Indian Journal of Weed Science (2022) **54**(1): 31–35
http://dx.doi.org/10.5958/0974-8164.2022.00005.3

RESEARCH ARTICLE

Phalaris minor Retz. infestation in wheat crop as influenced by different rice straw management practices usage in Punjab, India

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Received: 9 August 2021 | Revised: 9 December 2021 | Accepted: 12 December 2021

ABSTRACT

Phalaris minor Retz. is a competitive weed in wheat crop causing significant yield losses. In the rice-wheat cropping system, rice residue burning spoils the carbon cycle, pollutes the environment and deteriorates the soil health. An extensive survey was conducted during *Rabi* 2018-19 to analyse the *P. minor* infestation and wheat crop productivity under different rice straw management practices used by farmers in their fields and compared them with conventional straw burning practice. A total of 54% of respondents reported low infestation of *P. minor* in the fields sown with "*Happy-Seeder*" while 26% and 44% respondents observed low infestation of *P. minor* in fields where rice straw incorporation was done with harrow and mould board plough, respectively. The low infestation of *P. minor* in rice residue removed fields (no burning) was reported by 38% respondents. Overall, 8% respondents reported severe infestation of *P. minor* in rice straw managed fields while 30% respondents reported severe infestation of *P. minor* in wheat fields with conventional straw burning practice. *Phalaris minor* infestation was lower in fields with rice residue retention or incorporation. Therefore, rice residue management should be an important integrated weed management component especially for managing multiple-resistant *P. minor*.

Keywords: Happy-Seeder, *Phalaris minor*, Rice straw management, Rice residue burning, Residue incorporation, Transfer of technology, Wheat

INTRODUCTION

Rice-wheat is one of the major cropping systems in the Punjab state. Rice crop is being grown on an area of about 30 lakh hectares in Punjab with a production of 126 lakh tons of rice along with 220 lakh tons of straw. The large-scale adoption of coarse long duration high yielding rice varieties and combine harvesting have increased the incidence of in-situ rice residue burning in Indo-Gangetic Plains (Chaudhary *et al.* 2019). Farmers consider burning of rice straw as the easiest way to get rid of left-over rice straw in their fields. About 70-75% of the total rice straw produced in the state is being burnt in the fields in a short window of 15-20 days (Singh *et al.* 2018). The burning of rice straw has serious environmental, human and animal health implications and results in loss of organic matter and nutrients which adversely affects soil health. About 40% of N, 30-35% of P, 80-85% of K, and 40-50% of S taken up by rice plant remains in rice straw at maturity, and it is estimated that 80-90% of N and S and 15-20% of P and K present in rice straw are lost to air during burning (Jain *et al.* 2014).

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The issue of burning is not limited to state or region only but it has harmful impact across the globe. The smoke that arises from these burning contains toxic substance, including $PM_{2.5}$, CO_2, CH_4, CO, NO_x, SO_x and black carbon which are beyond international and national standard limits. To manage rice straw left in the field after combine harvesting, Punjab Agricultural University (PAU), Ludhiana has developed various site-and situation-specific straw management techniques (Mahal *et al.* 2019). It was estimated that a total of 11.4 MT of rice straw may be put into ex-situ uses and 8.3 MT of rice straw is still left for in-situ utilization. It can effectively be managed within the same field by sowing wheat with "Happy-Seeder" machine after harvesting of rice with combine harvester fitted with PAU-Super Straw Management System. The rice straw can be incorporated with mould board plough after chopping with straw chopper or mulcher or it can be collected and removed either mechanically or manually from the harvested rice fields.

Yield losses of wheat due to weeds are estimated around 25-50% and in very severe cases, the losses may go up to 80% (Malik and Singh 1995). Chemical weed control with isoproturon and 2,4-D and monoculture of rice-wheat cropping system resulted in the dominance of grass weeds particularly, *P. minor* Retz. in late 1970s. *Phalaris minor* infestation occurs in several winter crops, but it is a severe weed in wheat due to their similar morphology and growing requirements. In wheat, initial period of 4-6 weeks after sowing is most critical regarding weed competition, and large scale weed control failures in farmers' fields have been being reported. These failures were attributed mainly to delayed sowing, evolution of herbicide resistance, adverse climatic factors (low temperature, rainfall and reduced sunlight) during herbicide spray and inaccurate spray technology usage. Moreover, evolution of multiple herbicide resistance in *P. minor* has resulted from the repeated use of herbicides with a similar mode of action which could threaten the sustainability of the rice-wheat cropping system in North-West India.

Rice straw management methods have variable effect on weeds and other crop pests (Kaur *et al.* 2021). The emergence of first flush of *P. minor* is reduced to about 50% in zero-till wheat, irrespective of the soil texture and aeration (Singh *et al.* 1999, Franke *et al.* 2007). Weed dynamics are significantly affected by residue retention on surface or residue incorporation. The residue helps to reduce weed seed emergence by avoiding exposure to light and through mechanical impedance to the weed seedlings (Chhokar *et al*. 2007) or altering soil conditions (Teasdale and Mohler 2000) or by exhibiting allelopathic effects which inhibit weed seed germination (Weston 1996). The emergence of *P. minor* was lowered by 25-50% under residue retained wheat crop fields than residue removed fields under the rice-wheat cropping system (Franke *et al.* 2007). Thus, the covering or mulching the soil surface using crop residues can reduce weed problems by preventing weed seed germination and by suppressing the growth of emerging weed seedlings. Trainings and demonstrations are being undertaken to educate the farmers about benefits of maintaining mulch at soil surface on weed control especially, *P. minor*. A survey was undertaken to analyse the effect of different crop residue management technologies on weed infestation and crop productivity at farmers' fields by conducting a survey after popularising the rice residue management technology. The hypothesis of the survey study was to analyse the impact of rice residue management methods on crop, weeds and cost of cultivation at the farmers field-scale level.

MATERIALS AND METHODS

An appeal to the farmers of Punjab, India was made to avoid burning rice residues/stubbles during the months of October-November of 2017 and 2018. Extension efforts were undertaken to promote efficient agro-technologies for the crop residue recycling in rice machine harvested areas as an alternative to rice straw burning. An awareness was created with the combination of extension activities and innovative technologies to solve the problem of residue burning to a greater extent. The extension activities like distribution of extension literature, *Kisan Goshti* (farmers meeting), and conducting field days, farmers scientists' interface, training programs and campaigns on the use of "Happy-Seeder" machine for rice seeding and crop residue management techniques were undertaken by various *Krishi Vigyan Kendras* (Agricultural Science Centers) in which farmers were educated about the facts, issues and government policies about crop residue management (Mahal *et al.* 2019). The central/ state government has given huge subsidy on newly developed machineries for residue management. The farmers were advised to follow either farm machinery banks or custom hiring system approach (as farm machinery is costly) for effective and cost-friendly residue management. The technological knowledge was given to the farmers on proper handling and economic use of farm implements (Happy-Seeder, chopper, straw collector and baler) recommended by Punjab Agricultural University (PAU) for the rice residue incorporation in soil. These technologies have substantially aided farmers to manage rice residue in-situ. Happy-Seeder machines were used for sowing of wheat in combine harvested rice fields without any straw burning or removal of rice straw. The loose straw was uniformly distributed in the field prior to wheat sowing with Happy-Seeder. The chopper or mulcher or roto-drill or rotavator or cultivators or disc harrows were used by certain farmers for incorporating the rice residues in the 0-15cm soil depth. Mould-board ploughs were also used for residue incorporation and soil inversion by certain farmers. Incorporation of rice straw with rotavator or disc harrow resulted in rice straw incorporation in upper 3–5-inches soil layer only while incorporation with mould board plough resulted in inversion of soil layer and rice straw is incorporated in deeper layer (up to 8-13-inches deep). Residue removal included collection and removal of straw from the harvested rice fields mechanically using stubble shaver or rake or baler or it was removed manually by a few farmers. Residue incorporation or removal was followed by sowing of wheat crop with zero till drill or conventional seed drill.

After the completion of wheat season, an extensive survey was conducted in 22 districts of

Punjab during *Rabi* 2018-19 to analyse the pattern of usage of different rice straw management technologies by farmers in farmers' fields and to assess impact of straw management practices on the cost incurred, herbicide and irrigation water usage in wheat and wheat grain yield. The questionnaire consisted of both qualitative and quantitative questions about crop agronomy, weeds, crop yield, costs involved and their experience. In each of the district, a total of 90 farmers were identified for survey. The survey involved interviewing one-third of total farmers who have burnt the rice straw before seedbed preparation of winter wheat crop and two-third of total farmers who have managed the rice straw with any one of the methods including: sowing of wheat with Happy-Seeder machine in standing rice stubbles, incorporation of rice straw with disc harrow or with mould-board plough and removal of rice straw from fields. The total sample size was 1980 farmers, out of which sample size of 1322 farmers were those who managed the rice straw. Another sample of 658 farmers, adopting the conventional rice straw burning, was also surveyed for comparison.

RESULTS AND DISCUSSION

The crop residue management practices require hard work, time and expenditure. The elaborative extension campaign on crop residue management technologies organized during 2017-18 and 2018-19 across the Punjab state, India has helped farmers to realize or understand that burning crop residue is a disincentive for them. Farmers understood the ill effects of rice straw burning. The efforts made by PAU in popularization of short duration rice varieties cultivation in Punjab, rice straw management machinery and ex-situ use of rice straw through demonstrations, lectures, field days, Radio/TV talks, popular articles, *etc*. has resulted in scientific management of about half of the rice straw in Punjab.

The survey has revealed that the rice residue management has reduced air pollution and caused additional benefits such as water saving, weed suppression, higher yield, buffering of temperature, and quick and better wheat germination. It was observed that 60% of farmers managed rice straw by Happy-Seeder sowing (**Table 1**). Out of all straw management techniques, total cost of expenditure was the lowest for wheat sowing using Happy-Seeder in rice stubbles (₹ 4,518/- per hectare) as Happy-Seeder machine can be operated directly in combine harvested rice field and hence saved field preparation tillage cost. The wheat sowing was done using the soil moisture retained after last irrigation to rice. Thus, there was a saving of pre-sowing irrigation when compared with traditional method. The chopped straw acts as mulch and saves irrigation water in addition to weeds growth control.

Farmers opined that rice residue incorporation practice, apart from adding to soil health and controlling environment pollution from rice residue burning, results in advancement in sowing time of potato by seven days (approximately) which subsequently results in timely uprooting of potato as well as timely sowing of next crop. In addition to the timely sowing of potato by incorporating the rice straw into the soil, it also helps in improving the fertility status of the soil. Out of 37% farmers, 32% farmers preferred incorporation by rotavator and disc plough while mould board plough was used by 5% farmers (**Table 1**). The expenditure incurred was maximum when straw incorporation was done with mould board. Incorporation of rice straw has led to an increase in the soil organic carbon in the plough layer. Farmers observed that residue incorporation increased the water holding capacity, so it also aids in saving of water by reducing the number of irrigations. Earthworm population was also observed to increase in residue retained soils. Earlier studies also corroborated this finding that rice residue addition back to soil resulted in increased soil organic carbon (Ogbodo 2009, Mahal *et al.* 2019) and improved the biological life (Tian *et al.* 1993), thus creating a suitable environment for the crops to grow. In conventional straw burning method, ₹ 7,975/- per hectare was incurred by farmers as farmers use stubble cutter and spreader for cutting rice stubbles and spreading it over the field before burning the straw.

Wheat sowing was completed by 75% of total farmers up to first fortnight of November irrespective of rice straw management techniques (**Table 2**). Nearly 45% farmers sowed their wheat crop during fourth week of October to first week of November in both rice straw managed fields and in conventional sowing method (with rice residue burning). *Phalaris minor* emergence and its growth was affected by sowing date, and biomass accumulation by *P. minor* was found to be greater in November sowing (960 kg/ha) as compared to October or December (450 kg/ha) sowing of wheat under Punjab conditions (Kolar and Mehra 1992). In this study, sowing time of wheat was not affected by adoption of different rice straw management techniques and therefore sowing time was not a variable factor affecting *P. minor* density. The farmers reported average number of irrigations applied to wheat crop and wheat productivity was statistically similar in all the methods of rice straw management (**Table 1**).

Table 1. The impact of rice straw management method adopted by Punjab farmers on the cost incurred on straw management, number of herbicide sprays and irrigation usage in wheat and wheat grain yield

Rice straw management method	No. of farmers	Area (ha)	Cost incurred on rice straw management (`/ha)	Average number of herbicide sprays in wheat	Average number of irrigations given to wheat	Wheat grain yield (t/ha)
Happy-Seeder usage for wheat seeding	789(60)	3588(50)	4,518	0.86 a	2.91 a	5.34 a
Incorporation of rice straw	425(32)	2468(35)	9,718	1.40 b	3.07 a	5.28 a
Mould board plough usage	66(5)	323(5)	12,905	0.78 a	3.28 a	5.28 a
Rice straw removal	42(3)	249(4)	9,225	1.18 ab	3.17 a	5.32 a
Total: In rice straw managed fields	1322(100)	7157(100)	-	-	-	-
Conventional wheat sowing (after rice straw burning)	658	-	7,975	1.46 b	3.22 a	5.29 a

*Mean values in each column not connected by the same letter are significantly different according to Fisher's protected least significant difference (LSD) test (p=0.05); Figures in the parentheses indicate % to their respective totals of sample size.

Phalaris minor infestation was low to moderate (up to 50 plants/m^2) in 96% of cases when wheat sowing was done with Happy-Seeder (**Table 3**). The density of *P. minor* was 0-10 plants (low) and 11-50 plants/m^2 (moderate) in 26% and 58% cases, respectively when rice straw was incorporated with rotavator/disc plough. On the other hand, *P. minor* density was low and moderate in 44% and 45% cases when rice residue was incorporated with mould board plough. Further, only 4% of respondents recorded severe infestation of *P. minor* in Happy-Seeder sown fields, while 11-16% respondents observed severe infestation of *P. minor* in fields with rice straw incorporation. Presence of crop residues on soil surface creates micro-environments that are either inhibitive (Brar and Walia 2008, Sharma and Singh 2010, Mobil *et al.* 2020) or favorable (Franke *et al.* 2007) to weed emergence, seed predation and decomposition. The *P. minor* emergence was observed to be in patches in the farmers' fields, where residue mulching was not uniform in the field. Retention of residue load of 5.0 and 7.5 t/ha can reduce the weed infestation by 27.2 and 40.2%, respectively (Kaur *et al.* 2021). In residue removed field, 52% and 10% respondents reported moderate and severe density of *P. minor*, respectively. Only 12% respondents reported low weed density in fields where rice straw burning was done.

The rice residue load at farmers' fields varied from 4-9 t/ha with average of 4-6.5 t/ha residue load for short duration varieties and about 7-9 t/ha of residue load from medium to long duration rice varieties. The surveyed farmers reported that rice residue of 6 t/ha or more resulted in complete coverage of soil surface and ultimately less infestation of *P. minor* was observed as compared to less residue load (4-5 t/ha). Increasing the crop residue load as surface mulch in wheat can increase the suppression of weeds. It has been observed that increased soil moisture content in the top soil layer due to the presence of crop residues on soil surface can stimulate weed germination and consequently the emergence, particularly under a partially covered soil (Sharma and Singh 2010). On the contrary, burning of rice straw on soil surface enhanced weed seed germination of *Phalaris minor*, besides hampering the efficacy of soil active herbicides such as pendimethalin and isoproturon (Chhokar *et al.* 2009).

Weed management was done with the post-emergence herbicides, and farmers used either sequential or tank-mix applications. Farmers used clodinafop or sulfosulfuron or mesosulfuron plus iodosulfuron or metribuzin plus clodinafop to control *P. minor*. The usage of lower number of herbicides sprays was observed when wheat sowing was done by Happy-Seeder and when rice straw incorporation was done with mould board plough as compared to conventional sowing method (**Table 1**). The residue burning and residue incorporation with disc harrow has resulted in significantly a greater number of herbicides sprays for weed management. The cases of herbicide resistance evolution are more frequent with continuous usage of herbicide or herbicides belonging to the same group (Chaudhary *et al.* 2021).

Table 2. The variation in wheat sowing time by respondent farmers of rice straw managed fields vis-à-vis conventional method

Sowing time	Rice straw managed fields	Conventional sowing
4th week of October	190 (14)	86 (13)
1st week of November	392 (30)	213 (32)
2nd week of November	406 (31)	190 (30)
3rd week of November	242 (18)	114 (17)
4th week of November	92 (7)	55 (8)

Figures in the parentheses are percentages to their respective totals of sample size

Table 3. The infestation of *Phalaris minor* in wheat crop as affected by rice straw management method adopted by farmers

Rice straw management method	*P. minor* infestation		
	Low (0-10 plants/m^2)	Moderate (11-50 plants/m^2)	Severe (>51 plants/m^2)
Happy-Seeder usage for wheat seeding	421 (54)	334 (42)	34 (4)
Incorporation of rice straw	109 (26)	249 (58)	67 (16)
Mould board plough usage	29 (44)	30 (45)	7 (11)
Rice straw removal	16 (38)	22 (52)	4 (10)
Total: In rice straw managed fields	575 (44)	635 (48)	112 (8)
Conventional wheat sowing (after rice straw burning)	78 (12)	380 (58)	200 (30)

Figures in the parentheses are percentages to their respective totals of sample size

Hence, greater focus should be on integration of crop rotation, herbicide rotation, herbicide mixtures usage along with implementation of other agronomic practices like stale seed bed, zero tillage, early planting, competitive cultivars selection and increased crop seeding rate which will create the environment in favour of the crop over weeds.

It was concluded that rice residue management methods influence weed dynamics and wheat crop productivity. The residue retention at soil surface resulted in the lowest infestation of *P. minor* coupled with less cost of cultivation. The rice residue incorporation involved more cost of cultivation and resulted in less infestation of *P. minor* as compared to conventional method of rice residue burning.

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