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PADDY STRAW MANAGEMENT PRACTICES AND THEIR IMPACT ON WHEAT YIELD

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Rice-Wheat cropping system (RWCS) is a widely followed system in the Asian countries primarily in the South Asian countries. In the Indo-Gangetic Plains (IGP). It is practised nearly on 13.5 million hectares covering major countries of Bangladesh, India, Nepal and Pakistan (Davre *et al*., 2004; Ladha *et al*., 2000). RWCS has tremendously contributed in maintaining food supply in accordance with rising population in these regions (Pathak *et al*., 2003). But, with the passage of time, this system is generating sustainability threat in the form of its negative effects on soil quality and environment. Soil nutrients and soil organic carbon (SOC) are reported to be declining and the yield of crops is declining which is in turn being maintained by consumption of huge amount of fertilizers. The use of high amount of fertilizers in the soil leads to reduction of soil organic carbon *(SOC)* (Pichotet *et al*., 1981).

In this system, management of the residue of any crop has an important implication on the physical, chemical and biological properties of soil, nutrient content and organic content of soil. Paddy and wheat are being produced in a cyclical manner in RWCS. While the residue of wheat is widely used as fodder for livestock but a major proportion of paddy straw remains unutilized due to its inferior quality. Presence of high amount of *silica* in paddy straw makes it difficult to digest for animals and which negatively affects their health and milk productivity. Management of paddy straw is a tedious task especially because farmers are left with little time after paddy harvesting for the sowing of wheat crop. Thus, in order to get rid off paddy straw as early as possible, farmers resort to its burning as the most convenient alternative which has negative environmental implications. It is an important source of emission of Air Pollutants, Greenhouse Gases (GHGs) and Particulate Matter ($PM_{2.5}$). Apart from its strong implications on environment, burning of paddy straw also negatively affects the soil and yield of succeeding wheat crop.

Complete Incorporation (CI), Partial Incorporation (PI), Mulching (MUL) and Complete Removal (CR) are some in-situ paddy straw management alternatives available to farmers. Each paddy straw management practice has its own positive and negative effects on the soil quality and yield of wheat crop. Based on the climate and type of soil, these practices have different effects on soil health and yield of crops. Various scientific studies regarding the impact of paddy straw management practices on the quality of soil and yield of paddy and wheat crops have been done, but there is a dearth of social science studies in this sector which examine their impact on soil and yield of next wheat crop from farmers' point of view. In the light of that, this study aims to investigate the impact of paddy straw management practices on the consumption of fertilizers (Urea and Di-Ammonia-Phosphate) and wheat yield from farmers' point of view.

The present study is based on multi-stage stratified random sampling technique for the collection of primary data. A sample size of 270 farmers was selected randomly from 27 villages of 3 districts of Haryana state of India. The data has been collected by using semi-structured questionnaire and then analyzed by using paired t-test.

$$t = \frac{(\sum D)/N}{\sqrt{\frac{\sum D^2 - \left(\frac{(\sum D)^2}{N}\right)}{(N-1)(N)}}}$$

Where, D = difference per paired value
N = number of samples

Paddy straw management practices

1. Complete Incorporation (CI): Under the practice of complete incorporation, the intact and loose part of the straw is incorporated in the soil either by following multiple tillage operations (harrow, cultivator, planker or rotavator) or by using super seeder machine on the combine harvested field. After the incorporation of straw, wheat sowing has been done by zero till seed drill machine or simple sowing machine.
2. Partial Incorporation (PI): It is the practice under which the loose part of the straw has been manually extracted from the field whereas the intact part of the straw has been incorporated in the soil by following multiple tillage activities. Sowing of wheat

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has been done by using ZT seed drill or simple sowing machine.

3. Mulching (MUL): Happy Seeder machine has been used for the mulching of paddy straw. This machine simultaneously performs the dual function of straw mulching and wheat sowing.
4. Complete Removal (CR): It is that operation in which both the loose and intact part of the straw has completely been removed .

Impact of paddy straw management practices on fertilizer consumption

Table 1 shows the results of paired t test for the impact of paddy straw management practices on fertilizer consumption (Urea and DAP). Before and after analysis reveals that the mean consumption of both Urea and DAP has been increased after the adoption of complete burning from 130.1 kg/acre to 151.4 kg/acre and from 50 kg/acre to 52.6 kg/acre, respectively. On contrary , the reduction in the utilization of both Urea and DAP has been observed after the adoption of complete incorporation. The consumption of Urea has also been increased to 156.4 kg/acre in mulching because the mulched straw act as a barrier to the direct application of urea in the soil as a result of this the urea consumption has been increased. In case of complete removal and partial incorporation, DAP consumption has remained intact at 50 kg/acre but the consumption of Urea has been decreased because of the availability of nitrogen in the soil. . Thus, except burning and mulching, there is a decline in the application of Urea in other practices. Though DAP use has been increased in burning and decreased in mulching, but for other practices it remained same.

The outcomes of paired samples test of fertilizer consumption presented in Table 2 depict a significant increase in Urea and DAP utilization after the adoption of complete burning since its p-value is less than 0.05 and mean increase in Urea and DAP consumption is 21.3 kg/acre and 2.6 kg/acre, respectively. In context of other practices like complete incorporation and complete removal, there was significant decrease in the consumption of Urea i.e. the Urea consumption has been reduced after the adoption of complete incorporation practice by 22.8 kg/acre whereas it has been reduced by 14.9 kg/acre under the practice of complete removal. A mere reduction by 1.8 kg/acre in the application of Urea has seen in partial incorporation practice but no difference in the consumption of DAP has been observed. Though, an increase in Urea consumption has been observed after the following of

Table 1. Paired sample statistics of fertilizer consumption (Kg/acre)

Practice	Fertilizer		Mean	N*	Std. Deviation	Std. Error Mean
Complete Burning	Urea	Before	130.1420	88	26.52357	2.82742
		After	151.4148	88	19.55015	2.08405
	DAP	Before	50.0000	88	.00000	.00000
		After	52.5568	88	7.61858	.81214
Complete Incorporation	Urea	Before	148.1538	65	24.80501	3.07668
		After	125.3077	65	47.89007	5.94003
	DAP	Before	50.0000	65	.00000	.00000
		After	48.4615	65	6.05464	.75099
Partial Incorporation	Urea	Before	149.2105	19	33.71709	7.73523
		After	147.3158	19	12.00395	2.75389
	DAP	Before	50.0000[a]	19	.00000	.00000
		After	50.0000[a]	19	.00000	.00000
Mulching	Urea	Before	149.7414	58	20.45368	2.68570
		After	156.4483	58	51.46867	6.75817
	DAP	Before	52.5862	58	11.17019	1.46672
		After	50.0000	58	.00000	.00000
Complete Removal	Urea	Before	149.6684	99	20.28482	2.04908
		After	134.7449	99	14.71328	1.48627
	DAP	Before	50.0000[a]	99	.00000	.00000
		After	50.0000[a]	99	.00000	.00000

a. The correlation and t cannot be computed because the standard error of the difference is 0. *N = Sample Size

Table 2. Paired Samples Test for Fertilizer Consumption (Kg/acre)

Practice*	Fertilizer	Pair	Paired differences					t	df	Sig (2-tailed)
			Mean	Std. deviation	Std. error mean	95% of confidence interval of the difference				
						Lower	Upper			
CB	Urea	Before-After	-21.27273	33.45729	3.56656	-28.36165	-14.18380	-5.964	87	.000
	DAP	Before-After	-2.55682	7.61858	.81214	-4.17104	-.94260	-3.148	87	.002
CI	Urea	Before-After	22.84615	59.99166	7.44105	7.98095	37.71136	3.070	64	.003
	DAP	Before-After	1.53846	6.05464	.75099	.03820	3.03873	2.049	64	.045
PI	Urea	Before-After	1.89474	30.79627	7.06515	-12.94859	16.73807	.268	18	.792
	DAP	Before-After	0	0	0	0	0	0	0	0
MUL	Urea	Before-After	-6.70690	43.04873	5.65258	-18.02598	4.61219	-1.187	57	.240
	DAP	Before-After	2.58621	11.17019	1.46672	-.35084	5.52326	1.763	57	.083
CR	Urea	Before-After	14.92347	22.76690	2.29980	10.35899	19.48794	6.489	97	.000
	DAP	Before-After	0	0	0	0	0	0	0	0

*Complete Burning (CB), Complete Incorporation (CI), Partial Incorporation (PI), Mulching (MUL) and Complete Removal (CR).

mulching by 6.7 kg/acre which is insignificant at 95% confidence level as its p-value is greater than 0.05, but a reduction of 2.6 kg/acre DAP has been showed in case of Mulching.

To sum up, there is a significant increase in the utilization of both Urea and DAP after the adoption of Complete Burning of paddy straw. However, the Urea consumption has also been increased in the practice of Mulching. But no increase in DAP consumption has been found in Partial Incorporation and Complete Removal of paddy straw. Due to the following of the practice of Complete Incorporation, a significant decrease in the consumption of both Urea and DAP has been observed. Therefore, it can be concluded that burning of paddy straw leads to increase the usage of fertilizers in the soil whereas non-burning decreases its utilization.

Impact of paddy straw management practices on the yield of wheat Crop

The Table 3 shows the impact of paddy straw management practices on the yield of wheat crop. It shows that the mean yield of wheat has been decreased from 23.6 q/acre to 20.5 q/acre after the adoption of Complete Burning. Burning of straw results in the deterioration of soil quality which negatively affects the yield of wheat crop. On the other hand, the wheat yield has increased in the remaining practices of non-burning of paddy straw.

The highest increase of approximately 3 kg/acre in wheat yield is observed in the practice of Complete Incorporation. The results are significant since the p-value is less than 0.05 in all the given paddy straw management practices.

Table 3. Paired sample statistics of wheat yield (q/acre)

Practice	Pair	Mean	N	Std. deviation	Std. error mean
Complete Burning	Before	23.6591	88	2.03919	.21738
	After	20.5114	88	1.53873	.16403
Complete Incorporation	Before	21.0968	65	2.17821	.27663
	After	24.0806	65	2.19760	.27910
Partial Incorporation	Before	20.4211	19	1.42657	.32728
	After	22.0000	19	1.88562	.43259
Mulching	Before	21.3448	58	1.73257	.22750
	After	23.4138	58	2.59578	.34084
Complete Removal	Before	19.7604	99	1.78145	.18182
	After	20.2813	99	1.91780	.19573

Table 4. Paired sample test of impact on wheat yield

Practice	Pair	Paired Differences					t	df	Sig (2 tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Complete Burning	Before-After	3.14773	1.57961	.16839	2.81304	3.48241	18.693	87	.000
Complete Incorporation	Before-After	-2.98387	3.48059	.44204	-3.86777	-2.09997	-6.750	61	.000
Partial Incorporation	Before-After	-1.57895	1.70996	.39229	-2.40312	-.75477	-4.025	18	.001
Mulching	Before-After	-2.06897	3.47352	.45610	-2.98228	-1.15565	-4.536	57	.000
Complete Removal	Before-After	-.52083	1.32966	.13571	-.79025	-.25142	-3.838	95	.000

The recycling of paddy straw in the soil is crucial for maintaining soil health and improving crop yield. Burning and removal of paddy straw both lead to the loss of important soil nutrients from the soil because paddy straw consists of 15.86 per cent of fixed *carbon*, 3.01 per cent of calcium oxide (CaO), 1.75 per cent of magnesium oxide (MgO), 0.96 per cent of nitrous oxide (N_2O) and 12.3 per cent of potassium oxide (K_2O) (Binod *et al.,* 2009*).* Therefore, burning and removal of paddy straw generate deficiency of important nutrients in the soil and increase the infertility of the soil. Consequently, it leads to increase in the consumption of large amount of chemical fertilizers to maintain crop productivity which subsequently exacerbates the problem.

Various scientific studies support that incorporation of paddy straw in the soil is comparatively more efficient in improving soil quality and increasing productivity of next crop as well. It helps in recycling of nutrients in the soil and enhances soil organic carbon (SOC). With the incorporation of residue in the soil, the Nitrogen (N), Phosphorus (P) and Potassium (K) content of soil significantly increases as compared to burning or removal of paddy straw (Davari *et al., 2012,* Surekha *et al., 2003*). This practice of retention of straw in the soil increases the amount of Nitrate (NO_3) by 46 per cent, Nitrogen (N) by 29 per cent and yield of next crop (wheat) by 37 per cent (Mandal *et al., 2004*). But this increase in yield of these crops is observed after two years of adoption of the practice of incorporation (Gupta and Seth*, 2007*). However, the yield of crop and soil health can be improved by incorporating residue along with green manure (it is a crop which is especially produced to plough back in the soil while it is still green like peas, lentils, clovers, etc.) in the soil (Surekha *et al.,* 2003). Apart from these advantages to soil fertility and crop yield, this practice has some disadvantages too. It leads to the immobilization of inorganic Nitrogen (N) (Mandal *et al., 2004*) and in the initial years it leads to the generation of pests and weeds in the wheat crop which require the use of chemical fertilizers. Mulching of paddy straw under the cultivation of wheat crop effectively improves its yield (Erenstein*, 2002*). Keeping in view the climate and quality of soil, it may be pointed out that each paddy straw management practice has its own positive and negative effects on the yield of paddy and wheat crops.

From the analysis made above by using paired t test, it can be concluded that due to the burning of paddy straw in the field, the fertilizer (both Urea and DAP) consumption has significantly been increased and simultaneously the wheat yield has reduced significantly. But in case of non-burning, particularly Complete Incorporation of paddy straw, not only the application of fertilizers has reduced but the yield of wheat has also increased significantly. Thus, non-burning of paddy straw especially Complete Incorporation is the sustainable practice .

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