have been successfully used for weed control and enhancement of crop yield in many crops (Campiglia *et al*. 2010, Waterer 2010).

The aim of this work was to find out the effect of sowing dates, organic and inorganic mulch application and on performance of wheat and weeds in general, and *P. minor* in particular.

Materials and Methods

The field trial was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India (128.93 m above mean sea level, $25^0$18'N, $83^0$30'E), at same site and plots, for three consecutive winter seasons from 2008–2009, 2009–2010 and 2010–2011. Soil was sandy clay loam (Typic Ustochrept; Order Inceptisol) with 0.43% organic C, pH 7.10, low in available N (196.5 kg/ha), and medium in available P (25.7 kg P_2O_5/ha) and K (220.0 kg K_2O/ha). During the three years of experimentation, the average maximum and minimum temperature was found to range between 20.5–38.7^0C and 9.2–22.1^0C, respectively.

The experiment was laid out in the split plot design with 3 replications. Keeping two sowing dates (November 25 and December 10) were assigned in the main plots, while six mulch treatments [no-mulch, paddy straw 6 t/ha (dry weight basis), carpet waste 6 t/ha (dry weight basis), jute mat, black polyethelene (2 mm sheet), white clear polyethelene (2 mm sheet)] were in sub-plots. In 5.0 by 3.0 m plots, wheat (variety: HUW-468) was sown at 22 cm row spacing with 100 kg seed/ha. Mulches were applied immediately after sowing. The rest of the field operations were carried out as per standard agronomic practices.

Plant height and length of panicle were measured from five randomly selected plants. At physiological maturity, grain and straw yield were recorded and expressed in kg/ha. Test weight (1000-seed weight) was estimated by randomly counting *P. minor* seeds and wheat grains from the bulk produce of every plot and weighed. Tiller count of wheat was recorded from two spots, each of 50 cm row length, per plot and presented in number/m^2. In *P. minor*, parameter like, biomass, number of tillers, panicle count and leaf area were estimated from 0.25 m^2 area from each plot. Leaf area index was calculated as per the formula prescribed by Watson (1952). Seed count was calculated by threshing five randomly sampled panicles and the number of seed/panicle was counted. Weed density was recorded on January 25 (i.e. critical stage of crop-weed competition) as per the procedure mentioned by Singh and Saini (2008).

Bartlett's test was used to test the homogeneity of variance among treatments. Heterogeneous weed data i.e. total weed (density and biomass) and *P. minor* biomass were square-root transformed prior to the analysis to produce a near normal distribution, although non transformed means are presented for clarity. After testing for homogeneity, all data were put to analysis of variance (ANOVA) as described by Gomez and Gomez (1984). The mean separation was accomplished by least significant difference (LSD) at 5% level of probability. ANOVA results indicated that there were no significant interactions between treatments and experimental years for most of the parameters recorded, thus, the data were pooled for combined analysis.

Results and Discussion

In wheat, observation recorded on January-25 showed, a significant higher plant height under the November-25 date of sowing (DoS hereafter) as compared to the December-10 DoS; but at the harvest, the difference was non-significant ($p < 0.05$) (Table 1). In fact, on the January 25, wheat crop sown on November-25 DoS was at late tillering/terminal spikelet stage, whereas the December-10 sown crop was at crown root initiation stage and was 15 days younger than the November-25 sown crop. So, obviously, by virtue of the age, November-25 sown crop had taller plant height over the December-10 sown crop. On the other hand, however, December-10 DoS produced a higher tiller count and grain yield over November-25 sown crop. Length of panicle, 1000-seed weight and straw yield differed non-significantly, with the difference in DoS.

Furthermore, January-25 observation revealed that November-25 sown crop increased the density and biomass of the weed as compared to later sowing date i.e. December-10 DoS (Table 2). *P. minor* grown under November-25 sown crop showed higher plant height, biomass, leaf area index, tiller count and panicle count as compared to the December-10 DoS (Table 2). LAI on January 25, length of panicle, seed count, 1000-seed weight, seed and straw yield (Table 3) did not differ significantly with the difference of DoS.

Higher number of tiller and grain yield of wheat recorded at the December-10 DoS are ascribed due to the fact that this timing coincided with low temperatures that caused the poor germination and growth of weeds in general, *P. minor* in particular, thus favoring the competitive advantage to the crop. Earlier findings also demonstrated successive decrease in weed infestations and their dry biomass under delayed sowing from normal (20, 30 November) to mid-late (5, 15 December) or late (20, 30 December) sowing (Kurchania *et al*. 1993). Indeed, an ideal temperature required for the germination of *P. minor* is 17 - 20^0C (Singh and Ghosh 1982). In November, the minimum ambient temperature was 16^0C, whereas in December the minimum temperature was below 11^0C, and this lower temperature continues till January. Thus, lower temperature not only hampered the germination of *P. minor*, but also negatively influenced its growth, *viz.* plant height, biomass, LAI, and number of tiller.

Kolar and Mehra (1992) also observed a higher biomass in *P. minor* in November sowing compared to that of October or the December sowing. Furthermore, the data clearly indicated that November-25 sowing (because of the higher number of panicles) had higher chances of seed production over later DoS.

In fact, previous findings also reveal that substantial wheat area, specially in eastern Uttar Pradesh, suffers from terminal heat stress firstly due to delayed sowing of long duration paddy varieties in rice-wheat cropping areas (Joshi *et al.* 2007) and secondly, because of the climate change and its results in shorter winters as well as the onset of significantly higher temperatures much earlier than normal (Joshi *et al.* 2007a). This could result in a reduced grain yield. The present findings also showed a lower yield under both the late sowing conditions as compared to the previously reported yield of the normal sown crop (Hussain *et al*. 2012). In addition, the present finding supplements the previous experimental facts that linear reduction of wheat yield under delayed sowing after October 25 (Hussain *et al*. 2012), could only be noticed when weeds are properly taken care of. However, if weeds are not properly managed, more yield loss can be observed under early late sowing (November-25) as compared to sowing (December-10) of wheat.

Both plant height and tiller count did not differ significantly during the January-25 observation ($p < 0.05$) (Table 1). Even, at the harvest, plant height and number of tiller showed similar result with all the tested mulch treatments, except for the carpet waste mulch. Application of the carpet waste noticeably produced lowest plant height. Furthermore, application of the carpet waste mulch produced a longest panicle length and was statistically at par with the jute mat. Contrary to panicle length, the lowest 1000-seed weight was recorded under the carpet waste mulch and was statistically at per with paddy straw mulch; though jute mat mulch recorded the highest 1000-grain weight. Statistically similar higher wheat grain yield was recorded under the

Table 1. Effect of date of sowing and mulching on growth, yield attributes and yield of wheat [Pooled data of 3 years (2008-2011)].

Treatment	Growth Parameters				Yield attributes		Yield	
	Plant height (cm)		Tillers count (number/m^2)		Length of panicle (cm)	1000-seed weight (g)	Grain (kg/ha)	Straw (kg/ha)
	Jan-25	Ah	Jan-25	Ah				
Date of sowing								
Noveber 25	60.48a	84.78	416.06b	294.37b	9.41	29.69	2840.33b	6597.78
December 10	36.49b	84.47	534.79a	384.45a	9.66	29.13	3491.76a	6503.80
$LSD_{p=0.05}$	3.85*	NS	71.06*	24.09*	NS	NS	390.62*	NS
Mulching								
No mulch	47.02	86.11a	429.84	273.71b	9.04c	29.92b	2922.10b	6019.53
Paddy straw 6t/ha	47.63	84.65a	490.67	361.64a	9.32cb	27.69c	3460.00a	6555.23
Jute mat	50.64	87.40a	488.29	363.47a	9.77a	33.83a	3577.14a	6762.43
Carpet waste 6t/ha	50.26	77.68b	465.02	373.33a	9.89a	26.63c	2536.48c	6607.31
Black polythene	46.97	88.38a	498.05	363.76a	9.68ab	29.81b	3552.68a	6723.44
White clear polythene	48.39	83.54a	480.67	300.56b	9.51ab	28.58b	2947.86b	6636.81
$LSD_{p=0.05}$	NS	5.16*	NS	47.42*	0.40*	1.35*	342.318*	NS

In a column, mean values followed by a common letter are not significantly different at $p < 0.05$. NS = Means not significant, Ah = Means at harvest.

Table 2. Effect of date of sowing and mulching on total weed and growth of *P. minor* [Pooled data of 3 years (2008-2011)].

Treatments	Total weed		*Phalaris minor*							
	Density† (number/m^2)	Biomass† (kg/ha)	Biomass† (kg/ha)		Plant height (cm)		Leaf area index (LAI)		Tillers count (number/m^2)	
	Jan-25	Jan-25	Jan-25	At harvest (Ah)	Jan-25	Ah	Jan-25	Ah	Jan-25	Ah
Date of sowing										
Nov 25	16.54(320.15)a	22.62 (743.49)a	17.90(466.22)a	21.3 (612.65)a	51.65a	80.06a	3.18	3.43a	294.28a	130.69a
Dec 10	8.04(84.11)b	8.06 (84.96)b	6.76(62.94)b	12.0 (224.88)b	27.06b	65.45b	2.14	2.48b	100.51b	84.00b
$LSD_{p=0.05}$	4.89*	3.33*	3.23	4.40	5.12	4.59	NS	0.83	32.82	29.56
Mulching										
No mulch	14.96(307.67)a	16.76 (473.38)b	13.54(289.83)b	17.65(435.70)a	38.96c	75.43	2.77	3.59a	260.17a	128.00a
Paddy straw	11.10(156.67)c	13.31 (253.98)c	10.92(162.06)c	16.97(416.49)ab	38.66c	74.16	2.93	2.88b	172.01c	109.31ab
Jute mat	11.53(171.00)bc	14.23 (354.76)bc	11.50(205.83)bc	14.52(277.47)b	37.98c	69.58	2.60	2.29b	180.13c	76.37c
Carpet waste	12.98(213.44)b	18.32 (654.41)a	16.67(545.44)a	18.91(611.12)a	43.49a	69.81	2.90	3.85a	231.03b	112.53ab
Black polythene	10.66(145.33)c	13.79 (320.42)c	10.41(181.33)c	17.59(478.25)a	36.80c	73.65	2.54	2.56 b	170.54c	100.19b
White clear polythene	12.52(218.67)b	15.63 (428.41)bc	10.94(203.00)c	14.27(293.54)b	40.23b	73.89	2.24	2.55b	170.48c	117.67ab
$LSD_{p=0.05}$	1.53*	1.24*	2.52	3.26	2.34	NS	NS	0.76	22.50	22.43

In a column, mean values followed by a common letter are not significantly different at $p < 0.05$, †Values subjected to square root transformation. Original values presented in parentheses. NS = Means not significant.

jute mat, black polyethelene and paddy straw mulches; whereas the lowest grain yield was recorded under the carpet waste mulch followed by the white clear polyethelene mulch and no-mulch.

The black polyethelene, paddy straw and jute mat mulches produced the lower density and −biomass of total weeds. However, higher density and biomass were produced by no-mulch and the carpet waste mulch (Table 2). In case of *P. minor*, observation on January-25 showed significantly highest plant height under the carpet waste mulch, followed by the white clear polyethelene mulch (Table 2). However, plant height did not differ significantly at the harvest ($p < 0.05$). Furthermore, almost similar lower plant height and biomass were recorded, at the initial stage, under the black polyethelene, paddy straw and jute mat mulches. LAI did not differ significantly during the initial observation on January 25. But at the harvest, the highest LAI was recorded under the carpet waste and was statistically at par with no-mulch; while the rest of the treatment showed statistically at par results. Observation recorded on January 25 showed the highest number of tillers under no-mulch, followed by the carpet waste; rest of treatment showed statistically similar lower number of tillers. At harvest, the highest number of tillers was observed under no-mulch and the lowest number of tillers count was however, recorded under the jute mat mulch.

Table 3. Effect of date of sowing and mulching on yield attributes and yield of *P. minor* [Pooled data of 3 years (2008 - 2011)].

Treatments	Panicles count (No./m^2)	Length of panicle (cm)	Seed count (No./panicle)	1000-seed weight (g)	Seed (kg/ha)	Straw (kg/ha)
Date of sowing						
Nov 25	143.78a	4.78	84.68	1.40	257.18	641.04
Dec 10	118.89b	4.44	86.79	1.39	288.94	630.44
$LSD_{p = 0.05}$	7.44*	NS	NS	NS	NS	NS
Mulching						
No mulch	158.17a	4.68a	82.95b	1.31b	292.96a	567.49dc
Paddy straw @ 6t/ha	151.33b	4.61a	81.46b	1.39b	289.64a	851.81a
Jute mat	114.83e	4.79a	86.98b	1.42b	264.19ab	664.94b
Carpet waste @ 6t/ha	133.33c	4.84a	100.32a	1.60a	240.18b	626.68bc
Black polythene	122.58d	4.24b	65.48c	1.36b	270.56ab	511.88d
White clear polythene	108.08f	4.54ab	97.24a	1.31b	280.81a	591.65b
$LSD_{p = 0.05}$	5.18*	0.33*	6.48*	0.13*	33.97*	95.02*

In a column, mean values followed by a common letter are not significantly different at $p < 0.05$.
NS = Means not significant.

Significantly the lowest number of panicle/m^2 was recorded under the white clear polyethelene mulch, followed by the jute mat and black polyethelene mulch (Table 3). Smallest length of panicle was recorded under the black polyethelene and was statistically at par with white clear polyethelene mulch. The black polyethelene mulch produced the lowest number of seed, followed by paddy straw no-mulch and jute mat mulch and the highest 1000-seed weight was recorded under the carpet waste. Significantly the highest 1000-seed weight was recorded under the carpet waste mulch; the rest of the treatments showed statistically similar results. The lowest seed yield was recorded under the carpet waste, followed by the jute mat and black polyethelene mulch; whereas the highest seed yield was recorded under no-mulch which are statistically at per with paddy straw, and white clear polyethelene mulch. The lowest straw yield was observed under the black polyethelene mulch; whereas the highest straw yield was recorded under paddy straw mulch.

Application of the carpet waste mulch produced the lower plant height, length of panicle and grain yield. This could be attributed to lower the C : N ratio (Shekhawat *et al.* 2010); it gets readily decomposed and adds nitrogen to the soil through mineralization. Rapid mineralization of nitrogen and other nutrient shifts the balance of crop-weed competition in favor of weeds, thereby resulting in increased density and biomass of weeds in general and *P. minor* in particular. Another reason could be due to the poor partitioning of photosynthate from the vegetative part to the reproductive organs which leads to lower production of *P. minor* seeds. Application of the paddy straw, jute mat and black plastic effectively suppressed the weeds; at the same time, enhanced wheat growth and yield. One of the most common reasons for reduced infestation under the black polyethelene, paddy straw, jute mat and white clear polyethelene mulch could be attributed to better cover of ground surface, as it reduces the entry of light to the soil surface, thus inhibiting the germination of photoblastic seeds. Similar effects of straw mulch on weed growth are also observed by Singh and Saini (2008) in Japanese mint. Besides, previous studies also showed weed growth suppression under straw mulching due to one or combinations of reasons, *viz.*, the effect of light transmittance, soil temperature and soil moisture (Teasdale 1993); release of allelochemicals by decomposed straw (Liebman and Davis 2000, Weston 1996); mechanical hindrance or direct suppression of the emerging weeds (Dyck and Liebman 1994); reduced N-availability (Siebert and Pearce 1993); or weed seed predation (Reader 1991). Similarly, reduced light transmission plays a pivotal role in suppression of weed growth under the fabric mat mulch (Miao *et al*. 2013). Moreover, reasons for weed suppression and higher crop yield under the plastic mulch can be attributed to the twin effect of reduced light penetration (Upadhyaya and Blackshaw 2007) and increased soil temperature (Moreno *et al*. 2009). Most often, clear and dark colour mulches increase more temperature over reflective colour mulches (Moreno *et al*., 2009). The similar postitive effect of the black plastic and paddy straw mulch on the yield of tomato was observed by Moreno *et al*. (2009) and Anzalone *et al*. (2010). Niu *et al.* (1998) also reported that the plastic film mulches increased dry matter accumulation in the early stage and dry matter mobilization from vegetative tissues after anthesis increasing the grain yield. Furthermore, the jute mat mulch being resistant to decomposition (decomposes in 2 - 3 years) (Maiti 2013) effectively covers the ground surface and suppresses the growth of weeds due to combinations of reasons as mentioned in the straw mulching. Application of the jute mat mulch has added advantage that it is safe, biodegradable, non-toxic to both soil and plant (Maiti 2013) and is easily applied in the field. Higher *P. minor* seed yield under the paddy straw and the jute mat mulches might be due to higher length of the panicle, whereas higher seed yield under white clear polyethelene might be due to higher length of the panicle and seed count/panicle.

Experimental results normally reveal that polythene mulches are more effective in suppressing weeds and increasing the yield of crop over straw mulch (Anzalone *et al.* 2010). But the present results show that in most of the parameters they are comparable to the paddy straw and jute mat mulches. Reasons for this might be, in most of plastic mulching experiments, plastic films were laid on the soil surface and the edges were closed tightly with soil. Then, holes were drilled by a bar (Xie *et al.* 2005). After the seedling emergence, the film was cut along the row to allow the normal growth of plants (Li *et al.* 1999). This method is applicable in vegetable production, where seedlings are transplanted. But, in this experiment, as wheat was directly sown in the field, thus strips of plastic film were laid in between the inter-row spaces. To check its displacement and to keep it intact on the surface, plastic mulch was fasted with iron clip (like stapler pins) and their edges were not tightly sealed in the soil. This would result in less increments in temperature under the sheet and weeds on the edges of the sheet are not well managed. It is worthwhile to mention that laying of plastic mulch and keeping it intact on the ground surface is a tedious job, which pave the way to the agricultural engineer to device modification in agricultural machinery for laying of plastic films in the inter-row spaces. However, further research needs to be carried out to verify similar response under other sources and differential rates of mulch on crop growth and weeds.

In summary, under the Indo-Gangetic Plains of eastern Uttar Pradesh, early sowing (November-25) of wheat provided conducive environment for infestation of weeds and had a positive influence on vegetative growth of *P. minor*; in contrast late sowing (December-10) resulted in lower weed infestation and had a positive influence on wheat growth and yield. Application of organic mulches, such as paddy straw mulch 6 t/ha and jute mat mulch effectively suppress weed growth in general and *P. minor* in particular (especially during critical period of crop-weed competition) and at the same time enhanced wheat growth (plant height, tiller count) and produced a higher length of panicle and grain yield. Carpet waste mulch was found to be highly ineffective in suppression of weeds and produced a poor grain yield of wheat. Black as well as white clear polyethelene were effective in suppression of total weeds and vegetative growth of *P. minor*, but increase *P. minor* seed yield.

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