Productivity of the rice-wheat cropping system as influenced by nutrient management under conservation and conventional agriculture practices

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Abstract
A field experiment was conducted to evaluate the productivity of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) through nitrogen management practices under conservation and conventional agriculture practices during 2012-2013 at Chitwan, Nepal. The experiment on rice was conducted in strip-split plot design with two establishment methods (conservation agriculture and conventional practices), two rice varieties (improved variety Sabitri and hybrid Gorakhnath 509), and four nitrogen levels (0, 60, 120, and 180 kg/ha). The experiment on wheat was conducted in a split-plot design with two establishment methods and four nitrogen levels as in rice with Gautam variety. The research result revealed that the grain yield of the rice-wheat system was higher in conservation agriculture (6.6 t/ha). Gorakhnath 509 of rice followed by Gautam variety of wheat had a higher system grain yield (6.8 t/ha) than Sabitri followed by Gautam (6.5 t/ha). The highest system grain yield was obtained from 180 N kg/ha (8.1 t/ha) which was significantly higher than 0 and 60 N kg/ha but was statistically similar to 120 N kg/ha. Thus, in Chitwan and similar niches, the rice-wheat system either Sabitri followed by Gautam or Gorakhnath 509 followed by Gautam variety under conservation agriculture practices by applying 120 N kg/ha can be successfully grown by the farmers.

Keywords: Conservation agriculture, conventional agriculture, yield, nitrogen, varieties

Introduction

Rice (*Oryza sativa* L.) is the first and wheat (*Triticum aestivum* L.) is the third leading cereal crop of Nepal cultivated in 44.0% and 21.9% of the total cultivated area with a national average grain yield of 3.3 t/ha and 2.4 t/ha respectively (MoAD, 2012). Rice-wheat (RW) is one of the most prominent cropping systems in Nepal and accounts for 0.56 million hectares area (Khanal *et al*., 2008). Rice alone contributes about 20% and wheat contributes 4.5% in AGDP (MoAC, 2012). Cereals production in Nepal is constrained by factors such as limited irrigation potential, low fertilizer availability, unavailability of quality seeds, inadequate weed management practices, and weather stress (Marahatta, 2008). The rice-wheat system of terai and inner terai showed yield stagnation in the last two decades (Pathak *et al*., 2003). Due to which there is a huge yield gap between potential and farmers' management (rice 2.8 t/ha and wheat 3.2 t/ha) (Amgain and Timsina, 2005). Rice is grown during the monsoon season and wheat during the cold and dry winter season. There is a transition period of variable length between the harvest of wheat and the transplanting of rice, during which the land typically lies fallow. CA-based practices like zero or minimum tillage with residue retention and proper N management has been an alternative option for sustainable crop production systems under rainfed as well as irrigated conditions (Sayre and Hobbs, 2004; Govaerts *et al*., 2005).

Nitrogen is normally a key factor in achieving optimum rice grain yield (Fageria *et al*., 1997). About 78% of the world’s rice is grown under irrigated or rainfed lowland conditions (IRRI, 1997). Soils under these conditions are saturated, flooded, and anaerobic having low N use efficiency. Under these situations, increasing rice yield per unit area through the use of appropriate N management practices such as adequate amount, form, and method of application is crucial (Fageria and Baligar, 2001). Hence this study was conducted to evaluate the productivity of the rice-wheat system under different establishment methods and nitrogen levels.

Materials and Methods

The experiment was conducted at Rampur, Chitwan of Nepal from July 2012 to April 2013. The area is located 9.8 km South-West of Bharatpur. The site is located between 27^0 $37^'$ North latitude and 84^0 $25^'$ East longitude with an elevation of 256 meters above mean sea level (Thapa and Dangol, 1988). The monthly mean maximum temperature was 33.7 ^{0}C in August and the minimum temperature was 7.5 ^{0}C in November during the rice season and 1.8 ^{0}C in January and 34.6 ^{0}C in April during the wheat season. The maximum rainfall was observed in July (485.5mm) and no rainfall at all in November, December, and February. The soil of the experimental site was sandy loam with an acidic pH of 5.6.

The experiment was laid out in strip-split plot design for rice and split-plot design for wheat. During rice season there were three factors of which two level of crop establishment methods (CA and Conventional practices) in a vertical strip in rice and as main plots for wheat, two-level of varieties (Sabitri and Gorakhnath 509 of rice during summer and Gautam of wheat during winter) and four nitrogen levels (0, 60, 120 and 180 N kg/ha) in sub-sub plots. CA comprises dry direct-seeded rice in summer followed by zero tillage wheat in winter whereas, conventional practices comprise puddled transplanted rice in summer followed by conventionally tilled wheat in winter. Mung bean (*Vigna radiata* L.), cultivated in the previous season was used as a source of residue for zero tilled rice. The residue of rice (after harvested 33 cm above the ground surface to retain the standing residue) was used for the wheat crop. The individual plot size was 15 m^2 (5 m × 3 m) with a total experimental area of 957 m^2. Two individual plots were separated by 1 m along with bund and each replication was separated by 2 m along with bund. In direct-seeded rice and wheat (conventional and zero-till) was sown continuously in line with a row to row spacing of 20 cm but in conventional puddled transplanted rice, seedlings were transplanted in 20 cm x 20 cm using 21 days seedling. Various levels of Nitrogen (0, 60, 120, and 180 kg/ha) were applied as per treatment and they were applied in 3 splits and the entire amount of phosphorus and potash were applied as basal doses, at the rate of 40 P_2O_5 kg/ha and 40 K_2O kg/ha. Recorded data were processed and analyzed by MSTAT software. SigmaPlot was used for graphical representation. Data were subjected to analysis of variance (ANOVA). When significant differences were found, means were separated and assessed using the Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussions

Yield attributes of rice

Effective tillers per square meter were not significantly influenced by the establishment methods. However, higher effective tillers per square meter were recorded in CA. Significantly higher effective tillers per square meter (251.3) were obtained in Gorakhnath 509 as compared to Sabitri variety (211.7). Increasing the N levels consequently increased the effective tillers. Significantly higher effective tillers per square meter were found in 180 N kg/ha (278.4) than N omitted (178.7) and 60 N kg/ha (205.7) but statistically similar with 120 N kg/ha (263.1) applied plots. This is due to increase in the amount of nitrogen absorbed by the crop, increased the number of panicles per square meter (Yoshida *et al.*, (1972). Grains per panicle were significantly influenced by variety and nitrogen levels but not by establishment methods. Thousand grains weight was varied significantly among varieties and nitrogen levels and ranged from 16.1 to 20.4 g (Table 1) but was not significantly influenced by the establishment methods. Sterility percentage was significantly affected by establishment methods and varieties but was not affected due to nitrogen levels.

Table 1. Effect of establishment methods and nitrogen levels on effective tillers per square meter, grains per panicle, thousand grains weight (g) and sterility percentage of rice at Chitwan, Nepal 2012/13

Treatment	Yield attributes of rice			
	ET	Grains per panicle	Thousand grains weight (g)	Sterility (%)
Establishment methods				
CA	239.2	131.3	18.1	18.4[a]
Conv. Practice	223.7	143.7	18.5	15.9[b]
SEm(±)	5.2	2.8	0.2	0.3
LSD (P<0.05)	ns	ns	ns	1.8
Varieties				
Sabitri	211.7[b]	129.3[b]	17.8[b]	18.5[a]
Gorakhnath 509	251.3[a]	145.7[a]	18.8[a]	15.7[b]
SEm(±)	4.3	1.6	0.1	0.4
LSD (P<0.05)	26.2	9.5	0.9	2.4
Nitrogen levels				
0 kg/ha	178.7[c]	106.7[c]	16.1[c]	17.3
60 kg/ha	205.7[b]	126.8[b]	17.5[b]	17.1
120 kg/ha	263.1[a]	152.7[a]	19.2[a]	17.1
180 kg/ha	278.4[a]	163.8[a]	20.4[a]	17.1
SEm(±)	4.0	3.0	0.3	0.4
LSD (P<0.05)	11.6	8.6	0.9	ns
CV, %	6.0	7.5	5.9	8.0
Grand mean	231.5	137.5	18.3	17.1

Note: *ET, effective tillers per square meter; ns, non-significant. Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance*

Grain yield of rice

The grain yield of rice ranged from 2.7 to 5.1 t/ha due to nitrogen levels with the average yield in the experiment being 4.1 t/ha (Table 2). Grain yield was significantly influenced by varieties and nitrogen levels but establishment methods did not significantly influence. Hybrid variety Gorakhnath 509 with 4.3 t/ha had a 10.9% higher yield over Sabitri with 3.9 t/ha. The higher grain yield of Gorakhnath 509 was because of higher LAI, slower leaf senescence, which contributed to better light interception and higher assimilate production thus had a higher harvest index. The grain yield of rice increased with an increase in N levels up to 180 N kg/ha. The highest grain yield of 5.1 t/ha was obtained when 180 N kg/ha was applied. It was significantly higher than no N with 2.7 t/ha and 60 N kg/ha having 3.9 t/ha but was similar with 120 N kg/ha having 4.8 t/ha.

Harvest index of rice

The harvest index of rice was not evident due to establishment methods but significantly influenced by varieties and nitrogen levels (Table 2). However, the harvest index was higher in conventional practice (41.5 %) than conservation agriculture (41.3%). A significantly higher harvest index was observed in Gorakhnath 509 (44.4%) than Sabitri (38.3%). The harvest index of rice increased with an increase in N levels from 0 to 180 N kg/ha. The highest harvest index (44.8%) was obtained in 180 N kg/ha applied plot which was significantly higher than no N (36.5%) and 60 N kg/ha (40.3%) applied plots but was statistically similar with 120 N kg/ha (43.9%) application.

Table 2. Effect of establishment methods, varieties and nitrogen levels on grain yield and harvest index of rice at Chitwan, Nepal 2012/13

Treatments	Yield of Rice	
	Grain yield (t/ha)	Harvest index (%)
Establishment methods		
CA	4.1	41.3
Con. Practice	4.1	41.5
SEm(±)	0.1	0.4
LSD (P<0.05)	ns	ns
Varieties		
Sabitri	3.9[b]	38.3[b]
Gorakhnath 509	4.3[a]	44.4[a]
SEm(±)	0.1	0.5
LSD (P<0.05)	0.3	3.3
Nitrogen levels		
0 kg/ha	2.7[c]	36.5[c]
60 kg/ha	3.9[b]	40.3[b]
120 kg/ha	4.8[a]	43.9[a]
180 kg/ha	5.1[a]	44.8[a]
SEm(±)	0.1	0.9
LSD (P<0.05)	0.3	2.5
CV, %	9.5	7.3
Grand mean	4.1	41.4

Note: *ns, non-significant. Treatments means followed by common letter(s) within the column are not significantly different among each other based on DMRT at 5% level of significance*

Yield attributes of wheat

Effective tillers per square meter was significantly influenced by the establishment methods and nitrogen levels. Significantly more effective tillers per square meter were found in CA (240.1) than conventional practices (213.7). Effective tillers per square meter significantly increased with increase in N levels. Grains per spike were significantly influenced by establishment methods and nitrogen levels. Grains per spike significantly increased with increase of N from 0 to 180 N kg/ha. Thousand grains weight were not affected significantly by the establishment methods but was affected significantly among nitrogen levels (Table 3). However, thousand grains weight was observed higher in CA (48.7 g) than CT (48.4 g). Thousand grains weight had also increased with increase in N level. Non-significant results on sterility percentage due to establishment methods and nitrogen levels were observed. The average sterility percentage was 16.5% and it ranged from 16.1 to 16.6% depending upon the treatments. Sterility percentage was higher in 0 N kg/ha (16.6%) followed by 60 N kg/ha, 120 N kg/ha and 180 N kg/ha application.

Table 3. Effect of establishment methods and nitrogen levels on effective tillers per square meter, grains per spike, thousand grains weight (g) and sterility percentage of wheat at Chitwan, Nepal 2012/13

Treatment	Yield parameters			
	ET	Grains per spike	Thousand grains weight (g)	Sterility %
Establishment methods				
CA	240.1[a]	47.6[a]	48.7	16.6
Conv. practices	213.7[b]	45.5[b]	48.4	16.2
SEm(±)	7.0	0.9	0.7	0.2

Treatment	Yield parameters			
	ET	Grains per spike	Thousand grains weight (g)	Sterility %
LSD (P<0.05)	25.6	1.2	ns	ns
Nitrogen levels				
0 kg/ha	168.6[c]	41.4[d]	44.9[c]	16.6
60 kg/ha	210.8[b]	43.7[c]	47.8[b]	16.5
120 kg/ha	253.9[a]	46.9[b]	50.7[a]	16.3
180 kg/ha	274.3[a]	52.2[a]	50.8[a]	16.1
SEm(±)	8.5	0.8	0.9	0.4
LSD (P<0.05)	24.5	2.2	2.5	Ns
CV, %	13.0	5.8	6.1	8.3
Grand mean	226.9	46.1	48.6	16.5

Note: *ET, Effective tillers per square meter, ns, non-significant. Treatments means followed by the common letter(s) within column are not significantly different among each other based on DMRT at 5 % level of significance*

Grain yield of wheat

The grain yield ranged from 1.6 to 3.2 t/ha due to the various nitrogen levels and the average yield was 2.6 t/ha (Table 4). Grain yield was significantly influenced by establishment methods and nitrogen levels. CA (2.7 t/ha) had 10.5% higher grain yield than conventional practices (2.4 t/ha). Wheat planted under zero tillage increases yield by 6.7-9.7% over plow tillage (Jiaguo, 2000). Grain yield of wheat increased with an increase in N level up to 180 N kg/ha. The highest grain yield of 3.2 t/ha was obtained when 180 N kg/ha was applied. It was significantly higher than 0 N kg/ha having 1.6 t/ha and 60 N kg/ha with 2.3 t/ha but was similar to 120 N kg/ha with 3.2 t/ha. This result was in line with Aggarwal *et al.*, (1995) who reported that wheat productivity was substantially reduced when it followed puddled TPR, rather than other tillage and establishment practices. In the review, Kumar *et al.*, (2008) from many studies reported yield reduction of wheat ranged from 7 to 15% due to puddling for rice compared to non-puddled conditions. It was attributed mainly to subsoil compaction due to intensive wet tillage (puddling) that restricts root penetration of the post rice crop. The reason for the higher grain yield in zero tillage practice might be due to significantly higher effective tillers, grains per spike, and weight per spike. Also, due to the higher thousand grains weight.

Harvest index of wheat

The harvest index was not significantly affected due to establishment methods but was influenced by the N levels (Table 4). However, the harvest index was higher in CA (36.2%) than conventional practices (35.5%). Harvest index of wheat increased with an increase in N level up to 180 N kg/ha. Highest HI (39.1%) was obtained in the 180 N kg/ha applied plot which was significantly higher than 0 N kg/ha (31.4%) and 60 N kg/ha (34.3%) but was similar to 120 N kg/ha (38.6%).

Table 4. Effect of establishment methods and nitrogen levels on grain yield and harvest index of wheat at Chitwan, Nepal 2012/13

Treatments	Yield of wheat	
	Grain yield (t/ha)	Harvest index (%)
Establishment methods		
CA	2.7[a]	36.2
Con. practice	2.4[b]	35.5
SEm(±)	0.1	0.4
LSD (P<0.05)	ns	ns
Varieties		

Treatments	Yield of wheat	
	Grain yield (t/ha)	Harvest index (%)
Sabitri	3.9[b]	38.3[b]
Gorakhnath 509	4.3[a]	44.4[a]
SEm(±)	0.1	0.6
LSD (P<0.05)	0.2	ns
Nitrogen levels		
0 kg/ha	1.6[c]	31.4[c]
60 kg/ha	2.3[b]	34.3[b]
120 kg/ha	3.2[a]	38.6[a]
180 kg/ha	3.2[a]	39.1[a]
SEm(±)	0.1	1.0
LSD (P<0.05)	0.2	2.8
CV, %	8.5	9.3
Grand mean	2.6	35.9

Note: *ns, non-significant. Treatments means followed by the common letter(s) within column are not significantly different among each other based on DMRT at 5 % level of significance*

System productivity

Grain yield has been reported to be influenced highly by direct effects of total effective tillers, days to flowering, plant height, number of panicles, grains per panicle, biological yield, harvest index, and thousand grains weight (Yang, 1986; Surek and Beser, 2003). But the sum of individual crops is assigned as system yield. Grain yield depends on the production of photosynthates and their distribution among various plant parts. The synthesis, accumulation, and translocation of photosynthates depend upon the efficient photosynthetic structure as well as the extent of translocation into the sink (grains) and also on plant growth and development during the early stages of crop growth. The grain yield of the rice-wheat system was significantly influenced by nitrogen levels but non-significant due to establishment methods and varieties. The mean grain yield was 6.7 t/ha. The highest grain yield was obtained in CA with 6.8 t/haas compared to 6.6 t/ha in conventional practices (Figure A). Gorakhnath 509 of rice followed by Gautam variety of wheat had a higher grain yield of 6.8 t/ha than Sabitri followed by Gautam variety of 6.5 t/ha (Figure B). This was due to the significantly higher grain yield of Gorakhnath 509 than the Sabitri variety of rice. The highest grain yield was obtained from 180 N kg/ha (8.1 t/ha) which was significantly higher than 0 N kg/ha (4.3 t/ha), 60 N kg/ha (6.1 t/ha) but was statistically similar with 120 N kg/ha (8.0 t/ha) (Figure C). More system yield was due to more grain yield of both rice and wheat at a higher N level.The higher system yield in CA might be due to the use of crop residue as suggested by Becker *et al.* (2007) who obtained significantly higher system grain yield (5.0 t/ha) on mung bean incorporated plots than bare fallow (2.9 t/ha) plots. Similarly, Hobbs and Gupta (2004) obtained higher grain yield in CA on the rice-wheat system in South Asia.

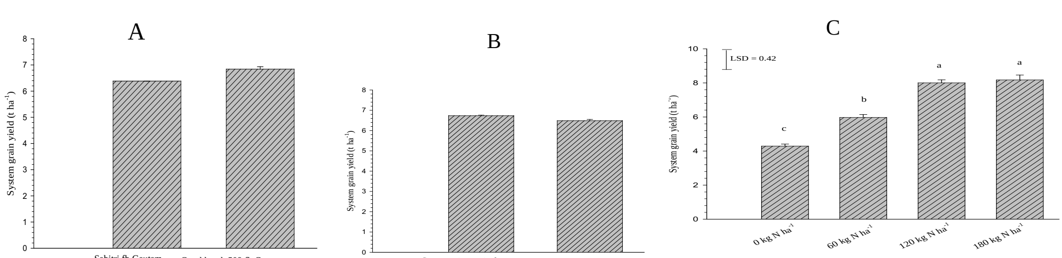

Fig. 1: Effect of establishment methods (B), varieties (A) and nitrogen levels (C) on system grain yield of the rice-wheat system at Chitwan, Nepal

Conclusion

Yield attributes of rice, effective tillers per square meter, grains per panicle and thousand grains weight was non-significant between two establishment methods and these value were higher under conventional practices. Gorakhnath 509 variety of rice had significantly higher effective tillers per square meter, grains per panicle and thousand grains weight than Sabitri variety of rice along with significantly lower sterility. Among yield attributing characters and yield related attributes of wheat, grains per spike, and effective tillers per square meter were significantly higher in CA. Thousand grains weight were also higher in CA. In both rice and wheat, sterility percentage was significantly higher in CA than in conventional practices. All yield related attributes of both rice and wheat were higher as the increasing nitrogen levels up to 180 N kg/ha except the sterility percentage. Hence, grain yield of rice was not influenced by establishment methods but the effect of CA was obvious for grain yield of wheat. Thus, in rice-wheat system either Sabitri followed by Gautam or Gorakhnath 509 followed by Gautam variety under conservation agriculture practices by applying 120 N kg/ha can be successfully grown by the farmers of Chitwan and similar niches.

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