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Comparison of Wheat Production under Different Paddy Residue Management Methods

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors designed the study. Author JSG performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MS managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to compare wheat production under two previous paddy crop residue management systems by taking into account wheat growth parameters, yield attributes and economics of both systems. Farm testing of wheat production in two methods of management of paddy residue viz: sowing of wheat with happy seeder in previous paddy crop residue (paddy residue retention) and sowing of wheat with normal drill after burning of previous paddy residue (paddy residue burning: farmer practice) done in Ferozepur and Jalandhar districts on 10 farmers' fields locations in each district during rabi season of 2016-17 and 2017-18. Dataset was analyzed using unpaired T test. Both paddy residue retention and paddy residue burning methods resulted in non-significant effect on growth parameters and yield attributes which resulted similar mean grain yields (5.48 t/ha) and (5.35 t/ha), respectively in both districts during two years of study. Paddy residue retention method reduced the cost of wheat cultivation and put a check on air pollution from burning of paddy residue in the field. It saved fertilizers by adding nutrients to the field.

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Keywords: Wheat; paddy residue retention; paddy residue burning; happy seeder; grain yield; cost; nutrients.

1. INTRODUCTION

Rice-wheat cropping system of the Indo-Gangetic Plains (IGP) is of great significance in the food security of the country. This cropping system covering an area of 10 million hectares of IGP of India and occupies around 2.7 million hectares in Punjab [1,2]. In Punjab, mostly the paddy and wheat crops are harvested by combine harvesters due to mechanization of rice-wheat system. The wheat residue is often used to feed the animals. However, the paddy straw is considered low-quality feed for animals due to its high silica content. Burning of paddy straw (loose straw and standing stubbles) is an easiest and cheap method of crop residue management option. Presently, more than 80% of the rice straw produced is being burnt by farmers [3]. Burning of crop residue causes loss of soil organic matter and nutrients, increasing carbon emissions, causing intense air pollution and reducing activity of soil microbial activity [4,5,6]. Efficient crop residue management can play a vital role in soil fertility management, refurbishing soil productivity and to increase efficiency of inorganic fertilizer. Keeping in view the objective of understanding differences between wheat sowing after burning of paddy residues and wheat sowing in previous paddy crop residues without burning, this study was planned to compare wheat sowing with happy seeder into previous paddy crop residue and wheat sowing with normal drill after burning of paddy residue and by taking into account wheat production.

2. MATERIALS AND METHODS

The on-farm testing on two methods of management of paddy residue viz: sowing of wheat with happy seeder a machine developed by Punjab Agricultural University (PAU), Ludhiana in previous paddy crop residue which include loose straw and standing stubbles (paddy residue retention) and sowing of wheat with normal drill after burning of previous paddy residue (paddy residue burning: farmer practice) by taking into account wheat production in Dhira Patra, Mallwal Jadid, Changali Jadid, Mankianwali and Dhanna Shahid villages of Ferozepur district and Nagar, Bias, Gol and Nawan Pind villages of Jalandhar district on 20 locations (farmer fields) in *rabi* season of 2016-17 and 2017-18. These locations were randomly selected to increase the number of replications. Plot size was 2000 m^2 (0.5 acre). These trials were researcher-designed and farmer-managed, with a single replicate, repeated over 20 locations. All the locations showed the soil texture sandy loam except two locations which had soil texture loamy sand in Ferozepur district and clay loam in Jalandhar district. Paddy was harvested with a combine harvester. In paddy residue retention method the loose straw windrows from the combine harvester were distributed evenly across the plots and standing stubbles of previous paddy crop were cut with help of the cutter or reaper (stubble shaver) prior to sowing with the PAU Happy Seeder. The wheat variety HD 2967 was sown at 100 kg/ha with 20 cm row spacing. Wheat was drilled directly into paddy residue with the PAU Happy Seeder. To supply phosphorus 137.5 kg (63 kg P_2O_5) per hectare of DAP was drilled at sowing and urea was applied in two equal splits each of 110 kg (50 kg N) per hectare before first and second irrigation. In paddy residue burning method the paddy straw (loose straw and standing stubbles) was burnt prior to sowing of wheat. Wheat was sown with seed-cum-fertilizer drill after field preparations. To supply phosphorus 137.5 kg (63 kg P_2O_5) per hectare of DAP was drilled at sowing. To supply nitrogen 112.5 kg (51.8 kg N) per hectare neem coated urea was applied with final preparatory tillage and remaining dose of urea was applied in two equal splits each of 56.3 kg (25.9 kg N) per hectare was applied after first and second irrigation. The various operations and inputs like field preparation, sowing, fertilizer, weedicide, insecticide, fungicide, harvesting, transportation and marketing were assessed at their custom hiring rates and at their prevailing rates in the open market. All the dataset was analyzed using unpaired T-test and differences among methods of paddy residue management were compared at 0.05 level of significance (Confidence Interval 95%).

3. RESULTS AND DISCUSSION

3.1 Emergence (m^{-2})

Plant emergence constitutes the very basis of optimum plant population stand, which ultimately account for the crop yield. So emergence count may be considered as a fair predictor of final plant population. The scrutiny of data in Table 1 revealed that the estimate of the difference

between paddy residue retention and paddy residue burning methods means was -6.49 for Ferozepur district and -6.66 for Jalandhar district, respectively. 95% confidence interval (CI) of the difference ranging from -14.05 to 1.08 for Ferozepur district and -13.97 to 0.64 for Jalandhar district. The calculated t-values 1.79 and 1.90 for Ferozepur and Jalandhar districts, respectively were smaller than tabulated value 2.09 at 0.05 significance level. The P-values 0.09 for Ferozepur and 0.07 for Jalandhar were greater than the significance level 0.05. These findings showed that paddy residue retention and paddy residue burning methods had a non-significant effect on emergence count during two years of study.

3.2 Plant Height (cm)

Plant height is an index of growth and development representing the infrastructure build-up over a period of time. As is evident from the data given in Table 2 that the estimate of the difference between paddy residue retention and paddy residue burning methods means was 0.80 for Ferozepur and -1.21 for Jalandhar district. 95% confidence interval (CI) of difference revealed that we confident that the difference between paddy residue retention and paddy residue burning methods means was between -0.49 and 2.09 for Ferozerpur and -2.86 and 0.44 for Jalandhar.

The calculated t-values 1.30 and 1.53 were smaller than tabulated value 2.09 at 0.05 significance level for Ferozepur and Jalandhar districts, respectively. The P-values 0.21 for Ferozepur and 0.14 for Jalandhar district were greater than the significance level 0.05. These results showed that the difference in plant height at harvesting between paddy residue retention and paddy residue burning methods was not significant during both the years of study in both districts. The wheat crop sown with happy seeder

Table 1. The difference of wheat emergence between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	172.24	162.32	7.91	8.93					-14.05 to 1.08	-13.97 to 0.64				
Paddy straw removed	178.73	168.98	9.06	7.42	20	20	-6.49	-6.66			1.79	1.90	0.09	0.07
											2.086***		P = .05	

F - Ferozepur, J** – Jalandhar, *** Value of the t-distribution table at 0.05 significance level*

Table 2. Difference of wheat plant height at harvesting between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	98.42	100.56	1.53	1.93					-0.49 to 2.09	-2.86 to 0.44				
Paddy straw removed	97.62	99.35	1.31	1.78	20	20	0.80	-1.21			1.30	1.53	0.21	0.14
											2.09***		P = .05	

into previous paddy residue produced wheat plants with equal height to residue burning method plants may be due to better nutrients uptake which in turn stimulated the cell division and cell elongation which resulted in better plant growth.

3.3 Effective Tillers (m^{-2})

The number of effective tillers i.e. tillers with fertile panicle is an important yield attribute which accounts for major variation in wheat grain yield. The data presented in Table 3 showed that the difference in paddy residue retention and paddy residue burning methods means were 4.32 and 2.89 for Ferozepur and Jalandhar districts, respectively.

95% confidence interval (CI) of difference between paddy residue retention and paddy residue burning methods means was likely to be between -0.48 and 9.11 for Ferozrpur district and -2.15 and 7.93 for Jalandhar district, respectively. The calculated t-values 1.88 and 1.20 for Ferozepur and Jalandhar districts respectively were smaller than tabulated value 2.09 at 0.05 significance level. The P-value of 0.07 for Ferozepur and 0.25 for Jalandhar districts were greater than the significance level 0.05. These results showed that wheat effective tillers were not significantly influenced by paddy residue retention and paddy residue burning methods during both the years of study in both districts. Good leaf area index and root growth and development in the upper layer of soil surface due to mulching where these got the good opportunity for nutrient uptake resulted in more effective tillers in paddy residue retention method. Kharia et al. [1] also reported a non-significant effect of paddy residue retention and paddy residue removed methods on wheat effective tillers per meter square.

3.4 1000-Grain Weight

The weight of individual grain calculated from 1000 grain weight (test weight) is an important yield attribute which provides information regarding the efficiency with which grain filling process took place. The data in respect of wheat 1000 grain weight presented in Table 4 revealed that the estimate of the difference of 1000 grain weight of wheat between paddy residue retention and paddy residue burning methods means was 0.24 for Ferozepur district and 0.31 for Jalandhar district, respectively. With 95% confidence interval the difference of 1000 grain weight of wheat between paddy residue retention and paddy residue burning methods was between -0.47 to 0.94 for Ferozepur district and -0.23 to 0.85 for Jalandhar district. The calculated t-values 0.70 and 1.20 of 1000 grain weight for Ferozepur and Jalandhar districts were smaller than tabulated value 2.09 at 0.05 significance level. The P-value 0.49 for Ferozepur district and 0.25 for Jalandhar district was greater than the significance level 0.05. These findings showed the insignificant difference between paddy residue retention and paddy residue burning methods. The positive effect of mulching in paddy residue retention method resulted in good crop growth, photosynthesis and nutrient uptake which caused good 1000 grain weight. Kharia et al. [1] and Rahman et al. [7] also reported that wheat 1000 grain weight was higher in wheat sown with happy seeder in previous paddy crop residue than conventional till wheat.

Table 3. Difference of wheat effective tillers between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	277.92	257.72	4.58	4.82	20	20	4.32	2.89	-0.48 to 9.11	-2.15 to 7.93	1.88	1.20	0.07	0.25
Paddy straw removed	273.60	254.83	6.09	6.39										
											2.09***		*P = .05*	

Table 4. Difference of wheat 1000 grain weight between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	40.26	41.74	0.92	0.69	20	20	0.24	0.31	-0.47 to 0.94	-0.23 to 0.85	0.70	1.20	0.49	0.25
Paddy straw removed	40.03	41.43	0.65	0.51										
											2.09***		*P = .05*	

3.5 Grains per Spike

The grains are fertilized; fully ripened ovule of spikelet in a spike that ultimately contributes to grain yield. The data on a number of grains per spike depicted in Table 5 showed that the difference of wheat grains per spike in paddy residue retention and paddy residue burning methods means was 2.23 for Ferozepur district and 1.60 for Jalandhar district, respectively. With 95% confidence interval the difference of wheat grains per spike in paddy straw retained and paddy straw removed methods was between -0.69 to 5.15 for Ferozepur district and -1.13 to 4.33 for Jalandhar district. The calculated t-values 1.59 and 1.22 of wheat grains per spike for Ferozepur and Jalandhar districts were smaller than tabulated value 2.09 at 0.05 significance level. The P-value 0.13 for Ferozepur district and 0.24 for tabulated value 2.09 at 0.05 significance level. The P-value 0.13 for Ferozepur district and 0.24 for Jalandhar district was greater than the significance level 0.05. The difference of wheat grains per spike between paddy residue retention and paddy residue burning methods was insignificant. The highest value of several grains per spike in paddy residue retention method was the resultant of good crop growth, photosynthesis and nutrient uptake due to the good effect of mulching on soil microclimatic conditions. Sidhu et al. [8] reported that wheat sown with happy seeder produced higher number of grains per spike than conventional till wheat.

3.6 Spike Length (cm)

Spike length is directly related to the number of grains per spike and hence this is an important determinant of grain yield. The perusal of data as presented in Table 6 showed that the difference of wheat spike length in paddy residue retention and paddy residue burning methods means was 0.02 for Ferozepur district and 0.23 for Jalandhar district, respectively. With 95% confidence interval the difference of wheat spike length in paddy residue retention and paddy residue burning methods was between -0.63 to 0.67 for Ferozepur district and -0.84 to 1.29 for Jalandhar district. The calculated t-values 0.06 and 0.45 of wheat spike length for Ferozepur and Jalandhar districts, respectively were smaller than tabulated value 2.09 at 0.05 significance level. The P-value 0.95 for Ferozepur district and 0.66 for Jalandhar district was greater than the significance level 0.05. These results revealed that the difference of wheat spike length between paddy residue retention and paddy residue burning methods was non-significant. Kharia et al. [1] and Rahman et al. [7] also reported that wheat spike length was higher in wheat sown with happy seeder in previous paddy crop residue than wheat sown after removal of paddy residue.

3.7 Grain Yield (t ha^{-1})

Grain yield is a function of various growth and yield attributing parameters. Grain yield is the main criterion for judging the comparative efficacy of different methods. The data on grain yield presented in Table 7 showed that the difference of wheat grain yield between paddy residue retention and paddy residue burning methods means was 0.11 for Ferozepur district and 0.15 for Jalandhar district, respectively. With 95% confidence interval the difference in paddy straw retained and paddy straw removed methods was between -0.05 to 0.26 for Ferozepur district and -0.06 to 0.36 for Jalandhar district. The calculated t-values 1.46 and 1.53 of wheat grain yields for Ferozepur and Jalandhar districts respectively were smaller than tabulated

value 2.09 at 0.05 significance level. The P-value 0.16 for Ferozepur district and 0.14 for Jalandhar district was greater than the significance level 0.05. Results showed that paddy residue retention and paddy residue burning methods produced similar grain yield. The retention of paddy residue had not reduced wheat yields compared to where paddy residue was burnt. The wheat crop sown with happy seeder in previous paddy crop residue produced comparable grain yield to wheat sown after removal or burning of paddy residue due to equal spike density and number of grains per spike. Kharia et al. [1], Naresh RK et al. [9], Sidhu et al. [10] and Sidhu et al. [8] also reported that wheat sown with happy seeder produced a comparable or higher yield than wheat sown after removal of previous paddy crop residue.

Table 5. Difference of number of grains per spike between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	52.54	54.52	3.83	3.54	20	20	2.23	1.60	-0.69 to 5.15	-1.13 to 4.33	1.59	1.22	0.13	0.24
Paddy straw removed	50.31	52.92	2.62	2.51							2.089***		*P = .05*	

Table 6. Difference of wheat spike length between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	11.32	10.61	0.73	1.14	20	20	0.02	0.23	-0.63 to 0.67	-0.84 to 1.29	0.06	0.45	0.95	0.66
Paddy straw removed	11.30	10.38	0.73	1.25							2.09***		*P = .05*	

Table 7. Difference of wheat grain yield between paddy residue retention and paddy residue burning methods

Methods	Means		Standard deviation		Degree of freedom		Difference of means		95 % CI		t-value		P-value	
	F*	J**	F	J	F	J	F	J	F	J	F	J	F	J
Paddy straw retained	5.50	5.45	0.18	0.20	20	20	0.11	0.15	-0.05 to 0.26	-0.06 to 0.36	1.46	1.53	0.16	0.14
Paddy straw removed	5.39	5.30	0.17	1.26							2.09***		*P = .05*	

3.8 Cost of Cultivation

The pattern of inputs used and various costs involved in both methods of wheat cultivation viz; wheat sowing with normal drill after burning of previous paddy crop residue and wheat sowing with happy seeder in previous paddy crop residue has been discussed in cost of cultivation (Table 8). Per hectare costs of field preparation and sowing showed a decline in the case of wheat sowing with happy seeder (Rs. 2030) against wheat sowing with normal drill after burning of previous paddy crop residue (Rs. 4785), which was mainly due to saving in preparatory tillage (2 discing, 2 harrowings, 2 plankings). Sidhu et al. [8] also found that the cost of establishment with the happy seeder ('custom' or contract hiring) is about half the cost of establishment using conventional practice. The expenditure on weedicides was observed more in wheat cultivation method wheat sowing with normal drill after burning of previous paddy crop residue (Rs. 750) than wheat sowing with happy seeder in previous paddy crop residue, which was due to suppression of weed growth by mulching with paddy straw in happy seeder sown wheat. Fertilizers costs (Rs. 4557), insecticide/fungicide (Rs. 875) and harvesting costs (Rs. 2750) were similar in both methods of wheat cultivation. There was a slight difference in transportation and marketing costs for paddy residue burnt method (Rs. 2813.1) and paddy residue retention method (Rs. 2845). This difference was due to slightly higher yield in wheat sowing with happy seeder in previous paddy crop residue which slightly increases the cost of unloading, sieving and weighing in grain market. Method of wheat sowing with happy seeder in previous paddy crop residue recorded lower cost of human labour (Rs. 1374.08) than wheat sowing with normal drill after burning of previous paddy crop residue method (Rs. 2174.25), which was mainly due to saving in land preparation labour cost. Dhillon [11] also reported similar results.

3.9 Economics of Wheat Cultivation

Comparison of profitability between method of wheat sowing with normal drill after burning of previous paddy crop residue and wheat sowing with happy seeder in previous paddy crop residue was done by computing cost and returns. The cost of cultivation was 15.17 percent less in wheat sowing with happy seeder method. Gross return and net return realized were 2 percent and 5.55 percent more in wheat sowing with happy seeder method over method of wheat sowing with normal drill after burning of previous paddy crop residue. The method of wheat sowing with happy seeder in previous paddy crop residue recorded higher B.C ratio. Dhaliwal et al. [12] also reported higher return over variable costs in wheat sown with happy seeder as compared to the conventional method of sowing.

The loose paddy straw and standing stubbles left over after the combine harvesting was not burnt in paddy residue retention method and wheat crop was sown with happy seeder machine in previous paddy crop residue. A part of nutrients taken up by paddy crop from soil during the growing period was remaining in paddy straw which was again got conserved in soils. Organic matter added to soils of farm field by retaining paddy residue (loose paddy straw and standing stubbles) improved the physical properties of the soils like water holding capacity, porosity, bulk density etc. The paddy residue biomass added 44.2 kg nitrogen, 14.3 kg phosphorus and 119 kg potash in one hectare area (Table 10). In this way retention of paddy residue in field saved 97.2 kg urea, 88.7 kg superphosphate and 202.3 kg muriate of potash fertilizers in one-hectare area. Wheat sowing into paddy residue also put check on the air pollution by burning of crop residue. It saved 20.4 kg particulate matter, 408 kg carbon monoxide, 9928 kg carbon dioxide, 1353.2 kg ash and 13.6 kg sulfur emission in the atmosphere.

Table 8. Costs of wheat cultivation under paddy straw retained method vs paddy straw burnt (Rs/ha)

Particulars	Paddy straw retained	Paddy straw burnt
Field preparation	2030	4785
Fertilizer	4575	4575
Weedicide	-	750
Insecticide/pesticide	875	875
Harvesting (Combine)	2750	2750
Transportation and marketing	2395.0	2363.1
Human labour	1374.08	14449.08

Table 9. Economics of wheat cultivation under paddy straw retained method vs paddy straw burnt

Particulars	Paddy straw retained	Paddy straw burnt
Cost of cultivation (Rs/ha)	13999.1	18268.6
Grain yield (t/ha)	5.50	5.39
Gross return (Rs/ha)	95425	93516.5
Net return (Rs/ha)	81425.92	75247.9
B:C ratio	5.82	4.12

Savings by retaining paddy straw over the burning of paddy straw

Table 10. Savings by retaining paddy straw over burning of paddy straw

Particulars		Rs/ha or amount	
Field preparation		Rs. 2755	
Nutrients (kg/ha)			
(i) N		(i)	44.2
(ii) P		(ii)	14.3
(iii) K		(iii)	119
Fertilizers (kg/ha)			
(i) Urea		(i)	97.2
(ii) Superphosphate		(ii)	88.7
(iii) Muriate of potash		(iii)	202.3
Check on air pollution due to emissions from burning of crop residue (kg/ha)			
(i)	Particulate matter	(i)	20.4
(ii)	Carbon monoxide	(ii)	408
(iii)	Carbon dioxide	(iii)	9928
(iv)	Ash	(iv)	1353.2
(v)	Sulfur dioxide	(v)	13.6

The data on nutrients saving were calculated from estimates of 10.7 Mt of rice straw burning in 2001-02 (Gajri et al. [13]), straw yield of 6 t/ha (Sidhu et al. [8]), and nutrient composition of straw and per cent lost in burning by Dobermann and Fairhurst [14] mentioned in (Singh et al. [15]). The data on emissions from crop residue were calculated from estimates of Gupta and Sahai [16]

4. CONCLUSION

The method of wheat crop sowing with happy seeder in previous paddy crop residue gave similar or slightly higher grain yield than wheat crop sown with normal drill after burning of previous paddy residue. This method reduced cost of machinery operations for wheat crop establishment by reducing the time taken for field operations, reduced weed control costs (suppression of weeds by mulching) and labour costs. It avoids the need for burning and the terrible air pollution due to burning. Retention of paddy residue in field added nutrients to the field along with organic matter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kharia SK, Thind HS, Goyal A, Sharma S, Dhaliwal SS. Yield and nutrient uptake in wheat under conservation agriculture based paddy-wheat cropping system in Punjab, India. Int J Curr Microbiol Appl Sci. 2017;6(2):1698-1708.
2. Singh A, Kang JS, Kaur M. Planting of wheat with happy seeder and rotavator in paddy stubbles. Indo Am J Agr Vet Sci. 2013;1(2):32-41.
3. Singh Y, Singh M, Sidhu HS, Khanna PK, Kapoor S, Jain AK, Singh AK, Sidhu GK, Singh A, Chaudhary DP, Minhas PS. Options for effective utilization of crop residue. Directorate of Research, Punjab Agricultural University, Ludhiana (Punjab) India. 2010;32.

4. Singh Y, Singh B, Ladha JK, Khind CS, Khera TS, Bueno CS. Effects of residue decomposition on productivity and soil fertility in paddy–wheat rotation. Soil Sci Soc Am J. 2004;68:854–64.
5. Singh Y, Singh B, Timsina J. Crop residue management for nutrient cycling and improving soil productivity in paddy-based cropping systems in the tropics. Adv Agron. 2005;85:269-407.
6. Kumar K, Goh KM. Crop residue management: Effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. Adv Agron. 2000;68:197-319.
7. Rahman MA, Chikushi J, Saifizzaman M, Lauren JG. Paddy straw mulching and nitrogen response of no-till wheat following paddy in Bangladesh. Field Crops Res. 2005;91:71-81.
8. Sidhu HS, Manpreet-Singh, Humphreys E, Yadvinder-Singh, Balwinder-Singh, Dhillon SS, Blackwell J, Bector V, Malkeet-Singh, Sarbjeet-Singh. The happy seeder enables direct drilling of wheat into paddy stubble. Aus J Exp Agric. 2007;47:844–54.
9. Naresh RK, Singh SP, Kumar D, Pratap B. Experience with managing paddy residue in intensive paddy-wheat cropping system in north-western India. Int J Life Sci Biotechnol Pharma Res. 2013;2(2):85-96.
10. Sidhu HS, Singh M, Yadvinder-Singh, Blackwell J, Singh V, Gupta N. Machinery development for crop residue management under direct drilling. In: Resilient Food Systems for a Changing World. Proceedings of the 5th World Congress on Conservation Agriculture. Incorporating 3rd Farming Systems Design Conference, 25-29th September, Brisbane, Australia. 2011;157-58.
11. Dhillon GS. Comparative evaluation of happy seeder technology versus normal sowing in wheat (*Triticum aestivum*) in adopted village Killi Nihal Singh of Bathinda district of Punjab. J Appl Nat Sci. 2016;8(4):2278-82.
12. Dhaliwal HS, Singh RP, Kaur H. Financial assessment of happy seeder. Conserv Agric. 2011;17:4-5.
13. Gajri PR, Ghuman BS, Singh S, Misra RD, Yadav DS, Singh H. Tillage and residue management practices in paddy wheat system in Indo-Gangetic Plains – a diagnostic survey. Technical Report, National Agricultural Technology Project, ICAR: New Delhi and Department of Soils, PAU: Ludhiana; 2002.
14. Dobermann A, Fairhurst TH. Paddy straw management. Better Crops Int. (Special Supplement). 2002;16:7-11.
15. Singh RP, Dhaliwal HS, Humphreys E, Sidhu HS, Singh M, Singh Y, Blackwell J. Economic assessment of the happy seeder for paddy-wheat systems in Punjab, India. AARES 52nd Annual Conference, Canberra, ACT, Australia; 2008.
16. Gupta PK, Sahai S. Residue open burning in paddy-wheat cropping system in India: An agenda for conservation of environment and agricultural conservation agriculture. In 'Conservation Agriculture – Status and Prospects', ed. by I. P. Abrol, R. K. Gupta and R. K. Malik. Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre: New Delhi. 2005;50-54.

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