Agronomy Journal of Nepal. ***6****(1):45-58*
ISSN: 2091-0649 (Print)
DOI: https://doi.org/10.3126/ajn.v6i1.47936

Reasonable Fertilization Improves the Conservation Tillage Benefit for the Yield of Winter Maize in Rice-based Cropping System of Central Inner Terai of Nepal

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Received: May 15, 2022
Revised: June 15, 2022
Published: July 08, 2022

The authors declare that there is no conflict of interest.

ABSTRACT

To investigate the effects of fertilization, tillage, and their interaction on maize yield, an experiment on rice-maize was conducted on 2018/19 and 2019/20 at Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal. The experiment was in a split-plot with two establishment methods viz. (i) zero tillage followed after (fa) conventionally tilled dry direct seeded rice (ZT fa CT-DDSR) (ii) conventional tillage fa puddled transplanted rice (CT fa Pu-TPR) and four nutrient management practices, i.e. (i) recommended dose (100% RDF; 180-90-60 N-P_2O_5-K_2O kg ha^{-1}), (ii) Residue retention of rice crop @ 5 t ha^{-1} + 75% RDF (RR +75% RDF), (iii) Nutrient expert (NE) dose (150-50-90 N-P_2O_5-K_2O kg ha^{-1}), (iv) Rice residue @ 3.5 t ha^{-1} +75% RDF followed after brown/green manuring of Sesbania in rice (R+75% RDF fa BM/GM) and the treatments were replicated thrice. The data on yield and yield attributes were recorded and analyzed by R studio. Both crop establishment methods and nutrient management practices did not influence ($p>0.05$) the plant population, number of cobs per plant, number of grains per cob, thousand-grain weight, and sterility. The barrenness percentage was not significantly affected by the crop establishment methods but significantly ($p>0.05$) lower under residue retained treatments. Application of NE dose, sterility was significantly ($p<0.05$) reduced under ZT fa CT-DDSR. The average grain yield, straw yield, and harvest index (HI) were 6153 kg ha^{-1}, 4547 kg $ha^{-1,}$ and 53.81% respectively. The two years average grain yield was statistically at par ($p>0.05$) for both crop establishment methods whereas application of NE dose, RR+75% RDF, and R+75% RDF fa BM/GM resulted in significantly ($p<0.05$) higher grain yield than obtained in the 100% RDF applied plots. Maize planting on zero tillage followed after CT-DDSR was equally productive and the use of a nutrient expert for nutrient recommendation or retention of residues with a 25% reduction of the RDF had a yield advantage over the present RDF.

Keywords: Conservation agriculture, nutrient-expert, residue, rice-based system, wheat

How to cite this article:
Marahatta S and TB Karki 2022. Reasonable fertilization improves the conservation tillage benefit for the yield of winter maize in rice-based cropping system of central inner terai of Nepal**.** Agronomy Journal of Nepal. **6**(1):45-58. DOI: https://doi.org/10.3126/ajn.v6i1.47936

INTRODUCTION

Maize (*Zea mays* L.) is the dominant crop of the cereal-based cropping systems of the Asian region which alone contributes 29% to global maize production (FAOSAT 2017). It is the second most important crop of Nepal after rice in terms of both area cultivation and production. The national average yield of maize (2.35 Mt ha^{-1}) (MOF 2017) is far below the attainable yield of >8.0 Mt ha^{-1} (Devkota et al 2016). Current maize production of 1.3 million tons is not sufficient to meet the national demand thus yields of maize must be increased by 57% (CBS, 2014; KC et al; MOF 2017; Trend Economy 2020). The feed demand is increasing at 11% per annum, which demands a huge amount of maize thus resulting in the increment in the import of agri-products (CDD 2011). As the possibility of expanding the cultivation area in the future is very limited, thus the required extra production has to come through an increase in productivity. Poor crop management practices, low soil fertility, extreme climatic conductions, etc. are the main causes of low productivity (Raza et al 2019). The crop environment was manipulated through agronomic management such as seed rate, plant population, and fertilizer, which influence the growth and ultimately the grain yield (Lomte and Khuspe 1987). The haphazard and inefficient use of inputs not only reduced the yield and profitability but also caused the wastage of time and effort which leads to weak agricultural economic growth.

In the Nepalese rice-wheat cropping system, the popular rice establishment method includes the transplantation of 20-25 days old rice seedlings in the puddled field while wheat is established (in rice residue removed fields) by broadcasting/drilling seed after conventional tillage and planking operations (Bhatt et al 2016). The continuous practice of conventional tillage in most areas has led to degradation in soil properties (Zamir et al 2013; Moraru and Rusu 2013; Thomas et al 2007) and an increment in nutrient loss leaving the soil infertile in long run. The conventional wheat planting system involves repeated dry tillage and a long turnaround period which delays wheat planting (Kumar et al 2014) thus decreasing the wheat yield as the system yield (Marahatta et al 2018). Rice-maize system has now emerged as the best alternative to the rice-wheat system in some niches of IGP because of the better suitability of maize after harvest of long-duration rice cultivars, increasing demand of maize in the feed industry, higher productivity and profitability of maize compared to the other crops (Timsina et al 2010).

For optimum growth and better yield, the maize crop requires an adequate supply of macro-nutrients particularly nitrogen, phosphorus, and potassium. These elements are important for the formation of chlorophyll, nucleotides, phosphatides, and alkaloids as well as in many enzymes, hormones, and vitamins that optimized the grain yield (Ewees et al 2008). It is, therefore, pertinent to explore nutrient management, particularly nitrogen, phosphorus, and potassium needed for optimum growth and high yield. Nitrogen management is the key practice for obtaining the yield potential of maize (Sampath et al 2013). Even the research-based existing fertilizer recommendations advise using fixed rates of nitrogen, phosphorus, and potassium. But the need for supplemental nutrients is strongly associated with crop-growing conditions, crop and soil management, and climate. In this aspect, the site-specific nutrient management (SSNM) based nutrient management tool, nutrient expert (NE) is a suitable option even for the smallholders. Hence, the current study was carried out with the objectives of evaluating the effect of different crop establishment methods and nutrient management practices including the residual effect of crop and nutrient management practices of rice on the performance of maize crops grown in a sequence.

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 Bagmati Province of Nepal (27˚40ˈ N and 84˚23ˈ E and 256 masl) from June 2018 to May 2020 as two cropping seasons. The soil in the experimental field was sandy loam with slightly acidic to neutral pH, medium to low organic matter and nitrogen content, and high phosphorus and medium potassium content according to the standard rating of the Government of Nepal, Kathmandu.

The experimental site lies in the subtropical humid climate belt of Nepal. The area has a sub-humid type of weather condition with cool winter, hot summer, and a distinct rainy season with an annual rainfall of about 2000 mm. The weather data during the cropping seasons were recorded from the metrological station of the National Maize Research Program (NMRP), Rampur, Chitwan (Figure 1).

Experimental design and treatments

The experiment was conducted in a split-plot design, with two factors i.e. two establishment methods as the main plot and four nutrient management practices as subplot factors for both crops. The two establishment methods comprised (i) zero tillage followed after conventionally tilled dry direct seeded rice (ZT fa CT-DDSR) (ii) conventional tillage followed after puddled transplanted rice (CT fa Pu-TPR). The four nutrient management practices included- (i) 100% recommended dose (100% RDF; 180-90-60 kg N-P_2O_5-K_2O ha^{-1}), (ii) Residue retention of previous crop @ 5 t ha^{-1} + 75% RDF (RR + 75% RDF), (iii) Nutrient expert (NE) dose (150-50-90 kg N-P_2O_5-K_2O ha^{-1}), (iv) Rice residue @ 3.5 t ha^{-1} +75% RDF of each crop followed after Brown/green manuring of Sesbania in rice (R + 75% RDF fa BM/GM) and the treatments were replicated thrice. The variety 'Rampur hybrid-6' was used and sown at a spacing of 60 cm × 25 cm. Two seeds per hill were sown and maintained as one plant after thinning at 20 days after sowing.

Crop management

Conventional tillage dry direct seeded rice (CT-DDSR) and puddled transplanted (Pu-TPR) fields were managed as the zero tillage (ZT) maize and convention tillage maize, respectively. The maize residues @ 5 t ha^{-1} were applied to the rice crop as mulch in DDSR and incorporated into the soil for Pu-TPR. ZT plots were prepared by spraying the glyphosate-47SL @ 5 ml L^{-1} a week before sowing and maize seeds were directly sown in lines. For CT, after Pu-TPR, the field was plowed twice, pulverized and leveled and seeds were sown. For both establishment methods, the seed was sown on 5th November 2018 and 2nd November 2019. The RDF used was determined from the economic maximum dose obtained from various previous researches and the nutrient expert doses were calculated using Nutrient Expert Model developed by International Plant Nutrient Institute (IPNI). The residue amount varied with treatments and was used as surface mulch. The 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 into three equal splits and each split was applied as basal dose, and at 30 days after sowing (DAS) whereas the third split was applied at 90 DAS for maize synchronizing the critical stages. A tank mixture of Atrazine and Pendimethalin (each @ 0.75 a. i. kg ha^{-1}), was sprayed followed by one hand pulling of weeds at 45 DAS and 50 DAS respectively in 2018 and 2019 for both ZT and conventional tillage treatments.

Sampling and measurements

The final plants were counted from the net plot area (8.4 m^2) and converted to plants per ha. The total number of barren plants was counted in each net plot, and it was converted to the number of barren plants ha^{-1} and then into the barrenness percentage.

$$\text{Barrenness percentage} = \frac{\text{Number of barren plants in net plot area}}{\text{Total number of plants in the net plot area}} \times 100$$

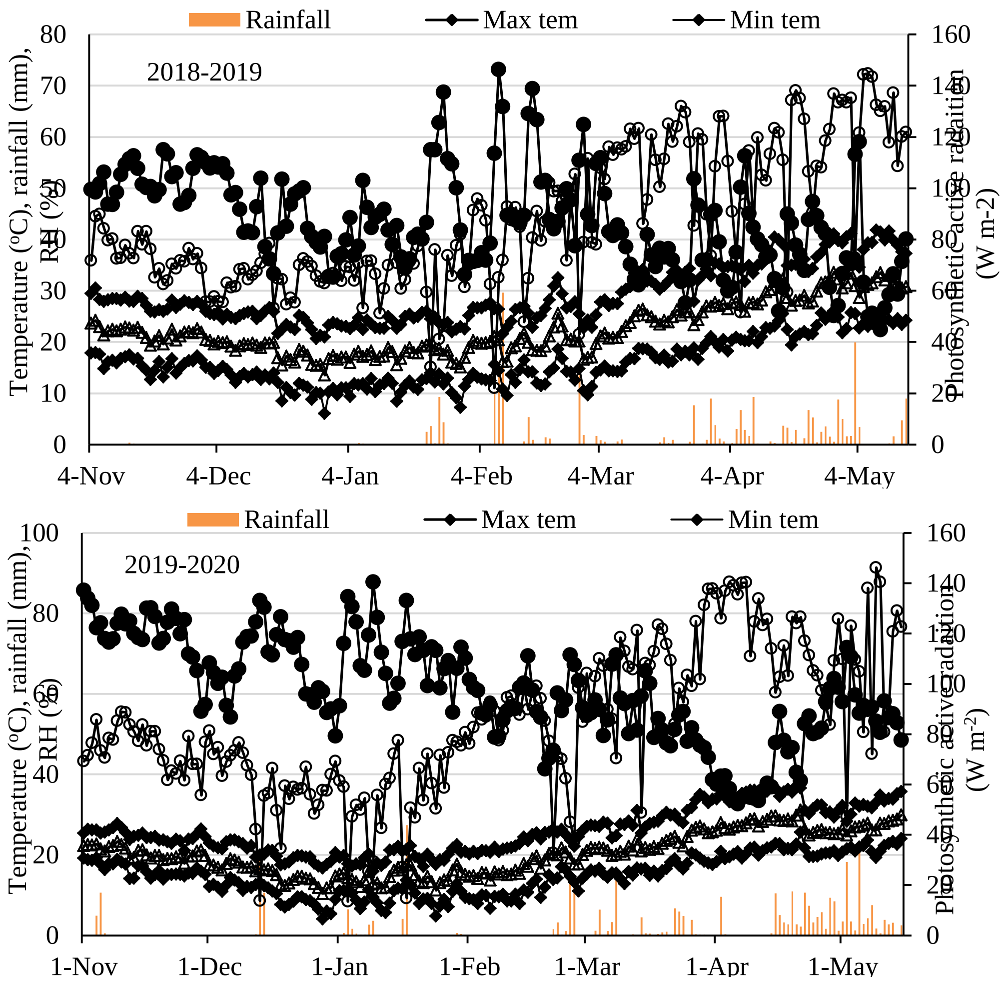

Figure 1. Minimum and maximum daily temperature (°C), daily rainfall (mm), and daily relative humidity during the experimental period at Rampur, Chitwan, Nepal (Source: NASA POWER - https://power.larc.nasa.gov/data-access-viewer/)

Note: Max tem, maximum temperature; Min tem, minimum temperature; Av, average temperature; RH, relative humidity; PAR, photosynthetic active radiation

Dehusking of cobs was done separately for each plot on the threshing floor. After the shelling of grains, seeds were carefully separated and dried, and weighed and moisture percent was recorded. After removing the cobs, the cut stalks were sun-dried for a few days and weighed, dry weight was also recorded by drying a subsample of stover. The final plant population at harvest, the number of grains per cob, and thousand grain weight were recorded. For determining the number of grains per cob, ten cobs were selected randomly, grains separated from the cob, and grains counted. After threshing, seeds were cleaned and weighed. From the same cobs, the total length of the cob and the sterile length of the cob was measured using a measuring scale and then the sterility percentage was calculated for individual cob and was averaged to determine the sterility percentage was calculated for each treatment.

$$\text{Sterility (\%)} = \frac{\text{Sterile length}}{\text{Total cob length}} \times 100$$

A sample of 250 grains was weighed from each replication to derive a thousand-grain weight. Total biomass (dry matter basis) and grain yield (adjusted to a moisture content of 13%), were recorded on the plot basis and were converted to kg ha^{-1} for statistical analysis.

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 and Gomez, 1984). Dependent variables were subjected to analysis of variance using the R Studio for split-plot design. MS Excel was used for the graphical representation.

RESULTS AND DISCUSSION

The influence of the nutrient management practices on the yield attributes and their relation to the grain yield under different crop establishment methods are presented and discussed as follows.

Table 1. Mean square from analysis of variance (ANOVA) for the effects of crop establishment methods and on evaluated traits of winter maize at Rampur, Chitwan, Nepal, 2018-2019 and 2019-20

Evaluated traits	Source of variation					
	Replication	Crop establishment methods (CE)	Error(a)	Nutrient management practices (NM)	CE x NM	Error(b)
First year						
Plant population ha^{-1}	416658	113631721	54063775	7458850	56704419*	9705073
Barrenness percentage	0.022	21.24	5.20	14.42	12.68	33.56
No. of cobs $plant^{-1}$	0.050	0.007	0.015	0.015	0.006	0.006
No. of grains cob^{-1}	610.00	3053.30*	88.80	407.40	57.20	331.90
Thousand grain weight	131.60	577.10	429.90	851.30	317.30	314.70
Sterility percent	28.45	61.41	11.48	3.07	22.39*	4.74
Grain yield	3314454	1653750*	70512	1120228	1774783	847389
Stover yield	6628429	564267	1772904	525789	390433	622828
Harvest index	465.14	0.50	49.02	9.38	14.14	23.98
Second year						
Plant population ha^{-1}	72116930	20094	12799801	4521123	23221826	26570805
Barrenness percentage	0.42	15.99	3.36	8.39**	3.58	1.10
No. of cobs $plant^{-1}$	0.016	0.016*	0.0004	0.006	0.003	0.003
No. of grains cob^{-1}	3517	70	1990	2523	4598	1536
Thousand grain weight	908.70	492.20	739.00	731.60	128.90	924.90
Sterility percent	35.47	58.13	10.33	5.30	24.43*	6.08
Grain yield	2787232	1500219	1039381	2156614	1465076	977271
Stover yield	377630	749778*	17612	627473	339257	430638
Harvest index	17.24	1.48	25.51	4.21	64.81	19.10

Evaluated traits	Source of variation					
	Replication	**Crop establishment methods (CE)**	**Error(a)**	**Nutrient management practices (NM)**	**CE x NM**	**Error(b)**
Average of two years						
Plant population ha^{-1}	12488169	29168484	27237050	5079399	17007671	10480897
Barrenness percentage	0.08	17.94	2.87	6.09*	3.49	1.43
No. of cobs plant^{-1}	0.028	0.011	0.003	0.006	0.002	0.004
No. of grains cob^{-1}	1644.80	550.20	315.90	322.20	1105.20	494.60
Thousand grain weight	420.50	533.80	562.20	743.80	168.40	337.50
Sterility percent	31.82	59.76	10.89	4.01	23.38*	5.18
Grain yield	3040803	1576050	313338	1586729*	294631	429936
Stover yield	962858	653732	367756	533441	135621	230034
Harvest index	165.35	0.93	0.95	4.99	12.04	10.56

Note: *, significant differences at 0.05 level of significance; **, significant differences at 0.01 level of significance

Influence of crop establishment methods and nutrient management practices on yield attributes

The average final plant population was 59604 ha^{-1}, which was almost similar for both years (59861 ha^{-1} in the first year and 59346 ha^{-1} in the second year). The final plant population was not significantly (p>0.05) by the crop establishment methods and nutrient management practices during both years (Table 1 and Figure 2). A significant interaction of establishment methods and nutrient management practices for plant population in the first year of experiments is presented in Figure 3. The highest plant population was recorded with NE dose under ZT fa CT-DDSR which was statistically at par with 100% RDF and R+75% RDF fa BM/GM but the lowest in RR +75% RDF. Under CT fa Pu-TPR, plant population was the highest for 100% RDF which was statistically similar to other nutrient management practices.

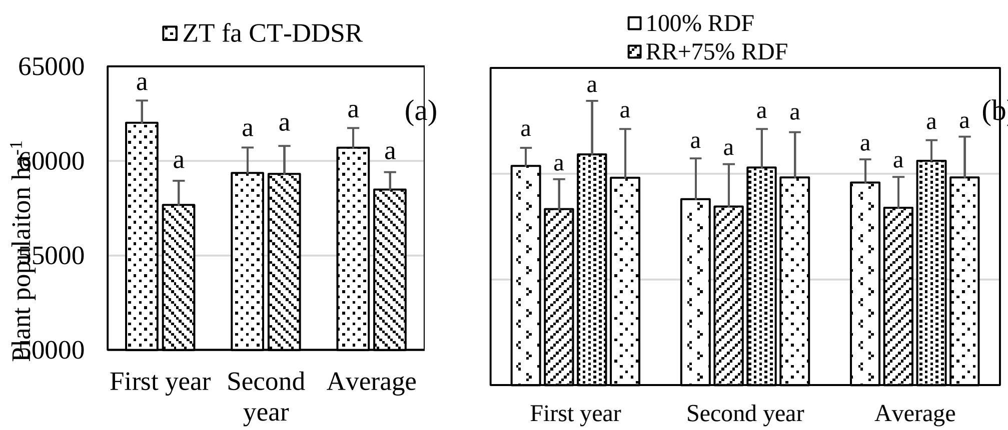

Figure 2. Plant population per hectare of maize as influenced by the (a) establishment methods and (b) nutrient management practices at Rampur, Chitwan, 2018-2019 and 2019-2020

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within each bar group represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

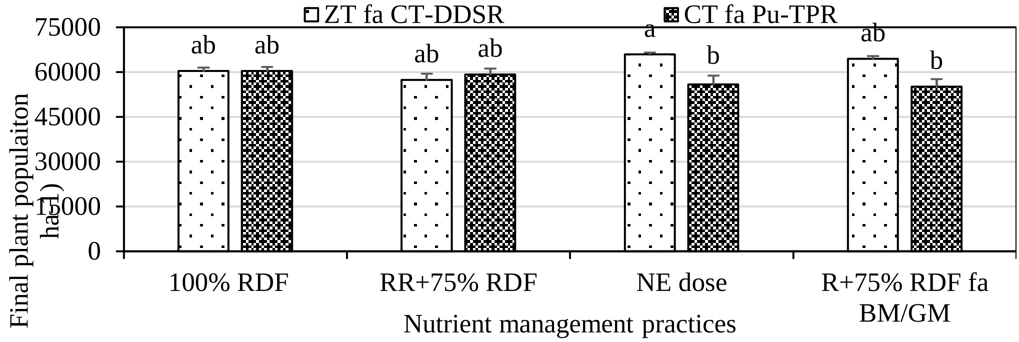

Figure 3. Final plant population ha^{-1} of maize as influenced by the interaction of establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The average barrenness was 4.14% and ranged from 2.85 to 4.98% among the different treatments. The barrenness percentage was not significantly (p>0.05) influenced by the crop establishment methods (Table 1 and Figure 4). The nutrient management practices had not significantly (p>0.05) influenced the barrenness percentage during the first year but differed significantly (p<0.05) in the second year and also on the average (Figure 4). The lowest barrenness (2.53 and 2.85% in the second year and average of the two years respectively) was recorded on the treatment RR +75% RDF which was significantly (P<0.05) lower than the other nutrient management practices in the second year whereas in the average of two years it was statistically at par (P>0.05) with the R+75% RDF fa BM/GM (Figure 3).

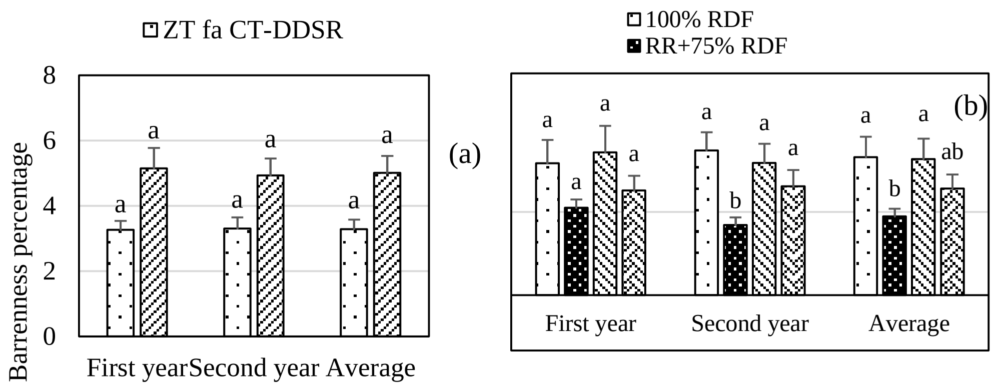

Figure 4. Barrenness percentage of maize as influenced by the (a) establishment methods and (b) nutrient management practices at Rampur, Chitwan, 2018-2019 and 2019-2020

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within each bar group represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

Crop establishment methods and nutrient management practices did not influence ($p>0.05$) the number of cobs per plant except in the second year where a significantly ($P<0.05$) higher number of cobs per plant was recorded in the crop establishment methods CT fa Pu-TPR (Table 1 and 2). Similarly, crop establishment methods and nutrient management practices did not significantly ($p>0.05$) influence the number of grains per cob except in the first years of an experiment where a significantly ($P<0.05$) higher number of cobs per plant was recorded in CT fa Pu-TPR (Table 1 and 2). Thousand-grain weight was not influenced ($p>0.05$) both by crop establishment methods and nutrient management practices (Table 1 and 2).

Table 2. Cobs per plant, grains per cob, and thousand-grain weight (g) of winter maize as influenced by the establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019 and 2019-20

Treatments	Cobs per plant			Grain per cob			Thousand grain weight (g)		
	First year	Second year	Average	First year	Second year	Average	First year	Second year	Average
Establishment methods									
ZT fa CT-DDSR	1.08	1.08[b]	1.08	296[b]	304	300	345	345	345
CT fa Pu-TPR	1.12	1.13[a]	1.12	318[a]	301	310	335	336	335
SEm (±)	0.035	0.006	0.014	2.72	12.88	5.13	5.99	7.85	6.84
LSD (<0.05)	ns	0.039	ns	16.56	ns	ns	ns	ns	ns
CV (%)	5.50	1.00	2.3	1.50	7.40	2.90	3.00	4.00	3.50
Nutrient management practices									
100% RDF	1.10	1.14	1.12	317	272	295	330	325	328
RR+75% RDF	1.17	1.09	1.13	299	312	305	357	351	354
NE dose	1.06	1.07	1.06	302	313	307	341	345	343
R+75% RDF fa BM/GM	1.07	1.10	1.08	310	314	312	333	338	336
SEm (±)	0.031	0.023	0.025	7.44	16.00	9.08	7.24	12.42	7.50
LSD (<0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	6.90	5.30	5.6	5.90	12.90	7.30	5.20	8.90	5.40
Grand mean	**1.10**	**1.10**	**1.10**	**307**	**303**	**305**	**340**	**340**	**340**

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within the column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The sterility percentage was not significantly ($p>0.05$) influenced by individual treatment factors but the interaction effect of crop establishment methods and nutrient management practices was significant ($p<0.05$) for sterility percentage. During both years of experimentation, sterility percentages for both crop establishment methods were statistically similar ($p>0.05$) in 100% RDF and RR + 75% RDF application whereas with the application of NE dose and R+75% RDF fa BM/GM, sterility was significantly ($p<0.05$) reduced under ZT fa CT-DDSR. But on average of two years significant ($p<0.05$) reduction in the sterility under ZT fa CT-DDSR with the NE dose application whereas with other nutrient management practices resulted in statistically similar ($p>0.05$) sterility percentage for both crop establishment methods.

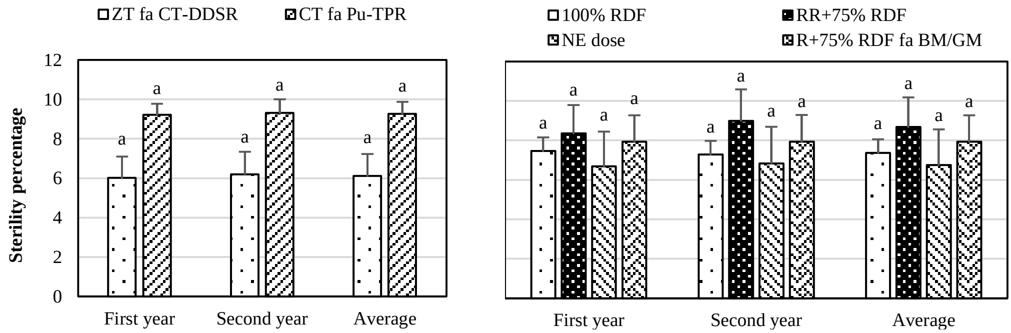

Figure 5. Sterility percentage of maize as influenced by the (a) establishment methods and (b) nutrient management practices at Rampur, Chitwan, 2018-2019 and 2019-2020

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within each bar group represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

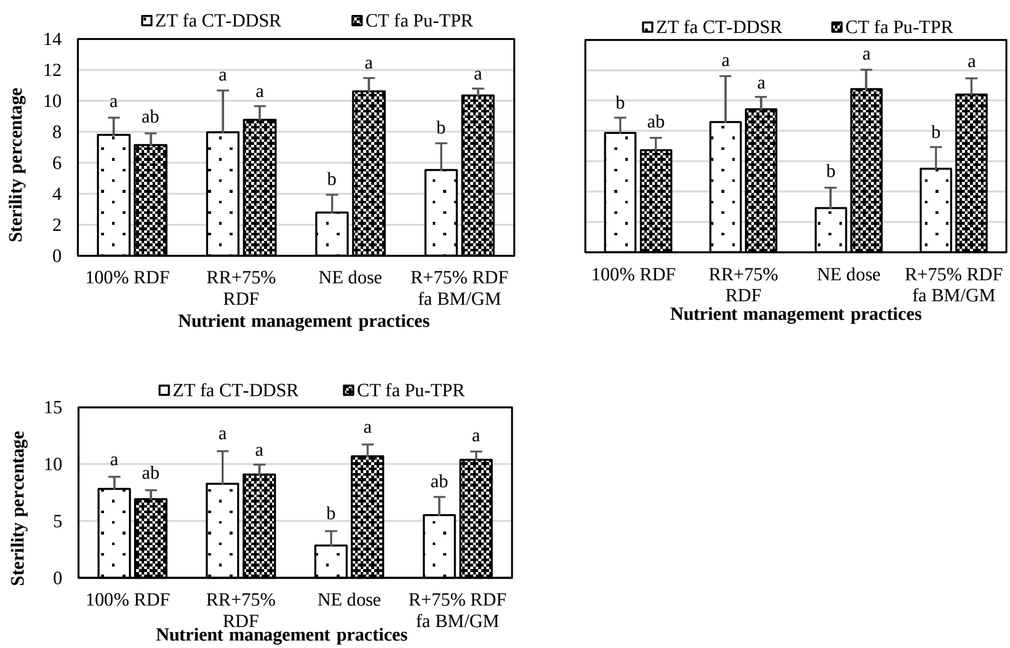

Figure 6. Sterility percentage of maize as influenced by the interaction of establishment methods and nutrient management practices during (a) 2018-2019, (b) 2019-2020, and (c) average of the two years at Rampur, Chitwan

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within each bar group represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

Regarding the nutrient management practices, most of the yield attributing characters were not significantly (p>0.05) influenced by the various practices (Table 1). NE fertilizer management had a relatively lower sterility percentage and higher number of plants per ha compared to residue applied plots. RR+ 75% RDF had the highest TGW (7.34% more than 100% RDF) and the highest cob per plant among the various nutrient management practices which might be due to increased soil moisture content, organic matter content, better partial factor productivity, and minimizing weed growth as also explained by Upadhyay et al (2016), Sime et al (2015), and Bastola et al (2020).

Influence of crop establishment methods and nutrient management practices on yield

The average grain yield, straw yield, and harvest index (HI) were 6153 kg ha^{-1}, 4547 kg ha$^{-1,}$ and 53.81% respectively (Table 3). Grain yield in the first year of the experiment was significantly (p<0.05) higher under ZT fa CT-DDSR (6362 kg ha^{-1}) than CT fa Pu-TPR whereas the nutrient management practices resulted in the statistically similar (p>0.05) grain yield but in the second year of experimentation both factors did not influence (p>0.05) the grain yield. The two years average grain yield was significantly at par (p>0.05) for both crop establishment methods whereas the highest grain yield (6772 kg ha^{-1}) was recorded in the NE dose applied plots which were significantly (p<0.05) higher than the yield obtained in 100% RDF applied plots but statistically similar (p>0.05) with the grain yield obtained in RR+75% RDF and R+75% RDF fa BM/GM applied plots. The stover yield was not significantly (p>0.05) differed by the crop establishment methods in the second year and also not by the nutrient management practices in both years of experimentation. Significantly (p<0.05) higher stover yield was recorded under ZT fa CT-DDSR in the second year of experimentation. HI was not significantly (p>0.05) influenced by both treatment factors.

Table 3. Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), and harvest index (%) of maize as influenced by the establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019 and 2019-2020

Treatments	Grain yield			Straw yield			Harvest index		
	First year	Second year	Av.	First year	Second year	Av.	First year	Second year	Av.
Establishment methods									
ZT fa CT-DDSR	6362^{a}	6457	6409	4587	4837^{a}	4712	54.32	52.90	53.61
CT fa Pu-TPR	5837^{b}	5957	5897	4280	4483^{b}	4382	54.61	53.40	54.00
SEm (±)	76.70	294.30	162.60	384.40	38.30	175.10	2.02	1.46	0.28
LSD (<0.05)	466.40	ns	ns	ns	233.10	ns	ns	ns	ns
CV (%)	2.20	8.20	4.50	15.00	1.40	6.70	6.40	4.80	0.90
Nutrient management practices									
100% RDF	5465	5362	5414^{b}	4042	4177	4109	54.97	52.28	53.62
RR+75% RDF	6243	6402	6323^{a}	4660	4840	4750	53.21	52.92	53.06
NE dose	6437	6772	6605^{a}	4367	4845	4606	55.97	54.29	55.13
R+75% RDF fa BM/GM	6252	6292	6272^{a}	4665	4779	4722	53.69	53.12	53.41
SEm (±)	375.80	403.60	267.70	322.20	267.90	195.80	2.00	1.78	1.33
LSD (<0.05)	ns	ns	824.80	ns	ns	ns	ns	ns	ns
CV (%)	15.10	15.90	10.70	17.80	14.10	10.50	9.00	8.20	6.00
Grand mean	**6099**	**6207**	**6153**	**4433**	**4660**	**4547**	**54.46**	**53.15**	**53.81**

Note: Av., average of two years; CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fa, followed after; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 Mt ha^{-1}); BM, brown manuring; GM, green manuring, R, residue retention (@3.5 Mt ha^{-1}); RDF, recommended dose of fertilizer (120-80-60 N- P_2O_5- K_2O kg ha^{-1}); NE, nutrient expert (150-50-90 N- P_2O_5- K_2O kg ha^{-1}); Same letter(s) within the column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The grain yield of maize in the present experiment under CA was significantly higher (8.68%) than under conventional agriculture. This finding of the experiment was similar to the findings of Zamir et al (2013), Bhatt et al (2004), Arshad et al (1999), Ghosh et al (2016), Karki et al (2014), etc. In the present experiment, the higher yield under CA was attributed to the higher plant population (3.77%), lowered barrenness percentage by 34.53%, more TGW (9.43 g), and lesser sterility (34.04%) compared to conventional agriculture which compensated for the effect of 3.09% more grain per cob under conventional agriculture. The findings of the research was following the findings of Karki et al (2014) and Zamir et al (2013) who reported a higher number of cobs per ha, number of grains per row, and TGW under CA and obtained higher yield. In the present experiment, the maize plants received a total of 249 mm rainfall in 2018-19 and 365.5 mm rainfall in 2019-20 during the entire growth period and the temperature regime was also within the range of 18.38˚C-33.61˚C. Ghosh et al (2016) explained that due to better infiltration capacity and increased WHC of soil under CA, the water use efficiency of the crop increased resulting in better yield of the crops which might be the possible reason for the higher yield of maize under CA. Since the crop was grown during the winter season, the crop experienced drought spells, and more water retained in the crop rooting zone under CA compared with conventional agriculture was thought to be the primary cause for increased grain yield. This explanation was given owing to the findings and reasoning of (Arshad et al 1999).

The yield was also not significantly influenced by the nutrient management practices as the individual years' but was significant on average. Among the various treatments, the highest yield was obtained under NE-assisted fertilizer management (22.00% more than 100% RDF) followed by RR+75% RDF and R+75% RDF fa BM/GM (Table 3). The amount of fertilizers used under NE dose (150-60-90 kg N, P_2O_5, K_2O ha^{-1}) was 16.66% less N, 44.44% less P_2O_5, and 50% more K_2O than 100% RDF (180-90-60 kg N, P_2O_5, K_2O ha^{-1}). Various supportive results of higher yield under NE dose were also obtained by Singh et al (2019), Banerjee et al (2013), Pooniya et al (2015), Dahal et al (2018), etc. They explained the beneficial effect of NE assisted fertilizer dose on the yield attributing characters. Their advocacy on the higher yield under NE was timely and need based nutrient supply under the treatment. The yield under residue retention treatments i.e. RR+75% RDF and R+75% RDF fa BM/GM were about 16% more than 100% RDF (Table 3). The higher yield under residue retention was also explained by Upadhyay et al (2016), Sime et al (2015), Bastola et al (2020), Singh et al (2016), etc. Khurshid et al (2006) said residues significantly affected the soil's physical properties, increased soil moisture content and organic matter content, and improved growth and yield. The residue mulch improved the soil porosity, reduced the bulk density, regulated the soil moisture and thermal regimes, and hence impacted maize root development consequently higher yield was obtained compared to the treatments devoid of residues (Singh et al 2016). In agreement with these findings, Bastola et al (2020) advocated that the yield advantage of applied residues maize was due to better partial factor productivity, soil moisture conservation, minimizing weed growth, and organic matter addition in the soil which makes good crop growth and biomass. Salahin et al (2013) stated that a 21% yield advantage was found when planted on the same plot on which green manuring treatment on rice crop was applied.

The coefficient of determination between the yield attributing and yield associated traits on the grain yield under different crop establishment methods have been shown in Table 4. Barrenness and sterility percentage were the highly variable characters for both crop establishment methods. The relationship between the final plant population, the number of grains per cob on the grain yield was significant ($p<0.05$) for ZT fa CT-DDSR whereas in the CT fa Pu-TPR, the number of cobs per plant and number of grains per cob had a significant ($p<0.05$) association with the grain yield.

Table 4. Simple linear regression results including coefficient of variation, slope, and slope significance for the relationship between grain yield with different yield attributes, and yield under different crop establishment methods of maize at Rampur, Chitwan, 2018-2019 and 2019-2020

Independent variables	ZT fa CT-DDSR						CT fa Pu-TPR					
	First year			Second year			First year			Second year		
	CV(%)	R^2	Slope	CV(%)	R^2	Slope	CV(%)	R^2	Slope	CV(%)	R^2	Slope
Plant population ha^{-1}	6.74	0.34*	0.16	8.13	0.12	0.10	7.98	0.05	-0.05	9.03	0.07	0.04
Barrenness percentage	30.04	0.20	515	42.12	0.02	-0.23	43.78	0.10	-140	40.68	0.07	0.18
No. of cobs plant^{-1}	10.05	0.02	1286	6.18	0.01	1975	9.88	0.46*	6226	5.97	0.23	-5737
No. of grains cob^{-1}	5.43	0.01	4.69	17.32	0.47*	18.74	5.95	0.02	7.78	14.24	0.75*	16.38
Thousand grain weight	5.59	0.24	28.86	9.26	0.31	25.07	5.91	0.02	7.35	6.84	0.01	-2.58
Sterility percent	65.09	0.09	86.33	66.34	0.01	14.38	21.75	0.17	208.68	26.49	0.04	67.66
Stover yield	18.28	0.00	0.01	10.41	0.19	1.24	30.94	0.05	-0.17	16.57	0.27	0.57

Note: * significant differences at 0.05 level of significance; **, significant differences at 0.01 level of significance

CONCLUSIONS

Zero tillage followed after CT-DDSR was as productive as conventional tillage followed after Pu-TPR. Nutrient expert fertilizer management was the best nutrient management practice. The yield advantage in subsequent maize could be obtained from the residue retention and green/brown manuring practices in rice along with enhancing the soil qualities.

ACKNOWLEDGEMENTS

Authors are thankful to Agriculture and Forestry Iniversity, Rampur, Chitwan for entire support in carrying out the experiment to manuscript preparation.

AUTHORS' CONTRIBUTION

S Marahatta formulated and carried out the experiment, collected data, prepared the manuscript for the journal. TB Karki contributed for the ANOVA and manuscript preparation.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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