

Effect of Organic Manures and Chemical Fertilizers on Maize Productivity and Soil Properties in the Winter Season

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ABSTRACT

Field experiments were conducted at the National Maize Research Program Rampur, Chitwan, Nepal, during the two consecutive winter seasons of 2018/19 and 2019/20. The objective was to identify the effects of different sources of nutrients on the growth and yield parameters of winter maize and soil properties. The experiment was laid out in a randomized complete block design with three replications and twelve treatments. Combinations of different organic and inorganic sources, including the recommended dose of chemical fertilizer, farmyard manure, poultry manure, biochar, vermicompost, mustard oil cake, sunhemp and bone meal, were tested. Different nutrient levels significantly influenced the maize grain yield. The maximum grain yields of 7102 kg/ha (2018/19) and 6985 kg/ha (2019/20) were obtained with the combined application of 50% recommended dose (RD) of chemical fertilizer along with mustard oilcake at the rate of 5 t/ha, which was at par (6969 kg/ha and 6535 kg/ha) with the sole application of mustard oilcake at 10 t/ha. It can be concluded that the highest grain yield (7043.5 kg/ha) was obtained when 50% of the recommended dose of N, P₂O₅ and K₂O fertilizers were combined with 5 t mustard oilcake/ha application, followed by sole application of 10 t mustard oilcake/ha (6752 kg/ha). Soil properties including organic matter were found to be significantly improved due to the application of a combined application of organic and inorganic fertilizer. Thus, in subtropical conditions, integrated organic manures and chemical fertilizers can enhance soil properties and increase maize productivity during the winter season.

Keywords: fertilizer, inorganic, maize, organic.

सारांश

चितवन जिल्लाको रामपुर स्थित राष्ट्रिय मकैबाली अनुसन्धान कार्यक्रमको परिक्षण स्थलमा सन् २०१८/१९ र २०१९/२० को लगातार दुई हिउँदे मौसममा अक्टोबरदेखि मार्चसम्म परिक्षण संचालन गरीएको थियो। यस अध्ययनको मुख्य उद्देश्य हिउँदे मकैबालीमा प्रयोग गरिने पोषक तत्वका विभिन्न स्रोतहरूको प्रयोगबाट माटोको प्रांगारिक तथा रासायनिक गुणमा पार्ने असर तथा मकैको वृद्धि तथा बाली उत्पादनमा यसले पार्ने प्रभाव पहिचान गर्नु थियो। उक्त अनुसन्धानमा बाह्र विभिन्न प्रकारका एकिकृत खाद्यतत्व व्यवस्थापनका विधिहरूलाई आर.सि.वि.डी. प्लट ढाँचामा तीन पटक दोहोर्याई परीक्षण संचालन गरिएको थियो। ती विधिहरूमा उन्नत मकै खेतीका लागि सिफारिस गरिए बमोजिमको नाइट्रोजन, फस्फोरस र पोट्यास तथा गोबरमल, बायोचार, कुखुराको मल, गड्यौलाको मल, तोरीको पीना, ढैंचा हरियो मल तथा हाडको धुलो जस्ता विभिन्न मलका श्रोतहरू प्रयोग गरिएको थियो। यस अनुसन्धानमा रामपुर-४ मकैको जात प्रयोग गरिएको थियो। माटोका विभिन्न गुणहरूको असर र प्रभाव अध्ययन गर्दा माटोको बल्क डेन्सिटी र अम्लियपना घटेको पाईयो।

त्यसैगरी माटोमा प्रांगारिक तत्वको मात्रा बढेको पाईयो । अनुसन्धानको नतीजा अनुसार सिफारिस रासायनिक मलको आधा मात्रा र ५ टन प्रति हेक्टर तोरीको पीनाको एकिकृत मिश्रण सबैभन्दा उत्कृष्ट पाईयो । यस विधिमा अन्य विधिहरुको तुलनामा सबैभन्दा धेरै उत्पादन ७०४३.५के.जी.प्रति हेक्टर भएको थियो । यस विधि भन्दा पछि सबैभन्दा धेरै उत्पादन ६७५२ के.जी.प्रति हेक्टर १० टन तोरीको पीना मात्र प्रयोग गरिएकोमा पाईयो । उत्पादनको हिसाबले पश्चिम चितवनको आद्रउपोष्ण हावापानी भएको ठाँउमा एकिकृत खाद्यतत्व व्यवस्थापनका यी दुवै विधिहरु प्रयोग गरी मकैको उत्पादन बृद्धि गर्न र माटोको गुणस्तरमा सुधार गर्न सकिने देखियो ।

INTRODUCTION

Maize is the second most important cereal crop after rice in Nepal and is grown in 9,56,447 ha area with an average productivity of 2.84 t/ha (MOALD 2020). Maize contributes about 3.15% to National Gross Domestic Product and 9.5% in Agricultural Gross Domestic Product (ABPSD 2020). Maize grain is used mainly for feed purposes in the Terai and as a staple food in the hills of Nepal; hence demand of maize grain is increasing due to the growing number of animal farming industries, as maize is the primary ingredient of animal feed (Pokharel et al 2016).

Nepal imported around 5,00,000 tons of maize grain in 2018/19 (MOALD 2020). So, there is an acute need to increase maize production in Nepal to sustain the national demand. The use of improved varieties or hybrids, timely irrigation, and fertilizers, and manure are some of the easy and effective methods to increase the productivity of maize in Nepal. The yield of maize, however, varies from variety to variety, location to location, and depends on the availability of essential factors such as soil nutrient status and application of fertilizers (Kogbe and Adediran 2003). The dose of 120:60:40 kg N, P₂O₅, and K₂O plus 10 ton FYM/ha is recommended for general cultivation of maize in Nepal (NMRP 2018). The blanket recommendation may not address all the soil types and properties, growing conditions, combinations, domains, and social and economic status of the farmers (Adhikari 2014). Nepal, being a mountainous country, there are heterogeneous soil in a different domain, and a tremendous amount of soil minerals are lost in the rainy season due to soil erosion and landslides (KC et al 2013).

Key soil parameters such as soil organic matter, pH, and plant nutrients reflect essential and dynamic soil properties and are governed by physical, chemical, and biological processes in soil (Karlen et al 2003). Among the available soil components, organic matter (OM) is the essential factor as a reservoir of nutrients and water in the soil. Organic sources are the foundation to increase organic matter in the soil (Funderburg 2001). It is crucial to identify the best available organic resources, either the alternatives or their best combined with an appropriate proportion of inorganic fertilizers. Integration of different nutrients is a practice where all sources of nutrients (organic, inorganic, bio-fertilizer) can be combined and applied to soils to enhance crop growth and good yield with the quality product (Mahajan et al 2007).

Maize is an exhaustive feeder hence nutrients requirement in maize are high (Shrestha et al 2018). The productivity of maize is dependent mainly on its nutrient management (Sharma et al 2019). Yield is a function of genotypes, environments, and crop management. Fertilizer management is crucial for maize cultivation (Baral et al 2015, Adhikari et al 2016). Application of proper amount of plant nutrients is necessary for good crop growth and grain yield (Adhikary et al 2012). Integrated nutrient management (INM) is an option as it utilizes available organic and inorganic nutrients to build an ecologically sound and economically viable farming system (Selim 2020). INM has assumed great importance and has a vital role in maintaining soil productivity and crop production.

The use of organics alone does not result in a remarkable increase in crop yields due to their high volume and low nutrient status. Organic manures (i.e. farmyard manure (FYM), poultry manure (PM), vermicompost (VC), oilcake (OC), bone-meal (BM), green manure (GM), crop residues and different inorganic fertilizers are essential components for INM. INM plays a critical role in sustainable agriculture

by maintaining the production and productivity of crops (Kundu and Pillai 1992). Excess and repeated use of chemical fertilizers are very costly and harmful for soil health as well. Therefore, integration of organic manure with inorganic fertilizer may maximize crop productivity and improve soil properties (Aulakh 2010). Keeping these factors in consideration, a field experiment was conducted at the National Maize Research Program (NMRP), Rampur, Chitwan, Nepal, to study the impact on soil properties and grain yield of maize due to different sources of organic manures along with chemical fertilizers.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the research field of NMRP, Rampur, Chitwan, Nepal. It is situated in central Nepal at 27°37' North latitude, 84°25' East longitude, and at an altitude of 228 meters above sea level (NMRP, 2018) with hot, humid, and sub tropical climate.

Weather conditions of the research site

During the crop growing period (September to April) of the first year (2018/19), the maximum temperature ranged from 23.5 to 33.4°C and the minimum temperature ranged from 8.7 to 26°C with relative humidity from 80.6 to 95.5%. The cumulative rainfall in the experimental period was 467.1 mm. Similarly, in the second year, the maximum temperature ranged from 20.3 to 33.53°C, and the minimum temperature from 9.02 to 23.56 °C with the total rainfall during of 528 mm (NMRP, 2020). Based on the meteorological data of the experimental site the pattern of rainfall was almost similar in both the years. The weather data during the experimental periods is given in [Figure 1](#) and [Figure 2](#).

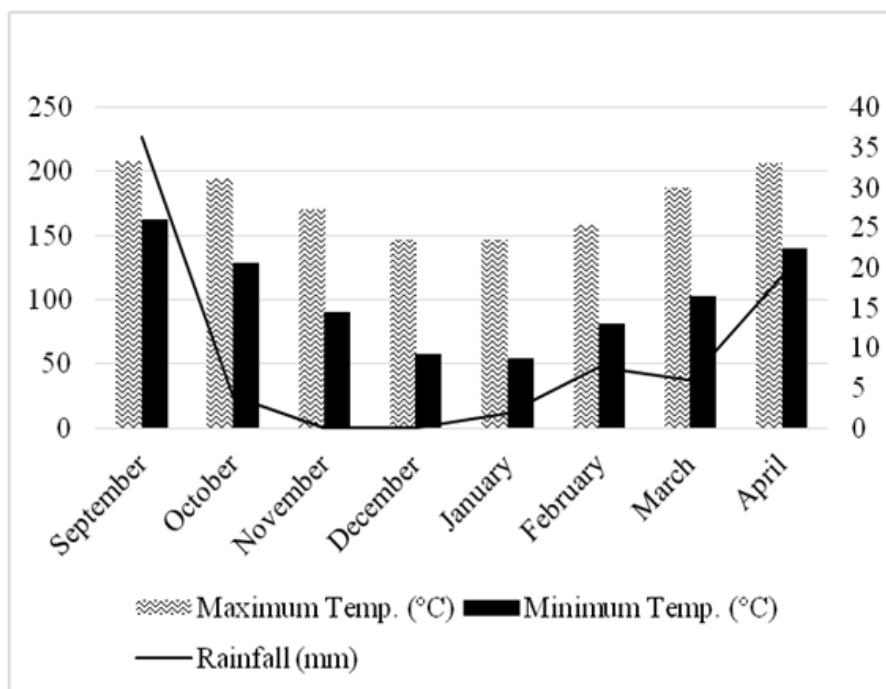


Figure 1: Weather data of the experimental site during the crop growing period (September to April) of 2018/19.

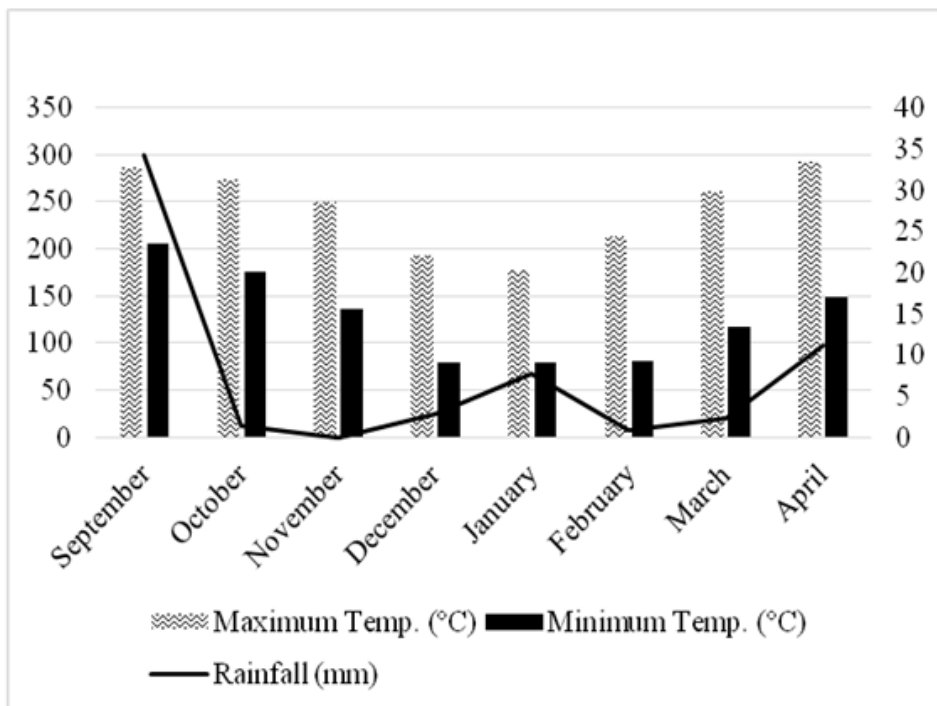


Figure 2: Weather data of the experimental site during the crop growing period (September to April) of 2019/20.

Experimental Details

The field experiment was conducted during the two consecutive winters of 2018/19 (2019) and 2019/20 (2020). The experiment was laid out in randomized complete block design (RCBD), comprising twelve treatment combinations with three replications. Seed sowing of the variety Rampur-4, a medium duration open pollinated maize variety, was done on 24 and 27 September respectively in 2018 and 2019. Planting was done at 25-cm interval within plants and the 60-cm interval between rows. The seed was placed in 5-cm depth and 3-5 cm away from the fertilizer spots. Fertilizer was applied as per assigned treatment combinations (Table 1).

Table 1. A detail of the treatments used in the experiments

Treatment no.	Treatment details
T1	120:60:40 kg NP ₂ O ₅ K ₂ O/ha
T2	120:60:40 kg NP ₂ O ₅ K ₂ O+ 10 t FYM/ha (Check)
T3	120:60:40 kg NP ₂ O ₅ K ₂ O+ 10 t FYM + 5 t Biochar/ha
T4	15 t FYM/ha
T5	10 t PM/ha
T6	10 t VC/ha
T7	10 t OC/ha
T8	60:30:20 kg NP ₂ O ₅ K ₂ O+ 5 t PM/ha
T9	60:30:20 kg NP ₂ O ₅ K ₂ O+ 5 t VC/ha
T10	60:30:20 kg NP ₂ O ₅ K ₂ O+ 5 t OC/ha
T11	60:60:40 kg NP ₂ O ₅ K ₂ O + 45 kg Sunhemp/ha
T12	120:40:40 kg NP ₂ O ₅ K ₂ O + 3 t BM/ha

Table 2. Effects on anthesis and silking due to application of different nutrient sources on maize grown during 2018-2019 and 2019-2020 at NMRP Rampur, Chitwan, Nepal

Treatments	Days to anthesis			Days to silking		
	2019	2020	Pooled	2019	2020	Pooled
120:60:40 kg NP ₂ O ₅ K ₂ O/ha	74	68	71	76	70	73
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM /ha	74	67	71	77	70	74
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM + 5 t Biochar/ha	74	67	70	78	69	74
15 t FYM/ha	74	69	71	79	72	76
10 t PM/ha	75	68	72	78	71	75
10 t VC/ha	79	70	75	86	73	80
10 t OC/ha	72	66	69	75	69	72
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t PM/ha	76	69	72	79	71	75
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t VC/ha	77	68	73	80	70	75
60:30:20 kg NPK 5 t OC/ha	72	67	70	75	69	72
60:60:40 kg NP ₂ O ₅ K ₂ O + 45 kg Sunhemp/ha	75	69	72	79	71	75
120:40:40 kg NP ₂ O ₅ K ₂ O + 3 t BM/ha	74	68	71	77	70	74
F test (Trt)	**	*	**	**	**	**
F test (Trt × Year)			**			**
LSD _{0.05}	3.5	1.7	1.9	4.4	1.8	2.7
CV%	2.7	1.8	2.5	3.3	1.8	3.3

*=Significant at 5% level of significance, ** = Significant at 1% level of significance.

Plant and ear height

Significant variation was observed on plant and ear height when under different nutrients sources. In the first year, the tallest plant height (221 cm) was observed from 120:60:40 kg NP₂O₅K₂O + 10 t FYM and 10 t OC/ha and the shortest height (188 cm) from 60:60:40 kg NP₂O₅K₂O+ 45 kg Sunhemp/ha. Similarly, in the second year, the tallest plant height (205 cm) was recorded with the application of 120:60:40 kg NP₂O₅K₂O + 10 t FYM + 5 t Biochar/ha, and the shortest height (162 cm) was obtained from 10 ton VC/ha (**Table 3**). The plant height of pooled analysis data revealed that the tallest plant height (209 cm) was obtained from 120:60:40 kgNP₂O₅K₂O+ 10 t FYM + 5 t Biochar/ha and 10 t OC/ha, respectively. Pooled analysis revealed that plant height was significantly higher ($p \leq 0.05$) by different nutrient sources.

Likewise, ear height was significantly influenced by different nutrient sources. The tallest ear height (118 cm) was found from 120:60:40 kg N:P₂O₅:K₂O, and the shortest height (98 cm) with the application of 60:60:40 kg NP₂O₅K₂O+ 45 kg Sunhemp/ha in the first year. In the second year, maximum ear height (121 cm) was obtained from 120:60:40 kg NP₂O₅K₂O+ 10 t FYM + 5 t Biochar/ha and shortest height (85 cm) from 10 ton VC/ha. Combined analysis showed that the tallest ear height (117 cm) was recorded from 120:60:40 kgNP₂O₅K₂O+ 10 t FYM + 5 ton Biochar/ha, and shorter ear height (97 cm) from 10 ton VC/ha, respectively (**Table 3**).

Table 3. Plant height and ear height (cm) as influenced by different nutrient sources on maize during 2018-2019 and 2019-2020 at NMRP, Rampur, Chitwan, Nepal

Treatments	Plant height (cm)			Ear height (cm)		
	2019	2020	Combined	2019	2020	Combined
120:60:40 kg NP ₂ O ₅ K ₂ O /ha	221	192	206	118	102	110
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM /ha	206	197	202	112	107	110
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM + 5 ton Biochar/ha	213	205	209	113	121	117
15 t FYM/ha	202	195	198	109	104	106
10 t PM/ha	201	203	202	105	107	106
10 t VC/ha	205	162	184	108	85	97
10 t OC/ha	216	202	209	111	112	111
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t PM/ha	204	193	199	102	101	102
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t VC/ha	205	188	197	108	103	106
60:30:20 kg NPK 5 t OC/ha	215	193	204	114	106	110
60:60:40 kg NP ₂ O ₅ K ₂ O + 45 kg Sun-hemp/ha	188	185	187	98	101	99
120:40:40 kg NP ₂ O ₅ K ₂ O + 3 t BM/ha	211	185	198	112	102	107
F test (Trt)	*	*	**	ns	**	*
F test (Trt × Year)			**			*
LSD _{0.05}	13.6	18.9	11	13.0	12.7	

*=Significant at 5% level of significance, ** = Significant at 1% level of significance, ns = non-significant

Thousand grain weight, grain yield and stover yield

Sources of different organic manures and inorganic fertilizers significantly ($P < 0.01$) influenced the maize grain yield. The maximum grain yield in 2019 was 7102 kg/ha and 6985 kg/ha in 2020. The thousand grain weight in both year 2019 and 2020 was found non-significant (Table 4). The combined data over both years showed that the maximum grain yield 7043.5 kg and thousand grain weight (426 g) were found with application of 60:30:20 kg NPK 5 t OC/ha (Figure 3 and Figure 4)

Table 4. Effects on grain yield and thousand grain weight due to application of different nutrient sources on maize grown during 2018-2019 and 2019-2020 at NMRP Rampur, Chitwan, Nepal

Treatments	Grain yield (kg/ha)		Thousand grain wt. (g)	
	2019	2020	2019	2020
120:60:40 kg NP ₂ O ₅ K ₂ O /ha	6142	6461	393	385
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM /ha	6264	6112	432	377
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM + 5 ton Biochar/ha	6303	6357	385	397
15 t FYM/ha	4005	4730	393	379
10 t PM/ha	4380	4902	403	348
10 t VC/ha	4229	3659	373	405
10 t OC/ha	6969	6535	424	401
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t PM/ha	4489	4689	371	344
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t VC/ha	5077	5229	365	424
60:30:20 kg NPK 5 t OC/ha	7102	6985	413	439
60:60:40 kg NP ₂ O ₅ K ₂ O + 45 kg Sunhemp/ha	5290	5043	377	375
120:40:40 kg NP ₂ O ₅ K ₂ O + 3 t BM/ha	5951	6164	421	367
Mean	5517	5560	396	387
F-test	**	**	ns	ns
LSD(0.05)	1162.03	1291.6	76.64	62.07
CV(%)	12.4	13.2	11.4	9.5

** = Significant at 1% level of significance, ns = non-significant

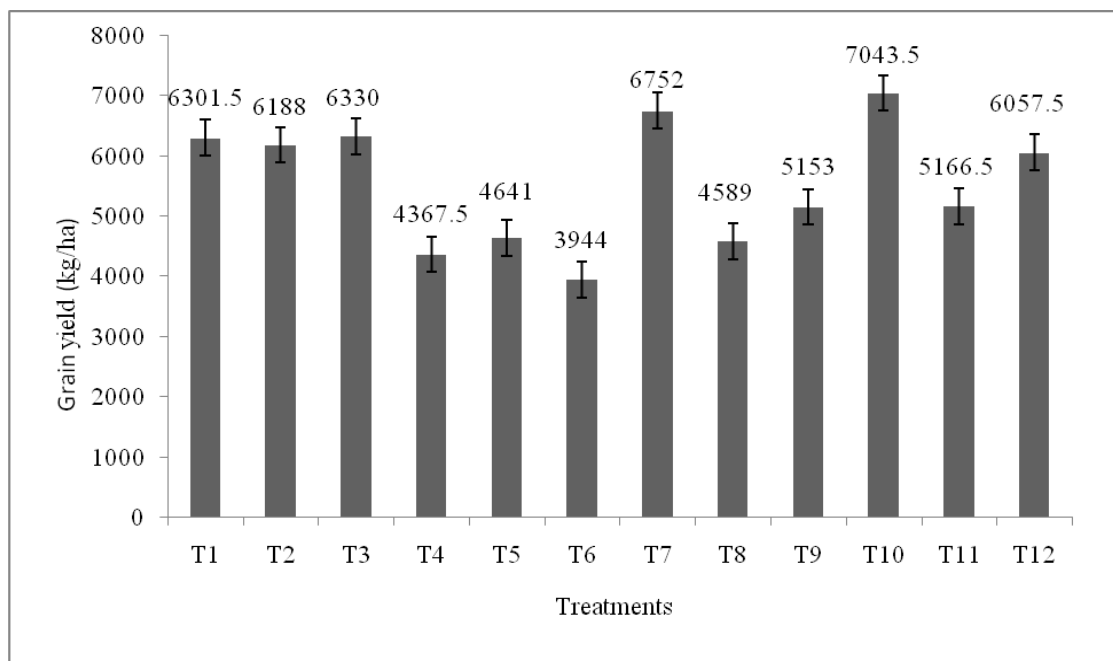


Figure 3: combined grain yield (mean+sem) as influenced by different nutrient sources, tested during the two consecutive winters of 2019 and 2020 at NMRP, Rampur, Chitwan, Nepal.

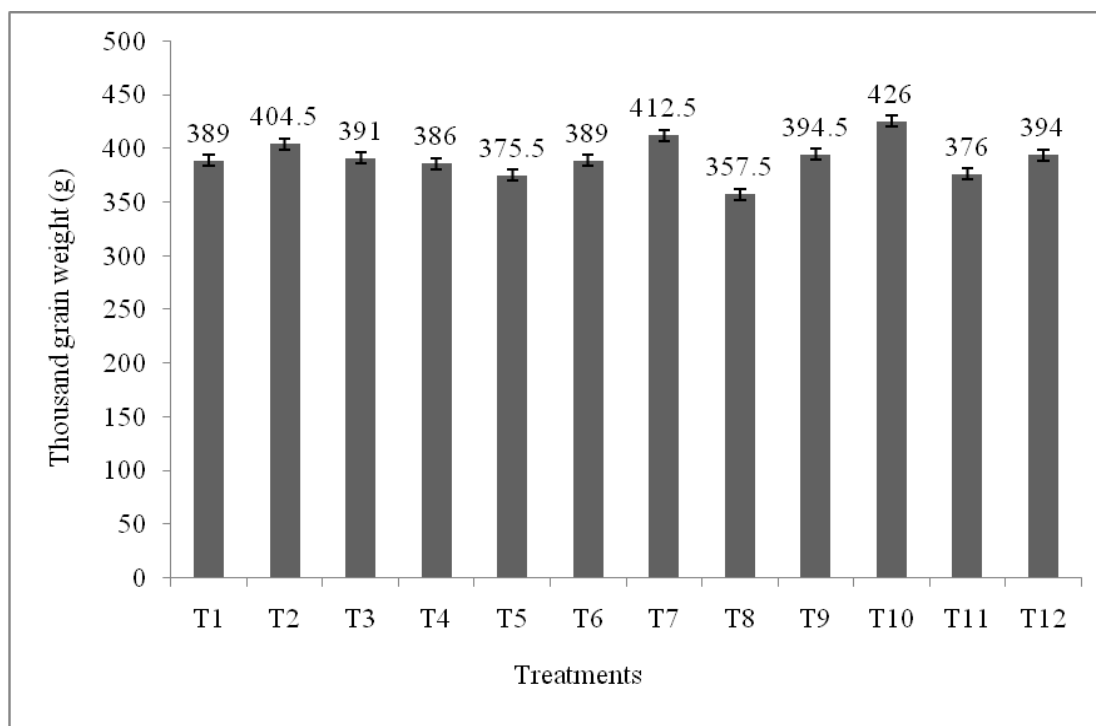


Figure 4: combined thousand grain weight (mean+sem) as influenced by different nutrient sources, tested during the two consecutive winters of 2019 and 2020 at NMRP, Rampur, Chitwan, Nepal.

Chemical properties of soil as influenced by the application of different nutrient sources

Influence on soil reaction

Soil pH was not significantly affected by various nutrient sources; however, variation was observed in individual treatment levels (Table 5). The mean value of soil pH was 5 before maize planting and 5.21 after maize harvest.

Soil Organic Matter

Different nutrient sources significantly influenced organic soil matter (SOM). SOM is the foundation for healthy and productive soils. The mean value of SOM was 3.4 % before maize planting and 3.2% after maize harvesting in second season (Table 5). The SOM value ranged from 1.17% at 120:60:40 kg NP₂O₅K₂O/ha to 4.10 % at 120:60:40 kg NP₂O₅K₂O + 10 t FYM/ha followed by 4% at 120:40:40 kg NP₂O₅K₂O + 3 t BM/ha.

Table 5. pH value and organic matter content in the soil before planting and after harvesting maize as influenced by different nutrient sources during winter at NMRP, Rampur, Chitwan, 2019 and 2020.

Treatments	pH before planting of 2018- 2019	pH after harvesting of 2019-2020	OM % before planting of 2018-2019	OM % after harvesting of 2019-2020
120:60:40 kg NP ₂ O ₅ K ₂ O/ha	5.20	5.28	2.47	1.17
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM/ha	5.02	5.37	4.18	4.10
120:60:40 kg NP ₂ O ₅ K ₂ O + 10 t FYM + 5 t Biochar/ha	5.19	5.00	4.22	3.43
15 t FYM/ha	5.22	5.37	3.96	3.43
10 t PM/ha	5.13	5.36	3.83	2.93
10 t VC/ha	5.00	5.39	3.64	3.68
10 t OC/ha	4.89	4.79	2.71	3.18
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t PM/ha	4.83	5.04	3.58	3.01
60:30:20 kg NP ₂ O ₅ K ₂ O + 5 t VC/ha	4.92	5.44	3.66	3.51
60:30:20 kg NPK 5 ton OC/ha	4.91	4.94	2.15	2.34
60:60:40 kg NP ₂ O ₅ K ₂ O + 45 kg Sunhemp/ha	4.90	5.11	4.64	3.51
120:40:40 kg NP ₂ O ₅ K ₂ O + 3 t BM/ha	4.81	5.41	2.69	4.00
Mean	5	5.21	3.47	3.20
F test	ns	ns	**	*
LSD (0.05)	0.41	0.71	1.61	1.2
CV%	4.9	8.1	28.3	17.1

* = Significant at 5% level of significance, ** = Significant at 1% level of significance, ns = non-significant

DISCUSSION

Significant influence of different sources of nutrients could be observed in anthesis and silking, plant and ear height, grain and stover yield, and 1000-grain weight. The results pointed out that the application of 5 ton OC/ha and half recommended dose of chemical fertilizer lowered both grain and stover yields. The contribution of nutrients to growing plants at any stage could be visualized, and therefore, a higher result could be obtained. The anthesis and silking and plant and ear height were significantly higher as influenced by different nutrient sources. Efficient use of nutrients simultaneously decreased the anthesis and silking days.

The grain yield was influenced significantly higher as influenced by different nutrient sources. Different organic manure and inorganic fertilizer sources significantly influenced the maize grain yield (p<0.005).

Priya et al (2014) reported that the yield advantage was observed in the combination of inorganic fertilizers with the application of bio-fertilizers and green manuring. Shanwad et al (2010) also noted that the enhancement in maize productivity with the combined application of nutrients through organic and inorganic resources. Similar findings have also been reported that the increase in maize yield with the combined application through organic and inorganic resources of nutrients (Singh et al 2018). The combination of organic and inorganic nutrient sources proved better in soil fertility in the long run (NARC1997/98).

The experimental data from our two years' research revealed that the non-significant effect was observed in thousand-grain weight, but individual variation was observed in different levels of treatment. Similar results were reported by Sharif et al (2004) that the 1000-grain weight was significantly affected by the recommended dose of fertilizer in combination with different organic sources. Similar findings were described by Kannan et al (2013). The beneficial influence of integrated supply of nutrients on yield attributing characters, i.e., cobs per plant, grain yield, 1000 grains weight of maize, has been reported by many workers (Chandrashekara et al 2000, Gaur and Kumawat 2004).

The measurement of pH value is an essential indicator for identifying soil's chemical nature, which affects the availability of essential plant nutrients. Soil pH was moderately acidic before maize planting. After two years of maize harvesting pH value slightly increased, which indicates decreases in soil acidity. SOM is the foundation for healthy and productive soils. The addition of OM is a potential increase in available nutrients (Bot 2005). Data showed that sole use of chemical fertilizer decreased OM percentage in soil because chemical fertilizer was well mineralized, whereas integrated use of organic manure increases SOM percentage after crop harvest. In this case, SOM was observed high in FYM, and BM treated plots because it takes time to decompose. It could not be mineralized all during the growth period of the first crop. Due to the nature and pattern of mineralization, the combined use of organic matter improves soil's physico-chemical properties rather than single organic matter. Data revealed that the supply of different organic sources increases the pH value, indicating a decrease in soil acidity. Data showed that sole use of chemical fertilizer decreased OM percentage in soil because chemical fertilizer was well mineralized, whereas integrated use of organic manure increase OM percentage after crop harvest. Organic matter can also change the level of available nitrogen in the soil.

CONCLUSION

The combined applications of organic manures and chemical fertilizer have proved superior and have noticeably contributed to the soil properties and the performance of maize. The maximum grain yield of maize was obtained with the combined application of 50% of the recommended dose of N, P₂O₅ and K₂O fertilizers and 5 t mustard oilcake/ha. In subtropical conditions, integrated manures and fertilizers can enhance soil fertility status and increase maize productivity during winter conditions.

REFERENCES

- Adhikari P, BR Baral and J Shrestha. 2016. Maize response to time of nitrogen application and planting seasons. *Journal of Maize Research and Development* 2(1): 83-93. DOI: <https://doi.org/10.3126/jmrd.v2i1.16218>
- ABPSD. 2018. Statistical Information on Nepalese Agriculture 2017/18. Government of Nepal, Ministry of Agriculture and Livestock Development. Agribusiness Promotion and Statistics. Division, Singh Durbar, Kathmandu, Nepal
- Adhikary BH, J Shrestha and BR Baral. 2014. Efficacy of organic fertilizers on maize (*Zea mays* L.) productivity in the acid soils of Rampur, Chitwan. In: *Proceeding of 4th SAS-N Convention*, April 4-6, 2012, National Agriculture Research Institute Complex, Khumaltar, Lalitpur; Pp .89-94

- Aulakh MS. 2010. Integrated Nutrient Management for sustainable crop production, improving crop quality and soil health, and minimizing environmental pollution. Research Gate. Symposium on 'Management and protection of receiving environments' during '19th World Congress of Soil Science', At Brisbane, Australia
- Baral BR, P Adhikari and J Shrestha. 2015. Growth and yield response of hybrid maize (*Zea mays* L.) to phosphorus levels in sandy loam soil of Chitwan valley, Nepal. *International Journal of Environmental Science* **4**(2): 147-156.
- Bot A. 2005. The importance of soil organic matter. *FAO Soils Bulletin*. V.80
- Chandrashekara, CP, SI Harlapur, S Murlikrishna, and GK Girijesh. 2000. Response of maize (*Zea mays* L.) to organic manures with inorganic fertilizers, Karnataka. *Journal of Agricultural Science* **13**(1): 144-146.
- Funderburg, E. (2001). What does organic matter do in soil? Noble Research Institute, LLC.
- Gaur BL and SK Kumawat. 2004. Integrated nutrient management in maize-wheat cropping system under South Rajasthan condition. In: National Symposium on Agronomy - challenges and strategies for the new millennium, held at GAU campus, Junagarh (Gujarat); **pp.55-56**.
- Gomez KA and AA Gomez. 1984. Statistical procedures for agricultural research. 2nd edition. International Rice Research Institute, College, Laguna; **pp. 680**.
- Kannan RL, M Dhivya, D Abinaya, KR Lekshmi and S Krishnakumar. 2013. Effect of integrated nutrient management on soil fertility and productivity in maize. *Bulletin of Environment, Pharmacology and Life Sciences* **2**(8): 61-67.
- Karlen DL, CA Ditzer and SS Andrews. 2003. Soil quality: why and how? *Geoderma* **114**: 145–156.
- KC A, G Bhandari, S Wagle and Y Banjade. 2013. Status of Soil Fertility in a Community Forest of Nepal. *International Journal of Environment* **1**(1): 56-67.
- Kogbe JOS and JA Adedirani. 2003. Influence of nitrogen, phosphorus, and potassium application on the yield of maize. *African Journal of Biotechnology* **2**(10): 345-349.
- Kundu DK and KG Pillai. 1992. Integrated nutrient supply system in rice and rice-based cropping systems. *Fertilizer News* **37**(4): 95-101.
- Mahajan A, RD Gupta and R Sharma. 2007. Organic farming. *Gram Vikas Jyoti*, July–September Issue; **pp. 7–8**.
- MOALD. 2020. Ministry of Agriculture and Livestock Development, Government of Nepal.
- NARC. 1997/98. Annual Report. Nepal Agricultural Research Council, Kathmandu, Nepal.
- NMRP. 2018. Annual Report. National Maize Research Program, Rampur, Chitwan, Nepal.
- Pokharel B, S Sharma, G Pun and N Chhetri. 2016. Phosphorous as the major yield limiting nutrient for maize in the river basin areas of western Nepal. *Journal of Maize Research and Development* **2**(1): 100-108. DOI: <https://doi.org/10.3126/jmrd.v2i1.16220>
- Priya S, MK Kaushik, SK Sharma and K Priyanka. 2014. Impact of integrated nutrient management on growth and productivity of hybrid maize (*Zea mays* L.). *Annals of Biology* **30**(1): 106–108.
- Selim, MM. 2020. Introduction to the integrated nutrient management strategies and their contribution to yield and soil properties. *International Journal of Agronomy*. DOI: <https://doi.org/10.1155/2020/2821678>
- Shanwad UK, BN Aravindkumar, UK Hulihalli, A Surwenshi, M Reddy and BR Jalageri. 2010. Integrated nutrient management (INM) in maize- bengal gram cropping system in Northern Karnataka. *Res. J. Agric. Sci* **1**(3): 252-254.
- Sharif MM, MSS Ahmed and RA Khattak. 2004. Effect of organic and inorganic fertilizers on the yield and yield components of maize. *Pakistani Journal of Agricultural Engineering and Veterinary Science* **20**:11-15.
- Sharma R, P Adhikari, J Shrestha and BP Acharya. 2019. Response of maize (*Zea mays* L.) hybrids to different levels of nitrogen. *Archives of Agriculture and Environmental Science* **4**(3): 295-299
- Sherchan DP and KB Karki. 2006. Plant nutrient management for improving crop productivity in Nepal. Food and Agriculture Organization, Improving Plant Nutrient Management for Better Farmer Livelihoods, Food Security and Environmental Sustainability.
- Shrestha J, S Subedi, KP Timsina, S Gairhe, M Kandel and M Subedi. 2019. Maize research. New India Publishing Agency (NIPA), New Delhi-34, India.
- Shrestha J., DN Yadav, LP Amgain and JP Sharma. 2018. Effects of nitrogen and plant density on maize (*Zea mays* L.) phenology and grain yield. *Current Agriculture Research Journal* **6**(2): 175-182.
- Singh R, A Masood, DZ Mahdi, M Asif and AM Malik. 2018. Integrated nutrient management in maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry* **7**(3):3110-3113

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