NUTRIENT MANAGEMENT PRACTICE FOR CONSERVATION AND CONVENTIONAL AGRICULTURE PRACTICES ON RICE BASED SYSTEM AT CENTRAL TERAI OF NEPAL

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ABSTRACT

A field experiment was conducted to evaluate the effect of inventive nutrient management practices on the system productivity and profitability of rice-wheat and maize in the rice-based cropping system under conservation agriculture and conventional tillage at Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal during 2018 - 2019.The experiment was executed in the field in split-split design (for rice), and split plot design (both for wheat and maize) with three replications which included two cropping system (rice-wheat and rice-maize) as main plot treatments, two establishment methods (conservation agriculture and conventional agriculture) as sub plots and four nutrient management practices (100% Recommended dose of fertilizer (RDF), Residue (5 t ha^{-1}) + 75% RDF, Nutrient Expert (NE) dose, brown/green manuring (BM/GM) + 75% RDF) as sub-sub plot treatments. The data on yield and economics were recorded and analyzed by R studio. The yield of wheat and maize were converted into rice equivalent yield (REY) from which system yield was calculated. The research revealed that the rice-maize system had significantly higher REY (12.21 t ha^{-1}), net returns (163.10 thousand NRs. ha^{-1}) over rice-wheat system (8.61 t ha^{-1} and 68.09 thousand NRs. ha^{-1}, respectively) whereas the crop establishment methods and nutrient management practices have no influence on the REY of the system. NE dose, Residue +75% RDF and 100% RDF produced similar REY. The rice grain yield was found higher (5.28 t ha^{-1}) for conventional tillage than under CA (4.52 t ha^{-1}) however the maize and wheat yield was not affected by the crop establishment methods. Under both establishment methods, NE dose performed better for all crops but NE dose and green manuring produced higher yields under conventional tillage for rice. The residue +75% RDF performed better than 100% RDF for maize and wheat. Rice-maize cropping system was more productive and eventually more profitable than rice-maize cropping system and the under both establishment methods, better yield can be obtained using NE dose, green manuring and residues in the fields with the saving of 25% RDF applied for each crops.

Keywords: Conservation agriculture, Green manuring, Nutrient expert, Residue management

INTRODUCTION

Rice-wheat cropping system is the world's largest cropping system occupying 85% of the Asia but its sustainability is being questioned due to stagnation in yield and reducing profitability, declining water availability and soil degradation (Ladha et al., 2003). Conventionally, rice in this region is established by transplanting rice seedlings on puddled field (Bhatt et al., 2016). But due to high labor and water demand in transplanted method, an alternative practice direct seeding is gaining popularity. Crop residues are the important plant nutrient sources and help to combat the nutrient mining through the

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intensive cropping. Green manures are the green plants or plant parts which are returned into the soil by incorporation in order to improve the growth of subsequent crops and soil organic carbon. The addition of green manure alone can help to make soil fertile, but the combined application of green manure and nitrogenous fertilizer increases the yield of rice by increasing the availability of NPK in the soil and hence the nutrient uptake (Islam et al., 2015). Brown manuring is an innovative cultural practice, especially for dry-DSR in which the *Sesbania* seeds are sown directly into field along with rice seeds and after allowing to grow for about 25-30 days after which the co-cultured *Sesbania* plants are killed by applying 2,4-D. Nutrient Expert (NE) is computer-based nutrient decision support software based on site-specific nutrient management (SSNM) principle and enables farm advisors to develop fertilizer recommendations tailored to a specific field or growing environment. NE does not require lot of data or very detailed information and is user friendly as NE combines all the steps and principles in SSNM into simple software tailored for farm directors and non-technicians (IPNI, 2017).

The current agricultural production practices in the rice-wheat systems are high resource demanding and also degrade the environment contributing to the climate change (Bhatt, 2016). The continuous practice of conventional system in most areas has led to degradation in soil health and consequently resulted in declined system productivity (Singh et al., 2011). In addition to this, the conventional wheat planting system involves repeated dry tillage to prepare the field which also leads to further delay in wheat seeding by almost a week compared to ZT planting (Kumar et al., 2014). Puddling in rice and also the intensive tillage for wheat delays wheat planting, and results in yield loss (Hobbs & Morris, 1996). Kumar & Ladha (2011) reported that the subsequent wheat increment was about 9% in the field followed after DSR than TPR. Rice-maize has now emerged as the best alternative to rice-wheat system where wheat planting is delayed after rice and faces terminal heat stress resulting in low productivity (Singh et al., 2016). The other drivers for replacing wheat are: better suitability of maize after harvest of long-duration rice cultivars, increasing demand of maize in poultry sector, higher productivity and profitability of maize compared to the other crops (Timsina et al., 2010). The edaphic needs of both subsequent crops i.e. maize and wheat are different from the rice crop. Aside the growing soil condition, the improper and imbalanced nutrition management and declining soil fertility are the major priorities of global research (Timsina et al., 2010). So, this research was done to examine the productivity and profitability of rice-based systems under different establishment methods and nutrient management practices. Along with this, the research aims at assessing the relevance and comparative advantage of the site-specific nutrient, management using Nutrient Expert (NE) software for all the major cereals.

MATERIALS AND METHODS

SITE DESCRIPTION

The experiment was conducted at the research block of Agronomy Farm of Agriculture and Forestry. University (AFU), Rampur, Chitwan district of Bagamati Province of Nepal (27°40' N and 84°23' E and256 masl) from June 2018 to May 2019. The soil in the experimental field was sandy loam with slightly acidic to neutral pH, medium to low OM and nitrogen content, high phosphorus and medium potassium content (Table 1) according to the standard rating of Government of Nepal, Kathmandu.

Table 1. Physico-chemical properties of the soil of agronomy farm at Agriculture and Forestry University (AFU), Rampur, Chitwan, 2018/19

S.N.	Properties	Average Content	Rating			Methods and References
1.	Physical properties					Hydrometer
	Sand (%)	63.10	Sandy loam			(Estefan, Sommer& Ryan,2014)
	Silt (%)	28.00				
	Clay (%)	8.90				
2.	Chemical properties					
		0-15cm	Rating	15-30cm	Rating	Methods and References
	Soil pH	6.40	Acidic	6.5	Neutral	Beckman Glass Electrode pH meter (Estefan et al., 2014)
	Soil organic matter (%)	3.20	Medium	1.79	Low	Walkey and Black (Estefan et al., 2014)
	Total nitrogen (%)	0.16	Medium	0.09	Low	Micro Kjeldhal Distillation (Estefan et al., 2014)
	Available phosphorus (kg ha^{-1})	85.03	High	130.97	High	Modified Olsen's method (Estefan et al., 2014)
	Available potassium (kg ha^{-1})	214.61	Medium	138.65	Medium	Ammonium Acetate method (Estefan et al., 2014)

The experimental site lies in the subtropical humid climate belt of Nepal. The area has sub-humid type of weather condition with cool winter, hot summer, and distinct rainy season with annual rainfall of about 2000 mm. The weather data during the cropping seasons was recorded from the metrological station of the National Maize Research Program (NMRP), Rampur, Chitwan (Figure 1).During the growth period of rice i.e. form third week of June to last week of October, the total rainfall during the experimental period 1430 mm and the average maximum temperature was 33.40˚C; average minimum temperature was 25.36˚C and average relative humidity was 89.46% (appendix 4). Likewise, during the wheat growth period (November first week to second week of March), the total rainfall, average maximum and minimum temperature, average RH was 59mm, 26.08 ˚C, 12.38 ˚C and 83.56% respectively and the same weather parameters during the growth period of maize (first week of November to second week of May) were 240.90mm, 31.05 ˚C, 18.92 ˚C and 91.22% respectively.

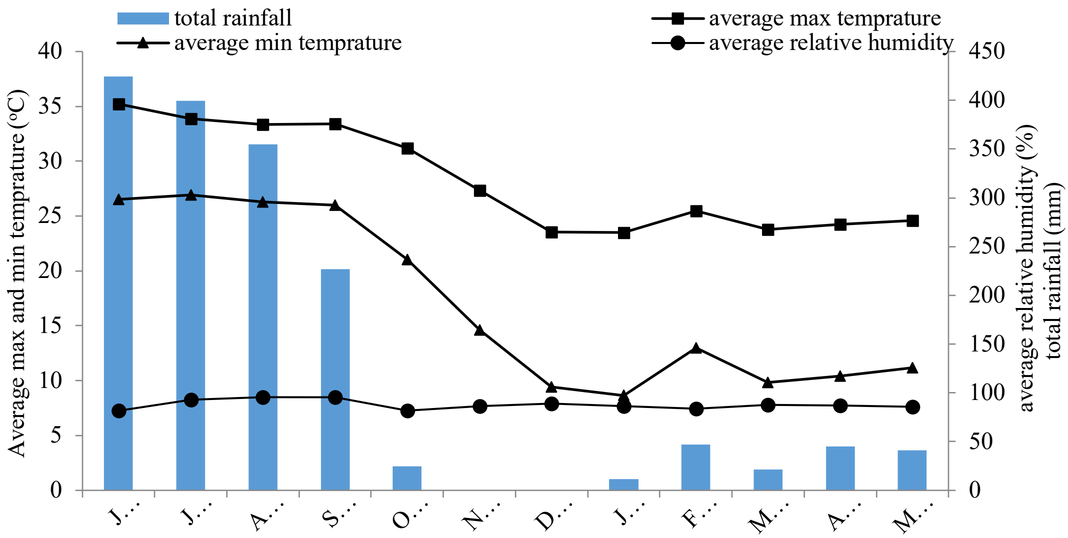


Figure 1: Minimum and maximum daily temperature (°C), daily rainfall (mm) and daily relative humidity during the experimental period at Rampur, Chitwan, Nepal, 2019 (Source: NMRP, 2019)

EXPERIMENTAL DESIGN AND TREATMENTS

In order identify the effect of various nutrient management practices for different establishment methods in R-W and R-M cropping system, an experiment consisting of 16 treatments combining two cropping system, two different establishment methods and four different nutrient management practice were laid out in split plot design with three replications. The variety of rice was US-312, a hybrid rice of maturity days of 120. The used variety of wheat was Bijay of maturity days 111-123 days and that of maize was Rampur hybrid 6, a winter maize with maturity days of 158-165 days.

The cropping system involved two rice based cropping systems viz. rice-wheat and rice-maize. In rice-wheat cropping system, wheat was sown after harvest of rice and for rice-maize system, maize was sown.

The establishment method for rice involved (i) dry-DSR at 20 cm row spacing after tillage (ii) transplanting 30 days old seedlings at 20 cm x 20 cm spacing on puddled field while for wheat (i) sowing the seeds in between the harvested rice rows without tillage making furrows with the help of hoes for the placement of the seeds (ii) sowing the seeds 20cm row spacing after tillage. Likewise, for maize establishment method included (i) sowing the seeds in between the rice rows at 60cm row spacing and 25 cm plant to plant spacing under no till making small furrows just to incorporate fertilizer and seeds (ii) sowing seeds at 60cm row spacing and 25 cm plant to plant spacing after tillage.

The nutrient management factor included (i) application of recommended dose of fertilizer ie. for rice 150: 45:45 kg N, P_2O_5 and K_2O ha^{-1}; for wheat 80:60:40 kg N, P2O_5 and K_2O ha-$^{1)}$ and for maize 180:90:60 kg N, P2O_5 and K_2O ha^{-1} (ii) mulching the straw of wheat and maize @5 t ha^{-1} at DSR plots under R-W and R-M systems respectively along with the 75% of the recommended fertilizer dose and incorporating the same amount of straw in which the rice seedlings are transplanted. Rice residues @5 t ha^{-1} was applied on the wheat and maize crops on which the same treatment is allocated. (iii) nutrient expert dose in which the fertilizer dose was determined using Nutrient Expert software prepared by IPNI i.e. for rice, Nutrient Expert for rice , Beta Version; for maize, Nutrient Expert for hybrid maize V 1.0; and for wheat, Nutrient Expert for wheat V 1.0., (iv) Green manuring (GM) along with the 75% of the recommended fertilizer dose for TPR plots where the *Sesbania* seeds (60kg ha^{-1}) were sown in the field 30 days before transplanting the rice seedlings and were cut and incorporated during the final land preparation. Likewise, the plots allocated with the brown manuring (BM) treatments, same rate of *Sesbania* seeds were broadcasted in the field along with the rice seeds and were killed by spraying 2, 4-D herbicide at the day when the GM crops were toppled down.

CROP MANAGEMENT

Conventional tillage dry direct seeded rice (CT-DDSR) and puddled transplanted (Pu-TPR) field were managed as the zero tillage (ZT) wheat/maize and convention tillage wheat and maize, respectively. The wheat and maize residues @ 5 t ha^{-1} were applied on rice crop as mulch in DDSR and incorporated in soil for Pu-TPR. ZT plots were prepared by spraying the glyphosate-47SL @ 5 ml L^{-1} a week prior to sowing and wheat and maize seeds were directly sown in lines. For CT, after Pu-TPR, the field was ploughed twice, pulverized and leveled and wheat and maize were sown. For both establishment methods, seed was sown on 5thNovember 2018. The RDF used for the crops was determined from the economic maximum dose obtained from various previous researches and the nutrient expert doses for all the crops were calculated using Nutrient Expert Model of each crop developed by International Plant Nutrient Institute(IPNI). The residue amount varied with treatments and was used as surface mulch for wheat and maize.

Full dose of K_2O and P_2O_5 was applied through muriate of potash (MOP) and di-ammonium phosphate(DAP) as basal dose whereas N in each treatment was divided three equal splits and each split was applied as basal dose, and at 30 days after sowing (DAS) for both crops whereas the third split was applied at 60 DAS for wheat and at 90 DAS for maize synchronizing the critical stages. For maize, tank mixture of Atrazine and Pendimethalin (each @ 0.75 a.i. kg ha^{-1}), was sprayed followed by one hand pulling of weeds at 50 DAS for both ZT and conventional tillage treatments. No weeding operation was conducted for wheat.

SAMPLING AND MEASUREMENTS

Biomass yield and grain yield of rice and wheat were taken at harvesting from net plot i.e. 12.60 m^2. The crop was sun dried in-situ for 3-4 days then threshed, sun dried, cleaned and final weight was taken along with grain moisture percent. The grain yield per hectare was computed for each treatment from the net plot yield. Finally grain yield was adjusted at 14% moisture using the formula as

Gain yield (t ha^{-1}) at 14% moisture = $\frac{(100-\text{MC}) \times \text{plot yield (kg)} \times 10000\ (\text{m}^2)}{(100-14) \times \text{net plot area}\ (12.60\ \text{m}^2)\ \text{x}\ 1000}$

Where, MC is the moisture content in percentage of the grains.

Biomass yield and grain yield of maize were taken at harvesting from net plot i.e. central 5 rows (9 m^2). Cobs were separated from the stover and both cobs and stover of each plot was sun dried, then shelling of grains and final weight of grain was taken along with exact grain moisture percent. The grain yield per hectare was computed for each treatment from the net plot yield. Finally grain yield was adjusted at 14% moisture using the formula above formula.

Cultivation cost of crops was calculated on the basis of local charges for different agro-inputs viz. labor, fertilizer, herbicides and other necessary materials and explained as total cost of NRs ha^{-1}.The price per unit kg of grain and straw on the basis of local market was multiplied with the grain yield and straw yield of each plot to determine gross return and expressed in NRs ha^{-1} for all treatments and replications. It was calculated by the use of following formula.

B: C ratio = $\frac{\text{Gross return}}{\text{Total cost of cultivation}}$

For system yield analysis, the wheat yield was multiplied by the price of wheat, and the product was divided by the price of rice, and maize yield was multiplied by the price of maize, and the product was again divided by the price of rice and then result was added to the rice yield.

Rice equivalent yield (REY) = Yield of rice +

$$\frac{\text{Yield of wheat (kg) x price of wheat (NRs per kg)}}{\text{Price of per kg rice}} + \frac{\text{Yield of maize (kg) x price of maize (NRs per kg)}}{\text{Price of per kg rice}}$$

STATISTICAL ANALYSIS

The data were subjected to analysis of variance, and Duncan's multiple range test at α level 0.05 (DMRT)for mean separations (Gomez & Gomez, 1984). Dependent variables were subjected to analysis of variance using the R Studio for split plot design. Sigma Plot v. 12 was used for the graphical representation. The rice equivalent yield of wheat and maize were compared using paired t-test.

RESULT AND DISCUSSION

PRODUCTIVITY AND PROFITABILITY OF RICE BASED CROPPING SYSTEMS UNDER DIFFERENT CROP ESTABLISHMENT METHODS AND NUTRIENT MANAGEMENT PRACTICES

The average rice equivalent yield (REY) was 10.41 t ha^{-1}(Table 2) and was significantly influenced by the cropping system where rice-maize cropping system had statistically high rice equivalent yield ie.12.21 t ha^{-1} than that of rice-wheat cropping system (8.61 t ha^{-1}). However, establishment methods and nutrient management practice did not have significant influence on the REY. However, REY under NE dose was 10.01% more compared to REY under100% RDF.

Table 2. Rice equivalent yield (t ha^{-1}), total cost of production (NRs. '000 ha^{-1}), gross and net returns (NRs. '000 ha^{-1}), and B:C ratio of rice-based systems as influenced by the establishment methods and nutrient management practices of rice, wheat and maize at Rampur, Chitwan, 2018-2019

Treatments	**System REY (t ha^{-1})**	**System economics**			
		Cost of cultivation (NRs. '000 ha^{-1})	**Gross return (NRs. '000 ha^{-1})**	**Net return (NRs. '000 ha^{-1})**	**B:C ratio**
Copping systems					
Rice-wheat	8.61^{b}	171.09	232.40^{b}	61.31	1.36
Rice-maize	12.21^{a}	183.71	329.77^{a}	146.07	1.81
SEm (±)	1.80		48.68	423.79	0.22
LSD (=0.05)	3.47		93.81	ns	ns
CV, %	26.90		26.90	72.90	26.30
Establishment methods					
CT Dry DSR fb ZT wheat/ZT maize	10.12	168.68	273.20	104.52	1.62
Pu-TPR fb CT wheat/ CT maize	10.70	186.12	288.97	102.85	1.55
SEm (±)	0.29		7.89	0.84	0.04
LSD (=0.05)	ns		ns	ns	ns
CV, %	8.00		8.00	21.70	8.10
Nutrient management practices					
100% RDF	9.99	169.39	269.63	100.24^{ab}	1.59^{b}
RR#+75% RDF	10.53	183.32	284.27	100.95^{ab}	1.55^{b}
NE dose	10.99	170.52	296.83	126.32^{a}	1.74^{a}
RR@+75% RDF	10.13	186.37	273.61	87.24^{b}	1.46^{b}
SEm (±)	0.23		6.09	8.17	0.06
LSD (=0.05)	ns		ns	26.36	0.14
CV, %	11.10		11.10	30.20	10.80
Grand mean	10.41	177.40	281.09	103.69	1.58

Note: RR#, residue retention (10t ha^{-1}); RR@, residue retention (green or brown manuring @ 60 kg Sesbania ha^{-1} followed by residue @ 3.5 t ha^{-1}); RDF, recommended dose of fertilizers (150:45:45 kg N, P_2O_5 and K_2O per ha^{-1}; 80:60:40 kg N, P_2O_5 and K_2O per ha^{-1}; 180:90:60 kg N, P_2O_5 and K_2O per ha^{-1} for rice, wheat and maize respectively); nutrient expert, (140:56:53 kg N, P_2O_5 and K_2O per ha^{-1}; 140:60:45 kg N, P_2O_5 and K_2O per ha^{-1}; 150:50:90 kg N, P_2O_5 and K_2O per ha^{-1} for rice, wheat and maize respectively); DAS, days after sowing. Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

Rice-wheat cropping system is the most practiced system in the IGP (Kumar &Ladha, 2011) and rice-maize system has emerged as a pre-dominant option for diversification of existing rice-based cropping systems in Asia (Singh et al., 2016). Based on the various its evident that these cereals are cultivated under intensive tillage, receive most of the irrigation and consequent to the increased production cost, yield penalties due to late planting and deterioration of soil properties (Ladha et al., 2003).In the present experiment, the rice equivalent yield (REY) of rice-maize cropping system (12.21 t ha^{-1}) was 41.81% more than the yield rice-wheat cropping system (8.61t ha^{-1}) (table 33). The higher REY of rice-maize cropping system was due to the increased yield of maize than wheat under both establishment methods. The higher yield of maize was due to the suitable meteorological conditions compared to wheat. The average maximum temperature was 26.06˚C which was higher than optimum temperature (< 25˚C) and total rainfall during wheat period was 59 mm which was also less than the optimum (63-87mm) rainfall resulting in the forced maturity of crops ensuing lower yield. But the temperature (31.05 ˚C) and rainfall of 37.6mm during March and 125.3mm during April coincided with the tasseling, silking and grain filling stage of the maize crop which also resulted in the improved yield of maize over wheat. Along with the meteorological advantages, maize being C_4crop is more efficient in carbon assimilation even at higher temperature(Steven & Salvucci, 2002) and the heterogeneous genetic combination of maize attributed to higher yield of maize. Hence, the yield of rice-maize cropping system was more than rice-wheat system. The REY of the system under CA was less (10.12t ha^{-1}) compared to 10.70 t ha^{-1} yield under conventional system, however, the difference was not statistically significant. The higher yield of the system under conventional system is due to the higher yield of rice and wheat under conventional system. Rice and wheat yielded 14.28% and 8.90% less yield under CA than conventional agriculture and hence the system yield under conventional system was more. The reasons behind the lower yield of component crops of the system under CA and nutrient management practices are explained later with literature supports.

The average total system cost of production was NRs. 177399.70 ha^{-1}. The rice-maize system was found to be NRs.12610.86 more costly than rice-wheat system and the total system cost of production under Pu-TPR fb CT-wheat/maize was NRs.17447.30 ha^{-1} more than that under CT-dry DSR fb ZT-wheat/maize (Table 2). The highest system cost of production was under residue$^{@}$ + 75% RDF followed by residue$^{\#}$ + 75% RDF and minimum cost was incurred in 100% RDF. The highest cost under residue$^{@}$ + 75% RDF and residue$^{\#}$ + 75% RDF was due to higher cost of *Sesbania* and residues applied for the treatments. The system gross return was significantly influenced by the cropping system but not by the establishment methods and nutrient management practices (Table 2).The rice-maize system gave NRs. 97383.67 more revenue than rice-wheat system forms a hectare. The average B:C ratio of the cropping system was 1.58 with rice-maize cropping system and CT-dry DSR fb ZT-wheat/maize being more profitable in terms of B:C ratio compared to rice-wheat system and Pu-TPR fb CT-wheat/maize(Table 2). However, the difference among the B:C ratio is statistically significant for different nutrient management practices. Highest B:C ratio (1.74) was found under NE dose whereas the remaining nutrient management practices had lower B:C ratio but were statistically at par among themselves.

The higher cost of cultivation was incurred in all the crops viz. rice, wheat and maize under conventional agriculture compared to CA. Rice under conventional agriculture required more cost for nursery preparation, and 46.67% of the total cost of production was incurred for labor which was about 18% more than labor requirement under CA**.** Similar results were found by (Kumar & Batra, 2017)**.** Moreover, the cost of herbicide used in rice under CA was 193% more than conventional agriculture. Similarly, more cost for machinery and labor was required under conventional agriculture for the production of both wheat and maize whereas more cost for herbicides and labor for seed sowing under CA were required for wheat and maize and the cost for seed, fertilizers and intercultural operations remained similar which was also explained by (Leghari, Mirjat, Qadir Mughal, Rajpar & Magsi, 2015). The similar explanations of higher cost of tillage under conventional agriculture and cost reduction under CA were also given by Kumar et al. (2015),Tripathi (2010) and Lales et al. (2008) etc. Under nutrient management practices, the cost of rice production was more for GM/BM+75% RDF. Despite using 25% less fertilizers, the highest cost under this was due to the added cost of *Dhaincha*, its' sowing and knocking down / incorporating. Likewise, for wheat and maize, highest cost was incurred under RR$^{\#}$+75% RDF followed by RR$^{@}$+75% RDF which was due to the higher cost of rice residues (a valuable livestock feed) applied/left under the treatment which constitutes 26.73% and 18.71% of average cost of wheat production and 22.26% and 15.58% of average cost of maize production under the respective treatments.

Rice-maize cropping system was most profitable under both CA and conventional agriculture than rice- wheat system which was due to the fact of lower cost of production under CA and higher REY of maize compared to wheat and similar explanations were given by Kumar et al. (2018)**.** The rice-maize system net return was 138% more than that under rice-wheat cropping system. The cropping systems were profitable under CA due to the lower cost of production. The maximum net return of system and B:C ratio under NE dose was due to the superior performance of component crops under that nutrient management and hence was the best nutrient management practice. The better performance of NE dose assisted fertilizer management in major cereals were also agreed by Dahal et al. (2018) and Gupta.

EFFECT OF RICE ESTABLISHMENT METHODS ON YIELD OF RICE AND SUCCEEDING NON-RICE CROP

The grain yield of CT-DSR (5.28 t ha^{-1}) was significantly higher than puddled TPR (4.62 t ha^{-1}). (Figure 2a) While the effect of rice establishment methods on the yield of maize and wheat was not significantly influenced (Figure 2a). The yield under conventional tillage and zero tillage were also statistically similar for both wheat and maize (Figure 2b)

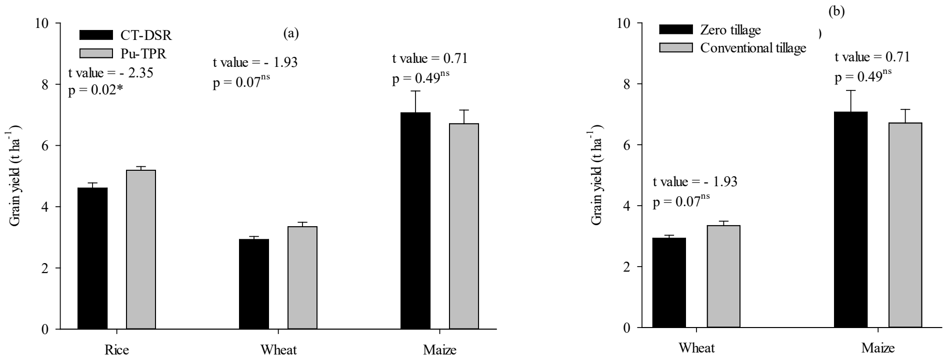
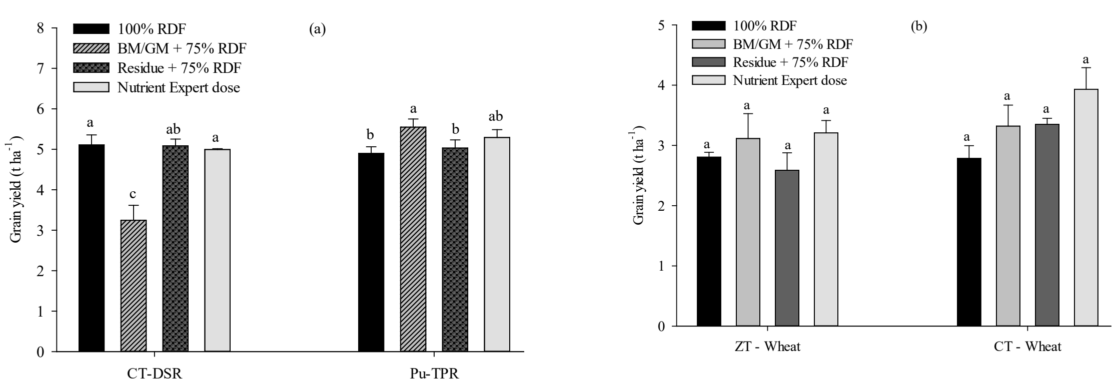


Figure 2. (a) Effect of rice establishment methods to the grain yield of rice, wheat and maize, (b) effect of tillage methods to the grain yield of wheat and maize at Rampur, Chitwan, 2018-19

NUTRIENT MANAGEMENT PRACTICES ACROSS THE DIFFERENT CROP ESTABLISHMENT METHODS

Overall, the maximum grain yield was found in GM + 75% RDF for conventional agriculture followed by NE dose and residue + 75% RDF treated plots under CA. Under CA, 100% RDF, NE dose and residue + 75% RDF had statistically similar grain yield and higher than the BM + 75% RDF and for conventional agriculture GM + 75% RDF had maximum grain yield which was statistically at par with that of NE dose treated plots. Among 100% RDF and residue + 75% RDF and NE dose were statistically at par for grain yield. The wheat grain yield under conventional tillage (3.31 kg ha^{-1}) was relatively higher than zero tillage (2.97 t ha^{-1}). The wheat grain yield for NE dose (3.43 t ha^{-1}) was the highest among the nutrient management practices followed by residue@ + 75% RDF (3.28 t ha^{-1}), residue# + 75% RDF (3.02 t ha^{-1}) and 100% RDF (2.84 t ha^{-1}). In response to nutrient management practices, the maize grain yield for NE dose (6.44 t ha^{-1}) was the highest among the nutrient management practices followed by residue@ + 75% RDF (6.25 t ha^{-1}) residue# + 75% RDF (6.24 t ha^{-1}) and 100% RDF (5.47 t ha^{-1}) where the differences were not significant.



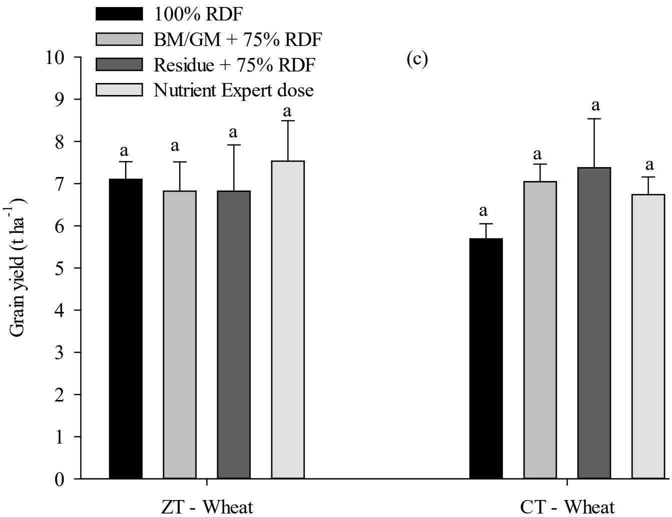


Figure 3. Interaction of establishment methods and nutrient management practice on (a) rice, (b) wheat, and (c) maize at Rampur, Chitwan, 2018-19

Note: Residue, residue retention (5 t ha^{-1}); RDF, recommended dose of fertilizer (150:45:45 kg N, P_2O_5, K_2O ha^{-1}); GM, green manuring (60 kg *Sesbania* ha^{-1}); BM, brown manuring (60 kg *Sesbania* ha^{-1}); DAS, days after sowing. Same letter(s) represent non-significant difference at 0.05 level of significance based on Duncan multiple range test. The nutrient expert dose used was 140:56:53 kg N, P_2O_5, K_2O ha^{-1}).

CONCLUSION

Rice-maize cropping system was more productive and profitable than rice-maize cropping system but the rice based cropping systems were similar in terms of productivity and profitability under both CA and conventional agriculture. Rice under CA was less productive but the profitability was similar under both establishment methods whereas wheat and maize were indifferent in terms of productivity and profitability under both CA and conventional agriculture. Nutrient expert model was found to be the best nutrient management practice for all crops for both CA and conventional agriculture whereas for TPR, green manuring was found equally efficient, nevertheless, for wheat and maize, residue retention in brown and green manure field was found better nutrient management practices under both establishment methods.

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