SAARC J. Agri., 13(1):37-49 (2015)

EFFECT OF RESIDUE RETENTION, TILLAGE OPTIONS AND TIMING OF N APPLICATION IN RICE-WHEAT CROPPING SYSTEM

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ABSTRACT

A field experiment was conducted at the research farm of the Directorate of Wheat Research, Karnal (Haryana) during 2007-08 to 2009-10 with the objective to compare the whole basal and split application of nitrogen under different residue management and tillage options in rice-wheat cropping system. Combined analysis of data revealed that puddled transplanted rice produced maximum rice grain yield, straw yield, thousand grain weight and grains /panicle. Rice yield under zero tillage was decreased to the tune of 27.8% (with residue), 33.9% (without residue) and 45.3% (under permanent bed planting) as compared to puddled transplanted condition. Split application of nitrogen increased the rice grain yield to the extent of 4.7% with residue, 8.0% without residue and 10.2% under puddled transplanted condition as compared to whole basal N application. Pooled analysis under zero tillage condition, retention of rice residue enhanced the wheat grain yield 21.3% at zero N, 8.3% at 150 N (whole basal) and 5.4% at 150 N (three split) applications. Application of nitrogen in three split doses increased the wheat grain yield up to 9.6% without residue retention and 6.7% with rice residue retention condition as compared to whole basal N application. In nut shell, it can be said that adoption of zero tillage, residue retention and whole basal N application did not work well for rice whereas it was better for wheat in rice-wheat system.

Keywords: Bed planting, Economics, nitrogen, Organic carbon, Residue retention, Rice-wheat, Yield, Zero tillage

INTRODUCTION

In South Asia, rice-wheat crop sequence is the largest agriculture production system and occupies about 13.5 million hectares area including 10 million hectares in India, extending from Indo-Gangetic plain to Himalayan foothills. Rice and wheat contribute 80 % of total cereal production in the region. In India, approximately 23%

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Received: 29.04.2014

and 40 % of total rice and wheat area, respectively, is represented by rice-wheat system alone (Timsina and Connor, 2001), which requires contrasting edaphic conditions. Rice is generally transplanted in puddled soil and is grown under submerged condition whereas wheat is grown in upland well-drained soils having good tilth. Rice-wheat crop sequence that yield 7 t ha^{-1} of rice and 4 t ha^{-1}wheat removes more than 300 kg N, 30 kg P and 300 kg K ha^{-1} from the soil. Continuous adoption of this system has been reported to decline soil and crop productivity (Nambiar and Abrol, 1989). Analysis of several long-term experiments on rice-wheat system (Dawe et al., 2000, Duxbury et al., 2000 and Yadav et al., 1998) indicated a negative average yield trend of rice (–0.02 t ha^{-1} yr^{-1} or 0.5 % yr^{-1}) under fixed set of inputs and agronomic practices.

Conservation agriculture requires three things, namely no tillage, residue retention and cropping system. Residue burning is the main problem under rice-wheat system in North West Plain Zone of India. To address this issue an experiment was planned with tillage options (zero tillage, bed planting and conventional tillage), residue retention/incorporation in rice as well as in wheat and application of nitrogen (whole quantity as basal v/s three splits) under rice-wheat system.

MATERIALS AND METHODS

A field experiment was conducted in rice-wheat cropping system during 2007-08 to 2009-10 at research farm of the Directorate of Wheat Research, Karnal (Latitude 29^{0} 43’ N, longitude 76^{0} 58’ E and altitude 245 m). Twelve treatments viz., T_1. Zero tillage with 0N, T_2. Zero tillage with 150N basal, T_3. Zero tillage with 150N split (3), T_4. Zero tillage with 0N +residue retention on surface, T_5. Zero tillage with 150N basal +residue retention on surface, T_6. Zero tillage with 150N split + residue retention on surface, T_7. Bed planting with 150N split, T_8. Bed planting with 150N basal + residue retention on surface, T_9. Bed planting with 150N split + residue retention on surface, T_{10}.Conventional tillage with 150N split +residue incorporated, T_{11}. Conventional tillage with 150N basal, T_{12}. Conventional tillage with 150N split, were conducted in randomized block design and replicated thrice. Residue of rice and wheat crop was retained or incorporated @ 6 t ha^{-1} and N was applied as per respective treatments followed by irrigation. Rice variety Govind was direct seeded in 1st week of June and 25 days old seedlings were transplanted in puddled condition in first week of July. Wheat variety PBW 502 was seeded after rice harvest in zero tillage and conventional tillage conditions. Fertilizers @ 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied to the rice and wheat crop as per treatment. Full dose of phosphorous in the form of single super phosphate and potash in the form of muriate of potash and one third dose of nitrogen in the form of urea was applied as basal i.e., before sowing and remaining two third dose of nitrogen was top dressed in two equal splits at first node stage (DC 31, DC stands for Decimal Code of Zadoks scale ranging from 0 to 99) (Zadoks et al., 1974) and at booting stage (DC 41). Irrigation was applied as per need of the crop. Weeds in zero till rice were controlled with the application of pendimethyline @1.0 kg ha^{-1} just after seeding whereas in transplanted rice weeds were controlled with the application of butachlor @ 1.0 kg ha^{-1} in 400 litre of water at 3-4 days after rice transplanting. Similarly weeds in wheat were controlled with the application of sulfosulfuron @ 25 g ha^{-1} in 400 liters of water at 30-35 days after sowing. All the other recommended practices were adopted in rice as well as in wheat. Observations were recorded on yield and its component characters and soil analysis, mainly organic carbon, electrical conductivity and pH were done at the start and end of the experiment. Standard statistical methods of analysis were followed for the yield and yield attributing parameters and soil analysis (Gomez and Gomez, 1984). Cost of cultivation was calculated by taking into account the prevailing price of inputs like fertilizer, seed, herbicides, irrigations, tillage operations, transportation charges, management charges, rental value of land and depreciation cost of implements. Returns were calculated by taking minimum support price of rice and wheat grain yield and market price of rice and wheat straw on pooled yield basis.

RESULTS

Rice yield

All the parameters like grain yield, straw yield, harvest index (HI), 1000-grain weight, panicles/m^2 and grains/panicle were significant for yearly as well as combined analysis over the years. Pooled analysis of data (Tables 1 and 2) revealed that puddled transplanted rice (T10 to T12) produced maximum rice grain yield, straw yield, thousand grain weight and grains /panicle. Direct seeded zero till rice was decreased to the tune of 27.8% (with residue), 33.9% (without residue) and 45.3% (under permanent bed planting) as compared to puddled transplanted condition. There was lesser decrease in rice yield where wheat residue was retained on the surface under residue retention treatments (T_5 and T_6) suggesting beneficial effect of wheat residue on rice yield. Split application of nitrogen increased the rice grain yield to the extent of 4.7% with residue, 8.0% without residue and 10.2% under puddled transplanted condition as compared to whole basal N application. Therefore, split N application under zero tillage with and without residue retention condition holds better for rice crop as compared to whole basal N application.

Residue retention under zero tillage condition enhanced the rice grain yield by 9.2% with zero N and 8.4% with 150 kg N ha^{-1} application as compared to respective no residue retention treatments. This suggests that there was positive role of wheat residue in increasing rice yield as compared to without residue condition. Maximum and significantly higher straw yield (13.0 t ha^{-1}) and HI (0.40) was recorded in puddled transplanted with split N application treatment. Under puddled transplanted condition, thousand grain weight and grains/panicle was maximum and significantly higher than all other treatments. However, there was no such difference in case of panicles m^{-2}. Direct seeded rice either under zero tillage or under bed planting (bed planting means raised surface 40 cm and furrow 30 cm, 3 rows on top of bed i.e. on raised surface, furrow to furrow distance 70 cm) produced significantly lower thousand grain weight and grains/panicle than puddled transplanted condition. This shows that rice grain yield under puddled transplanted condition was higher due to significantly higher thousand grain weight and grains/panicle. There was variation in rice yield during period of study and maximum grain yield was recorded in 2008. During crop cycle 2008, thousand grain weight and grains/panicle was maximum in all the treatments as compared to 2007 or 2009 crop cycle.

Wheat yield

All the parameters like grain yield, straw yield, HI, 1000 grain weight, panicles m^{-2} and grains per panicle were significant for yearly as well as across the year analysis (Tables 3 and 4). Pooled analysis under zero tillage condition, retention of rice residue enhanced the wheat grain yield 21.3% at zero N, 8.3% at 150 N (whole basal) and 5.4% at 150 N (three split) applications as compared to without residue condition. Three split application of 150 N under rice residue on surface with zero tillage produced similar yield (5.83 t ha^{-1}) as compared to conventional tillage condition (5.54 to 5.83 t ha^{-1}) condition. As compared to whole basal N application, grain yield increased in split application of N was due to significantly higher grains/ear head (11.2% without residue and 13.5% with residue condition). Therefore, it could be said that increase in grain yield under split N application with and without residue retention condition was mainly attributed by increase in grains/spike. At zero N application, residue retention increased the grains $spike^{-1}$ to the tune of 14.5%. Straw yield was maximum (8.52 t ha^{-1}) under conventional tillage with whole basal N application (150 kg ha^{-1}) and harvest index was maximum (0.47) with conventional tillage split N application (residue incorporation). There was no definite trend in case of thousand grain weight. Ear head m^{-2} was maximum (498) and significantly higher in conventional tillage with split N application as compared to other treatments**.**

Organic carbon

In general, organic carbon content, pH and EC were higher after three years of study in all the treatments (Table 6). Under zero tillage condition, residue retention with no nitrogen application increased the organic carbon to the extent of 14.2% as compared to without residue condition. Similarly residue retention at 150 kg N/ha application increased organic carbon content 9.3 to 13.9% as compared to without residue retention condition. Under bed planting condition residue retention enhanced the organic carbon content to the extent of 3.6% to 6.1% compared to no residue retention. Maximum pH and EC values were 8.16 and 0.518, respectively after three years study.

Economic Analysis

In general, cost of rice cultivation was higher than cost of wheat cultivation (Table 5). Under zero tillage or permanent bed planting conditions, return from rice was lower than cost of rice cultivation, whereas in case of puddled transplanted condition it was just reverse. Total cost of cultivation and total return were maximum under puddled transplanted rice followed by conventionally tilled wheat. Net return at zero N application and permanent bed planting condition of rice-wheat cropping was negative. This showed that these technologies are not feasible under no till conditions. Positive net return and B:C ratio more than one in case of puddled transplanted rice followed by conventional till wheat and zero tilled rice-wheat with and without residue retention were profitable. Benefit accrued by adoption of zero tillage for eco friendly cultivation and improvement in soil health was not included in the economics of different treatments.

DISCUSSION

Conservation agriculture (adoption of zero tillage with residue retention in a cropping system perspective) has emerged as a major strategy to achieve goals of sustainable agriculture. No-tillage when combined with surface managed crop residues sets in motion processes whereby slow decomposition of residues results in improvement in soil health. Rice yield under no till system declined drastically (27.8-45.3 %). These findings were against the observation of Kumar et al. (2005), who reported similar yield by adopting conservation practices. Sah et al. (2013) also reported higher rice yield with residue retention which is in contrast to our findings. In Haryana, where soils are sandy loam, it can be said that adoption of residue retention and whole basal N application are not suitable for rice in rice-wheat system. In wheat crop, three splits application of nitrogen increased the grain yield up to 9.6 % without residue retention and 6.7% with rice residue retention condition as compared to whole basal N application. These findings were in agreement with observation of Kharub and Chander (2010). Naresh et al. (2013) also reported that split application of nitrogen increased wheat yield under residue retention condition. Permanent bed planting treatments recorded lowest wheat grain yield (4.96 to 5.02 t ha^{-1}). This finding is in contrast to the observations of Hobbs and Gupta (2003a) under rice-wheat system. Economics play an important role in the adoption of technologies. Positive net return and B:C ratio more than one in case of zero tilled rice- wheat with and without residue retention were profitable and provides eco-friendly cultivation. Residue retention enhanced the organic carbon content of soil as compared to residue removal which was in agreement with observations of Naresh (2013). However, there was no significant difference between residue retention and residue incorporation for the organic carbon content. This finding was in agreement with observations of Ladha et al. (1986).

CONCLUSION

Puddled transplanted rice produced maximum rice grain yield, straw yield, thousand-grain weight and grains /panicle. Rice yield under zero tillage decreased to the tune of 27.8% (with residue), 33.9% (without residue) and 45.3% (under permanent bed planting) as compared to puddled transplanted condition. Application of nitrogen in three split doses increased the rice grain yield to the extent of 4.7% with residue, 8.0% without residue and 10.2% under puddled transplanted condition as compared to whole basal N application. Rice residue retention enhanced the wheat grain yield 21.3% under zero N, 8.3% 150 N (whole basal) and 5.4% under 150 N (three split) applications. Promoting conservation agriculture in rice-wheat system will call for moving away from the conventional compartmentalized and hierarchical arrangement of research that generated and perfected technologies, extension that delivers it and farmers who adopt it. All the stakeholders involved would need to be brought together on a common platform to conceive end-to-end strategies. Roles of research, extension, farmers and other stakeholders should be institutionalized in a way that strengthens these partnerships.

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Table 1. Effect of residue retention, tillage options and timing of N application on rice grain yield, straw yield and HI

Treatments	Grain Yield (t ha^{-1})				Straw Yield (t ha^{-1})				HI			
	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled
T_1	2.49	4.03	2.99	3.17	8.70	7.28	4.15	6.71	0.22	0.35	0.42	0.33
T_2	3.98	5.74	4.11	4.61	10.83	7.53	5.81	8.07	0.27	0.43	0.42	0.37
T_3	4.49	6.34	4.21	5.01	16.03	9.53	6.51	10.68	0.22	0.39	0.39	0.34
T_4	3.15	4.07	3.27	3.50	7.18	6.64	4.27	6.03	0.31	0.38	0.44	0.37
T_5	4.58	5.93	4.87	5.13	12.69	7.96	5.84	8.83	0.27	0.43	0.46	0.38
T_6	4.68	6.48	4.99	5.38	16.67	8.39	6.91	10.66	0.22	0.44	0.42	0.36
T_7	3.14	4.80	4.00	3.98	10.20	7.30	5.12	7.54	0.24	0.39	0.44	0.36
T_8	3.21	4.33	3.87	3.80	8.37	7.38	5.66	7.14	0.28	0.37	0.41	0.35
T_9	3.53	4.64	4.33	4.17	11.27	7.86	5.79	8.31	0.24	0.37	0.43	0.35
T_{10}	6.95	9.03	7.12	7.70	13.89	15.58	9.55	13.00	0.33	0.37	0.43	0.38
T_{11}	6.39	8.10	6.25	6.91	11.75	11.94	9.20	10.96	0.35	0.40	0.41	0.39
T_{12}	6.89	7.87	6.95	7.24	10.46	13.08	9.20	10.91	0.39	0.38	0.43	0.40
CD (P=0.05)	0.66	0.73	0.86	0.45	0.82	0.96	1.02	0.65	0.04	0.06	0.07	0.04

Table 2. Effect of residue retention, tillage options and timing of N application on rice yield attributes

Treatments	1000 Grain wt (g)				Panicles m^{-2}				Grains $panicle^{-1}$			
	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled
T_1	19.73	19.87	21.29	20.29	370	330	388	363	35.0	61.7	37.1	44.6
T_2	20.88	21.60	21.39	21.29	358	423	398	393	53.0	62.9	48.2	54.7
T_3	21.55	22.02	21.24	21.60	398	430	410	413	52.7	67.4	50.0	56.7
T_4	19.73	19.87	21.29	20.29	360	372	383	372	45.3	61.6	40.6	49.2
T_5	21.85	21.82	21.93	21.87	327	395	405	376	65.0	70.5	55.5	63.6
T_6	21.52	21.02	22.15	21.56	373	393	423	397	60.0	80.7	53.3	64.7
T_7	20.24	20.85	21.48	20.86	308	311	356	325	50.3	74.1	52.4	58.9
T_8	20.29	21.12	21.57	20.99	295	307	391	331	53.7	67.6	45.8	55.7
T_9	20.54	21.32	21.17	21.01	352	309	383	348	49.3	71.0	53.6	57.9
T_{10}	27.36	31.10	22.77	27.08	305	368	413	362	84.0	78.9	75.8	79.5
T_{11}	27.17	31.05	23.13	27.12	303	321	320	315	78.0	81.5	84.5	81.3
T_{12}	27.84	32.17	23.09	27.69	305	418	377	367	82.0	60.7	79.9	74.2
CD (P=0.05)	1.56	1.28	1.16	0.78	24	33	37	26	15.1	13.4	13.5	9.6

Table 3. Effect of residue retention, tillage options and timing of N application on wheat grain yield, straw yield and HI

Treatments	Grain Yield (t ha^{-1})				Straw Yield (t ha^{-1})				HI			
	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled
T_1	1.71	2.62	1.73	2.02	1.95	3.39	2.20	2.51	0.47	0.44	0.44	0.45
T_2	4.45	6.05	4.43	4.98	4.67	6.91	6.40	5.99	0.49	0.47	0.41	0.46
T_3	5.10	6.52	4.89	5.51	5.55	8.75	6.78	7.02	0.48	0.43	0.42	0.44
T_4	2.92	2.85	1.94	2.57	3.89	3.87	2.95	3.57	0.43	0.42	0.39	0.42
T_5	5.35	5.71	5.24	5.43	8.35	8.64	7.97	8.32	0.39	0.39	0.39	0.39
T_6	5.82	6.38	5.28	5.83	4.13	8.89	7.10	6.71	0.62	0.42	0.43	0.49
T_7	4.52	5.42	5.03	4.99	4.84	7.48	6.56	6.79	0.49	0.42	0.43	0.45
T_8	4.74	5.77	4.36	4.96	4.59	7.72	6.55	6.28	0.51	0.43	0.40	0.45
T_9	4.88	5.54	4.65	5.02	4.05	8.16	6.39	6.20	0.55	0.40	0.42	0.46
T_{10}	5.38	6.18	5.05	5.54	6.80	8.40	4.2.8	6.49	0.44	0.42	0.55	0.47
T_{11}	5.44	6.07	5.98	5.83	8.92	8.29	8.34	8.52	0.38	0.42	0.42	0.41
T_{12}	5.50	5.81	5.84	5.73	7.14	8.77	8.61	8.17	0.44	0.39	0.41	0.41
CD (P=0.05)	0.52	0.55	0.66	0.48	0.40	0.55	0.69	0.55	0.12	0.05	0.07	0.05

Table 4. Effect of residue retention, tillage options and timing of N application on wheat yield attributes

Treatments	**1000 Grain wt (g)**				**Ear head m^{-2}**				**Grains ear head^{-1}**			
	2007-08	**2008-09**	**2009-10**	**Pooled**	**2007-08**	**2008-09**	**2009-10**	**Pooled**	**2007-08**	**2008-09**	**2009-10**	**Pooled**
T_1	37.68	41.38	38.99	39.35	263	260	368	297	17.1	25.1	12.4	18.2
T_2	41.07	42.43	41.43	41.64	335	435	457	409	32.4	34.3	23.6	30.1
T_3	42.71	39.90	40.82	41.14	340	530	380	417	38.5	31.2	32.0	33.9
T_4	39.53	43.36	39.49	40.79	300	252	368	307	24.2	26.4	13.4	21.3
T_5	40.59	45.98	40.56	42.38	408	407	510	442	33.9	33.1	25.4	30.8
T_6	42.25	40.43	42.75	41.81	362	413	380	385	38.5	39.1	29.3	35.6
T_7	39.97	40.92	38.60	39.83	327	418	457	401	34.6	31.8	28.7	31.7
T_8	40.02	44.32	41.32	41.89	300	411	463	392	39.7	31.7	22.9	31.5
T_9	40.31	41.38	40.02	40.57	298	414	467	393	40.5	32.4	25.2	32.7
T_{10}	40.75	39.81	41.58	40.72	467	350	417	411	28.7	45.2	30.1	34.7
T_{11}	38.55	43.34	36.79	39.56	536	383	478	466	29.8	38.5	34.1	34.2
T_{12}	40.49	37.92	37.29	38.57	588	358	547	498	23.1	47.1	28.9	33.0
CD (P=0.05)	2.12	2.03	3.51	1.95	26.4	33.7	35.1	28.0	4.8	5.1	4.7	3.0

Table 5. Effect of residue retention, tillage options and timing of N application on economics of rice-wheat cropping system (Rs ha^{-1})

Treatments	Rice cost of cultivation	Wheat cost of cultivation	Total cost of cultivation	Rice return	Wheat return	Total return	Net return	B:C ratio
T_1	64275	46025	110300	31740	28920	60660	-49640	0.5
T_2	65675	47425	113100	46110	70747	116857	3757	1.0
T_3	66175	47925	114100	50140	79247	129387	15287	1.1
T_4	64275	46025	110300	34970	37663	72633	-37667	0.7
T_5	65675	47425	113100	51270	81655	132925	19825	1.2
T_6	66175	47925	114100	53830	82031	135861	21761	1.2
T_7	69300	48550	117850	39800	72851	112651	-5199	1.0
T_8	68800	48050	116850	38030	71251	109281	-7569	0.9
T_9	69300	48550	117850	41680	71705	113385	-4465	1.0
T_{10}	69175	51175	120350	76970	78225	155195	34845	1.3
T_{11}	68675	50675	119350	69130	86561	155691	36341	1.3
T_{12}	69175	51175	120350	72380	84597	156977	36627	1.3

Table 6. Effect of residue retention, tillage options and timing of N application on organic carbon (0-15 cm in %), pH and EC

Treatments	OC	pH	EC
Initial	0.388	8.02	0.453
	After three years		
T_1	0.39	8.05	0.46
T_2	0.43	8.06	0.47
T_3	0.41	8.03	0.42
T_4	0.46	8.01	0.49
T_5	0.48	8.07	0.47
T_6	0.47	8.09	0.48
T_7	0.39	8.11	0.47
T_8	0.41	8.47	0.51
T_9	0.42	8.16	0.51
T_{10}	0.42	8.11	0.49
T_{11}	0.41	8.10	0.44
T_{12}	0.40	7.97	0.47
CD (P=0.05)	0.03	0.26	0.09