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Assessing Growth, Productivity, Profitability and Yield Gaps of Spring Maize Using Site Specific Nutrient Management Approaches in Kailali

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Abstract

A field experiment was conducted during spring season of 2023 at the sub-tropical climate of Tikapur, Kailali to evaluate the impact of site-specific nutrient management on growth, productivity, profitability and yield gaps of spring maize. The experiment followed a Randomized Complete Block Design (RCBD) with six treatment combinations and four replications. Maize seeds were sown in four different farms on 27 February, 2023 with different site-specific nutrient management (SSNM) approaches viz. with Nutrient Expert®-Maize recommended dose (T1), three omission plots i.e., Omission of Nitrogen (T2), Omission of Phosphorus (T3), Omission of Potassium (T4), Government Recommended Dose (T5), and Farmer's Fertilizer Practices (T6). Using the Nutrient Expert® Maize model Computer Software, the SSNM+NE dose was recommended via a household survey in the respective farmer's field before the start-up of the experimentation. Various growth parameters, yield, yield attributing traits, and total cost of production of spring maize were recorded and subjected to analysis using Duncan's Multiple Range Test (DMRT) in R-studio. The results revealed that the highest grain yield (3.71 t ha^{-1}) was achieved with SSNM+NE, which was statistically at par with the Government Recommendation Dose (3.12 t ha^{-1}). Moreover, SSNM+NE showed significantly higher thousand grains weight (442.75 g) and straw yield (6.81 t ha^{-1}), respectively. Notably, the straw yield, grain yield, and thousand grain weight of SSNM+NE were statistically comparable to those obtained with the government recommendation. Economic analysis showed higher benefit-cost ratio as well as increased net and gross returns in SSNM+NE as compared to the other nutrient management practices. The SSNM+NE and Governmental Recommended Fertilizer based treatments were about 231% and 178% advantageous over the Farmer's Fertilizer Practices. It could be suggested that SSNM+NE would the best approach for increasing the growth, productivity and profitability of spring maize in the sub-tropical terai of Far Western Nepal.

Keywords: Growth, productivity, profitability and yield gaps, site-specific nutrient management, sub-tropical Far Western Terai

Introduction

Site Specific Nutrient Management (SSNM) is a scientific approach of feeding the crop with particular nutrients as and when needed (Timsina et al., 2021, Amgain et al. 2022), wherein the application and management of plant nutrients are dynamically adjusted to crop needs of the specific location and season. The SSNM approach aims to increase profit through increased yield per unit of applied fertilizer and through reduced disease and insect damage (Jata et al., 2011). SSNM is based on 4-R principles i.e. (Right dose, Right time, Right method and Right source) to manage the fertilizers in the field. Nutrient Expert–Maize (NE), a computer-based decision support tool, enables the maize growing farmers to implement SSNM for their individual plots, utilizing the information given by the local experts to suggest meaningful yield for that location and formulate a fertilizer management strategy (IPNI, 2017, Ananda et al., 2017), and hence it symbolizes its valid applicability in rice, maize and wheat in the similar agro-climatic regions like in Nepalese context (Devkota et al., 2022 and 2016, Sapkota et al., 2021, Amgain et al., 2016).

Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice in global position. Due to the highest yield potential among all other cereals, it is known globally as queen of cereals (Ranum et al., 2014). Maize is also the second most important staple food crop of Nepal after rice in terms of area and production (MoALD, 2021) in which the total maize production and productivity have been reported 2999733 M.T and 3.06 t/ha, respectively (MoALD, 2021). In sub-tropical climate of Far Western Terai, spring maize is most commonly planted in around 6225 ha, and the adjoining region of Tikapur covered an area of 725 ha with productivity of 3.20 Mt/ha (MoALD, 2022). Several reasons are catering for this lower yield and huge yield gaps of maize at Tikapur, among which balanced nutrient management ranked the top (Amgain et al., 2023). There are very scarce studies being done on SSNM approaches in this site mostly in spring crops and this study has been proposed to estimate the inherent nutrient supplying capacity of soil of Tikapur and the role of balanced fertilization on the growth, yield and economics of spring maize using site specific nutrient management approaches.

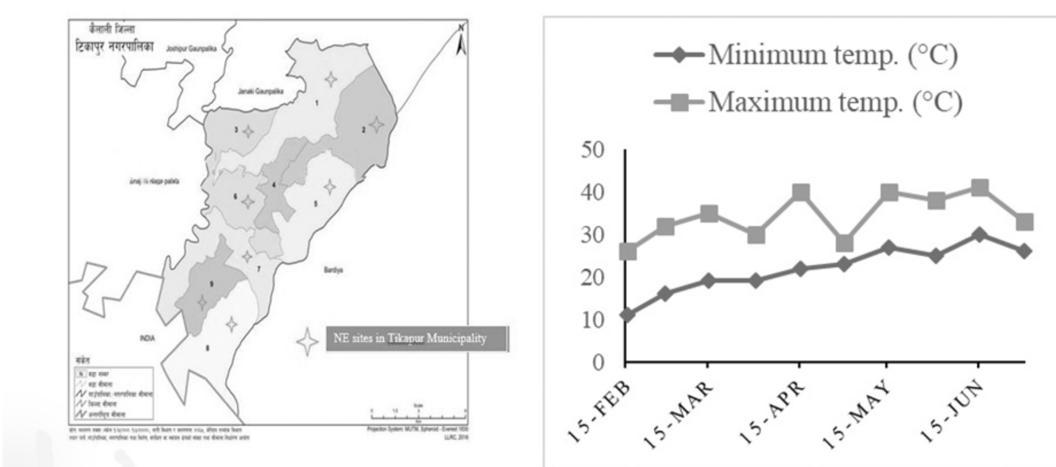
Methods

Site Selection for Nutrient Expert®-Maize, Soil and Weather Details

A field experiment was conducted in the field of four farmers at Tikapur Municipality (28º 30' N. 81º 6' 30" E and 156 masl.). The study site was fixed in ward # 1 (Bangaun), ward # 3 (Katanpur), ward # 4 (Asneri) and ward # 6 (Narayanpur) of Tikapur Municipality in Kailali district during the spring season of 2023 (Figure 1). The experimental soil was sandy loam in texture with sand (43.5%), silt (18.5%) and clay (16.43%) and the medium soil available phosphorus (53.87 kg ha^{-1}) and potassium (178.04 kg ha^{-1}) and the low amount of total nitrogen (0.09%) in the top soil layer. Weather variables mostly the maximum and minimum temperatures in the first and last weeks of February was 29ºC and 11^{0}C, and 37^{0}C and 26^{0}C in the last week of June found suitable for the growth and development of maize (Figure 1).

Figure 1

NE- Maize Research Sites of Tikapur Municipality and Weather records during the Spring Maize Growing Period in 2023



Selection of Farmers and Field Experimentations on NE®-Hybrid Maize Model

While selecting the spring maize growing farmers, the purposive sampling was followed. The identification of innovative and progressive farmers were the major criteria in selection of participants in the study. The NE®-Hybrid Maize Model embedded questionnaires was filled for estimation of the NE®-driven fertilizer dose to the 4 spring maize growers in the four wards of Tikapur municipality. Maize seeds were sown in four different farms on 27 February, 2023 with different site-specific nutrient management (SSNM) approaches viz. with Nutrient Expert®-Maize recommended dose (T1), three omission plots i.e., Omission of Nitrogen (T2), Omission of Phosphorus (T3), and Omission of Potassium (T4), Government Recommended Dose (T5), and Farmer's Fertilizer Practice (T6). Using the Nutrient Expert® Maize model Computer Software, the SSNM+NE dose was recommended via a household survey in the respective farmer's field before the start-up of the experimentation. The government recommended fertilizer dose for hybrid (150:60:40 kg NPK/ha), and open pollinated maize (120:60:40kg NPK/ha) cultivars were calculated for 50 m^2 area in each farmer's field and were compared for the yield gaps between the treatments.

Data Observations and Statistical Tools Used

Yield attributes of spring maize cultivars Kanchan as hybrid and Rampur Composite as FFP were recorded at the harvesting stage of crops as per the standard methods for maize (CIMMYT, 2009). Grain yield of the crop was recorded from the representative sampling areas at least from 25 m^2 area using the scientific techniques of crop cut survey (Reddy and Reddi, 2009). Grain yield and economics of various nutrient management options were compared to demonstrate the productivity and profitability of NE®-based recommendation to the level over the farmers' fertilizer practices. Yield gaps was analysed between the treatments tested from the data of NE® model trial. Various growth parameters, yield, yield attributing traits, and total cost of production of spring maize were recorded and subjected to analysis using Duncan's Multiple Range Test (DMRT) in R-studio.

Results and Discussion

Effect of Nutrient Management Practices on Phenological Stages of Maize

Crop phenology is a critical factor in determining crop yield. The result on the phenological stages like knee high, tasseling, silking and physiological maturity stages presented in Table 2 were found significantly superior under Nutrient Expert based on site- specific nutrient management (SSNM+NE). Among the nutrient management practices, Nutrient Expert based on site-specific nutrient management (SSNM+NE) recorded the lowest days (29.75 DAS) to reach knee high stage which was significantly superior to farmer fertilizer practice (32.13 DAS). It was also found that the minimum days to 50% tasseling was recorded from SSNM+NE (46.5 DAS) which was significantly superior to other nutrient management practices. The minimum days to reach silking stage (50.5 DAS) was recorded with Nutrient Expert based on site specific nutrient management (SSNM+NE) which was significantly superior than other nutrient management practices. The duration needed for the appearance of physiological maturity stage was significantly earlier in SSNM+NE (92.63 DAS) as compared to nutrient omission plots, FFP, and government recommended dose. Further, in FFP, crop took significantly longer duration (96.83 DAS) to attain physiological maturity. However, the days to reach physiological maturity in Government recommended dose (94.04 DAS) remained at par to three omission plots viz. N-omission (94.42 DAS), P-omission (94.88 DAS) and K-omission (95.11 DAS). Similar results were also advocated by Gautam et al. (2018), Khanal et al. (2017), Bogati et al. (2021).

Table 1

Effect of Nutrient Management Practices on Phonological Stages of Spring Maize at Tikapur during 2023

TREATMENTS	PHENOLOGICAL STAGES (DAS)			
	Knee high	Tasseling	Silking	Physiological maturity
SSNM+NE	29.75^{c}	46.50^{d}	50.50^{d}	92.63^{c}
NE-N	33.10^{a}	47.55^{c}	51.68^{c}	94.42^{b}
NE-P	32.31^{ab}	50.18^{a}	54.31^{a}	94.88^{b}
NE-K	31.42^{abc}	48.43^{bc}	52.33^{bc}	95.11^{b}
RD	30.88^{bc}	49.28^{ab}	52.98^{b}	94.04^{b}
FFP	32.13^{c}	48.40^{bc}	52.28^{bc}	96.83^{a}
LSD (0.05)	1.806	1.027	0.9199	1.3195
CV, %	3.792	1.408	1.166	0.925
GRAND MEAN	31.60	48.39	52.34	94.65

Means followed by the common letter (s) within each column are not significantly different at 5% level of significance by DMRT. DAS = Days after sowing

Effect of Nutrient Management Practices on Growth Attributes of Maize

The cursory view of data on Table 2 exhibited that the values of plant height recorded at SSNM+NE (40.13 and 56.18 cm) were found to be significantly higher than other treatments at the beginning (30 and 60 DAS).

Table 2

Effect of Nutrient Management Practices on Plant Height and Plant Population of Spring of Maize at Tikapur during 2022

TREATMENT	PLANT HEIGHT (CM)				PLANT POPULATION AT HARVEST (HA^{-1})
	30 DAS	60 DAS	90 DAS	At harvest	
SSNM+NE	40.13^{a}	56.18^{a}	188.43^{a}	201.50^{a}	62750
NE-N	35.50^{c}	49.10^{d}	178.30^{d}	191.95^{d}	58500
NE-P	38.28^{b}	49.63^{d}	183.15^{bc}	194.08^{cd}	60250
NE-K	35.73^{c}	50.48^{cd}	182.48^{c}	194.43^{c}	57250
RD	39.05^{ab}	53.10^{b}	185.10^{b}	198.60^{b}	61000
FFP	30.85^{d}	51.55^{bc}	177.08^{d}	192.00^{d}	57000
LSD (0.05)	1.487	1.583	2.237	2.412	Ns
CV, %	2.697	2.033	0.814	0.819	1.533
GRAND MEAN	36.59	51.67	182.42	195.43	59458.33

Means followed by the common letter (s) within each column are not significantly different at 5% level of significance by DMRT. DAS = Days after sowing

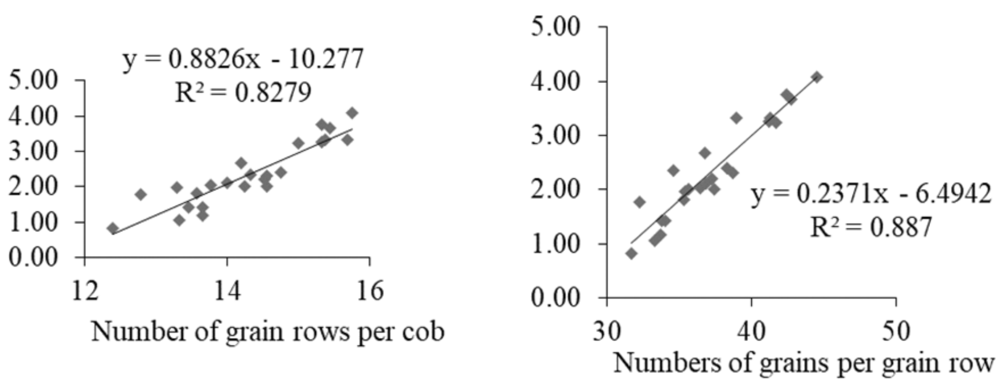
Further, at 90 DAS and at harvest, significantly higher plant height was reported in SSNM+NE (188.43 and 201.50 cm). At 90 DAS, significantly lower plant height was observed in FFP (177.08 cm) which was at par with N-omission plot (178.30 cm). Similarly, at harvest significantly lower plant height was recorded in N-omission plots (191.95 cm) which was at par with FFP (192 cm). Due to significant differences in soil fertility among farmer fields, plant height in maize varies in nutrient requirements from one field to the next. As a consequence, giving all fields the same nutritional recommendation might not be the best way to increase maize yields (Jat et al., 2013). The data further revealed that different nutrient management practices failed to cause significant variation in plant population at harvest. However, relatively higher plant population was recorded in SSNM+NE (62750). This result was corroborated with the findings of Bhatta et al (2020).

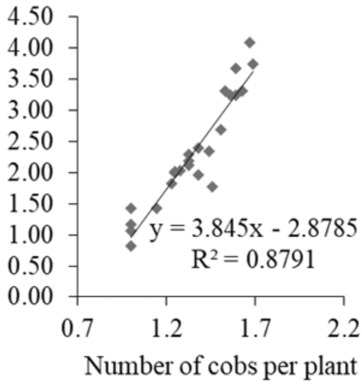
Effect of Nutrient Management Practices on Yield Attributes of Maize

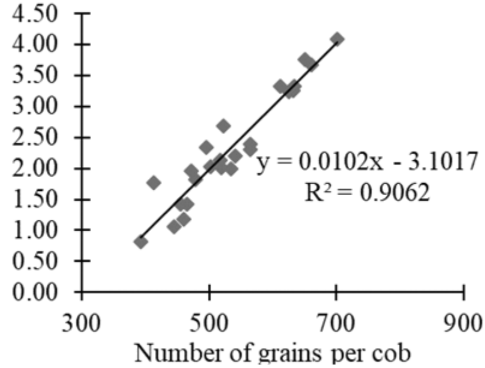
Table 3 and Figure 2 indicated the positive and strong correlation between the yield attributing traits and the grain yield of spring maize. The contribution of number of cobs per plant in grain yield formation was 87.9%. The similar results were also reported by Singh et al. (2019) and Khanal et al. (2017). Singh et al. (2019) also obtained significantly higher number of grains per row in SSNM-NE (18.8) as compared to FFP (16.4) which was at par with RD (17.8). The contribution of number of grain rows per cob for the increase in grain yield was 82.79% as shown in Figure 2. It is also obvious that the contribution of numbers of grain per row on grain yield was 88.7%. It means they are positively correlated with each other. Thus, higher number of grain rows per cob and grains per row together helps to increase number of grains per cob. Similar result was also reported by Bogati et al. (2021). Number of grains per cob gives 90.62% contribution to the grain yield formation. It was also remarked that 75% contribution of thousand grain weight on grain yield formation. Similarly, Acharya et al. (2020) also obtained significantly higher thousand grain weight of maize in SSNM (328.2 g) than FFP (274.1 g). The significant and positive correlation with all yield attributes and yield of maize has also been reported by Dahal et al. (2018) and Pant et al. (2022).

Figure 2

Correlation between the Major Yield Attributes of Spring Maize and Grain Yield







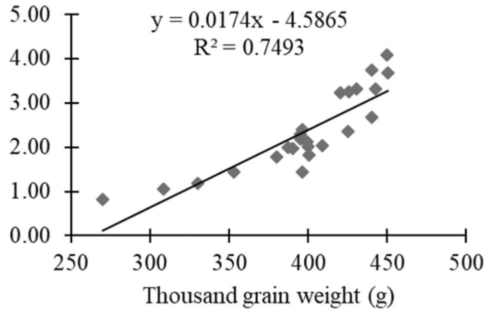


Table 3

Correlation Coefficients among Yield and Yield Attributes of Spring Maize at Tikapur

	SY	GY	HI	SP	Cob/pl	KR/cob	K/row	G/cob	Tw
SY	1								
GY	0.98	1							
HI	0.843	0.914	1						
SP	0.733	0.747	0.715	1					
Cob/pl	0.925	0.938	0.893	0.822	1				
KR/cob	0.894	0.910	0.842	0.553	0.767	1			
K/row	0.908	0.942	0.867	0.574	0.802	0.914	1		
G/cob	0.925	0.952	0.868	0.583	0.808	0.964	0.988	1	
Tw	0.875	0.866	0.870	0.687	0.838	0.790	0.761	0.780	1

Note: SY = Stover yield, GY = Grain yield, HI = Harvest index, SP = Standard plant populations, Cob/pl = Cob/plant, KR/cob = Kernel rows/cob, K/row = Kernels/kernel row, G/cob = Grains/cob, Tw= Thousand Grain Weight (g)

The ANOVA result further indicated that the SSNM+NE had produced significantly higher number of cobs per plant, number of grains row per cob, number of grains per grain row, number of grains per cob, thousand grain weight (g) and shelling percentage than other nutrient management practices. Numbers of cobs per plant recorded in SSNM+NE based nutrient management practice (1.65) was found to be significantly higher than that of FFP (1.04), NE-N (1.24), NE-P (1.35) and NE-K (1.34). Number of grain rows per cob was affected significantly by different nutrient management practices. SSNM+NE (15.56) recorded significantly higher number of grain rows per cob as compared to FFP (13.22) and NE- N (13.57), but remained at par with RD (14.98). Number of grains per row was significantly higher in SSNM+NE (42.19) than other treatments but remained at par with RD (40.24). Number of grains per cob differ significantly with the change in the nutrient management practices. Thousand grain weight (g) was found to differ significantly with the change in the nutrient management practices. SSNM+NE recorded significantly higher (442.75 g) thousand grain weight than FFP (315.25 g) but remained at par with RD (432.17 g). Among the nutrient omission plots, potassium omission plot (407.03 g) recorded significantly higher thousand grain weight than phosphorus omission plot (395.40 g) and nitrogen omission plot (390.96 g). Shelling percentage was not affected significantly by nutrient management practices. However, it was slightly greater in SSNM+NE (83.54%) as compared to FFP (80.44%), RD (82.87%), NE-N (81.29%), NE-P (81.82%) and NE-K (82.20%). Higher number of rows together with greater number of grains per row assisted to increase the number of grains per cob and consequently the grain yield. The higher number of cobs per plant assisted to increase the grain yield. Similar result was obtained by Khanal et al. (2017).

Effect of Nutrient Management Practices on Yield and Yield Components of Maize

The average grain yield of spring maize recorded in the experiment was 2.34 t ha^{-1} and ranged from 1.12 to 3.71 t ha^{-1}. It is obvious from the data (Table 4) that grain yield of maize differed significantly due to nutrient management practices.

Table 4

Effect of Nutrient Management Practices on Yield and Yield Components of Maize

TREATMENTS	GRAIN YIELD (THA^{-1})	YIELD GAP (%) OVER THE FFP	STOVER YIELD (THA^{-1})	HARVEST INDEX
SSNM+NE	3.71^{a}	231.3	5.67^{a}	0.395^{a}
NE-N	1.76^{d}	57.1	3.73^{c}	0.319^{d}
NE-P	2.14^{c}	91.1	3.83^{c}	0.359^{c}
NE-K	2.20^{c}	96.4	3.80^{c}	0.367^{bc}
RD	3.12^{b}	178.6	5.10^{b}	0.380^{b}
FFP	1.12^{e}	-	2.70^{d}	0.292^{e}
LSD (0.05)	0.302	-	0.464	0.016
CV, %	8.561	-	7.444	2.938
YIELD GAP (%) ON SSNM +NE	Over N	Over P	Over K	
	110.8	73.4	68.4	

Means followed by the common letter (s) within each column are not significantly different at 5% level of significance by DMRT. DAS = Days after sowing

Site specific nutrient management produced significantly higher grain yield (3.71tha^{-1}) than farmer fertilizer practice (1.12 t ha^{-1}) which was at par with government recommended dose of fertilizer (3.12 t ha^{-1}). On the other hand, among the nutrient omission plots the grain yield observed in nitrogen omission plot (1.76 t ha^{-1}) was significantly lower than potassium (2.20 t ha^{-1}) and phosphorus omission plot (2.14 t ha^{-1}). Further, all three-omission plot recorded higher grain yield than FFP but was significantly lower as compared to SSNM+NE and RD. Similarly, stover yield was significantly higher in SSNM+NE (5.61 t ha^{-1}) as compared to FFP (2.70 t ha^{-1}) and the three omission plots viz. NE-N (3.73 t ha^{-1}), NE-P (3.83 t ha^{-1}) and NE-K (3.80 t ha^{-1}) but remained at par with RD (5.10 t ha^{-1}). The average harvest index of spring maize reported in the experiment was 0.352 and ranged from 0.292 to 0.395 depending upon treatments (Table 3). Harvest index was significantly higher in SSNM+NE (0.395) than FFP (0.292), NE-N (0.319), NE-P (0.359) and NE-K (0.367), but remained at par with RD (0.38). Also, the three omission plots viz. NE-N, NE-P and NE-K were at par with each other.

The yield gap analysis between the treatments SSNM+NE, NE- N, NE-P, NE-K and RD over the FFP was found to be 231.3, 57.1, 91.1, 96.4 and 178.6 % respectively. Similarly, the advantage in yield due to SSNM+NE model was 110.8, 73.4 and 68.4%, respectively to NE- N, NE-P and NE-K (Table 4). It indicates that for achieving the higher yields the SSNM based NE- Maize model would be beneficial to the farmers. The maximum yield gaps were also recorded due to devoid of N, followed by P and then K nutrients at the research sites of Tikapur Municipality. Maize farmers are therefore suggested to use the balanced amount of NPK for achieving the higher grain yields of maize in sub-tropical far western terai region of Nepal. Similar results in spring maize and Chaite rice grown at Rani Jamara Kulariya Irrigation Command Areas of Tikapur was also noticed by Amgain et al. (2023).

Economic Analysis

The data for cost of cultivation, gross return, net return and B: C ratio is presented in Table 5.

Table 5

Effect of Nutrient Management Practices on Economics of Spring Maize

TREATMENTS	TOTAL COST (NRS HA^{-1})	GROSS RETURNS (NRS HA^{-1})	NET RETURNS (NRS HA^{-1})	B:C
SSNM+NE	59971.25^{c}	120981.5^{a}	61010.25^{a}	2.03^{a}
NE-N	60595.00^{c}	69865.00^{de}	9270^{d}	1.15^{c}
NE-P	70828.75^{a}	82387.5^{c}	11558.75^{cd}	1.16^{c}
NE-K	59452.5^{c}	73855^{d}	14402.5^{c}	1.24^{c}
RD	64707.5^{b}	106882.5^{b}	42115^{b}	1.65^{b}
FFP	58796.25^{c}	66425^{e}	7628.75^{d}	1.13^{c}
LSD (0.05)	3706.71	4879.33	4870.75	0.117
CV (%)	3.942	3.733	13.282	5.552

Means followed by the common letter (s) within each column are not significantly different at 5% level of significance by DMRT. DAS = Days after sowing

The gross return, net return and B:C ratio is significantly higher in SSNM+NE. Cost of cultivation was significantly higher in P-omission plot than other treatments. The average B:C ratio in spring maize production was 1.39 and ranged from 1.13 to 2.03 depending upon the treatments. With respect to nutrient management practices, significantly lower B:C ratio was obtained with FFP (1.13) as compared to SSNM-NE (2.03) and RD (1.65) but remained at par with NE-N (1.15), NE-P (1.16) and NE-K (1.24). Similar results were obtained by Khanal et al. (2017).

Conclusion

NE®- Hybrid Maize model have fairly predicted the Spring Maize yields and predicted the satisfactory economics with sound profitability after assuring the steadily increasing level of actual attainable yield over the farmer's fertilizer practice. Hence, the adoption of NE®- Hybrid Maize model is suggested to adopt as a sound decision support system (DSS) tool to manage the soil fertility and crop productivity in the project command areas of Tikapur, Kailali. Under the prevailing conditions, it is highly expected that there would be spill-over effects of this project activity to the nearby areas of Tikapur, and the NE® tool could potentially be used by national, provincial, agriculture knowledge centre and village-level stakeholders to provide fertilizer recommendations to many other farmers' field from Kailali to Kanchanpur, Bardiya and Banke districts. However, it is suggested that for more valid and reliable conclusion, the multi-locational trials at least for 2-3 years would be continued with increasing number of farmers.

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