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ORGANIC AND INORGANIC SOIL AMENDMENTS EFFECTS ON MAIZE (*ZEA MAYS* L.) YIELD, NUTRIENT CONTENT AND SOIL PROPERTIES

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Abstract

Two field experiments were conducted in Nubaria in sandy soil to study the effect of nitrogen level *i.e.*; 0, 180, 216 and 252 kg ha^{-1} and farmyard manure (FYM) at 12, 24 and 48 m^3 ha^{-1} with or without adjusted rate of N (216 kg ha^{-1}) on maize yield and nutrient content of grains as well as soil properties. The analysis of FYM indicated that farmyard manure applied considered amounts of N, P and K, where the average content was 10.99, 2.03 and 9.38 kg m^{-3} for N, P and K, respectively. FYM supplied maize by 3.43 kg, 784 g, 882 g and 644 g for Fe, Mn, Zn and Cu per cubic meter, respectively. The results showed significant effects of N fertilizer and manure application on maize yield per plant and per hectare in both seasons while straw and biological yields were significantly affected only in 2019 season. Maize yield significantly increased with increasing the rate of manure when farmyard manure was combined with inorganic fertilizer, demonstrating the responsiveness of maize to organic matter addition. Generally, farmyard manure application resulted in yield increases when applied alone and when combined with 216 kg N ha^{-1} in both seasons. The results also showed that there were no statistically significant differences in nutrient and trace element concentrations were detected in maize grains. Chemical analysis of the experimental soil revealed significant effects for EC, P and K according to the treatment applied. Highly significant decrease in EC ($P<0.001$) due to the treatments compared with the untreated control were reported. P concentrations were significantly increased by inorganic fertilizer ($P= 0.003$) and K by FYM ($P= 0.033$). The integrated application of FYM + 216 kg inorganic N fertilizer resulted in the greatest concentration of N, P, Fe, Mn and Zn in maize grains relative to the soil background concentrations of these nutrients. The nutrient ratios of micronutrients were greater than the macronutrients. In conclusion, soil incorporation of cattle manure, at reasonable rates, can enhance growth and increase grain yield at levels similar to those of inorganic N. Also, manure application can improve soil fertility, grain quality with respect to K and P, without increasing soil salinity in such sandy soil.

Key Words: Manure, N fertilizer, grain yield, quality, soil properties

Introduction

Low fertility and poor moisture retention are the most pronounced characters of sandy soils in Egypt. However intensive use of inorganic fertilizers in such poor soils, is associated with high cost and environmental pollution (Abayomi and Adebayo, 2014; Diacono and Montemurro, 2010; Komakech *et al*., 2015 and Savci, 2012). The use of bio wastes like cattle manure could be considered as partially alternative due to these detrimental effects of inorganic fertilizers and its capacity for storing and releasing nutrients over a longer time period Diacono and Montemurro (2010). The combined use of chemical fertilizers and organic material may be a good approach for sustainable production of crops is beneficial in improving crop yield, soil pH, organic carbon and available N, P and K in sandy loam soil Elfstrand *et al.,* (2007) and Rautaray *et al.,* (2003).

The use of organic matter is not a complete substitute to chemical fertilizers. Organic sources ameliorate the micronutrient deficiencies and increase uptake of water and nutrient elements (Cheng, 1997), leading to improve physical properties of soil (Sial *et al*., 2007).

Maize is a strategic dominant summer crop with high nutritional value and main food and fodder crop in Egypt

(Chaudhary, 1993). It is a high crop demand for N fertilization and it is recommended to integrate organic and inorganic fertilizers in maize nutrition Shakoor *et al.*, (2015). Recently, El Sheikha (2016) concluded that integrated use of organic manure and recommended dose of chemical fertilizers resulted in significant improvement in crop yields and quality despite being an active practice in nutrient management.

The objectives of this study were to evaluate the effect of integrated application of nitrogen and farmyard manure FYM on maize yield and nutrient content of grains as well as soil properties.

Materials and Methods

Two field trials were conducted in the summer seasons of 2018 and 2019 to study the effect of integrated organic and inorganic application on yield and nutritional status of maize (*Zea mays* L.) grown in sandy soil. The experiments were conducted in a private farm Tawfiq El Hakim village Nubaria, Behaira governorate (84 km Alex-Cairo desert road). The chemical analysis of the experimental soil site before the first season are listed in table 1. Each experiment included 10 treatments which were the combinations of three farmyard manure rates *i.e.*; 12, 24 and 48 m^3 ha^{-1} with or without adjusted rate of nitrogen fertilizer (216 kg N ha^{-1}) as well as 4 additional nitrogen fertilizer rates 0, 180, 216 and 252 kg ha^{-1}. The experimental design in both trials was complete randomized block design with 4 replicates. The organic manure analyses applied to the trial are presented in table 2 (means of two seasons of study). The farmyard manure was obtained from the district.

The experimental area was ploughed twice, ridged and divided to experimental unites each of 21 m^2. Organic manures rates were applied after manually calibration on a volumetric basis to the assigned plots. In order to secure homogenous incorporation with the soil surface layer.

Rotary cultivator was used. Maize (*Zea mays* L.) *cv.* Single Hybrid-10 grains were sown in the experimental plots on June 12 and 15 in 2018 and 2019, respectively. Nitrogen fertilizer levels were applied in two equal doses at 21 and 35 days from sowing as well as a common application of potassic fertilizer was applied at 57 kg K_2O ha^{-1} before the second irrigation. Irrigation was carried out as followed in the district weekly by sprinkler irrigation. Weeds were controlled by manual cultivation after 20 and 34 days from sowing. Chemical analyses of soil (0-30 cm depth) for some selected treatments (control, and the heavy applications rates of inorganic and organic fertilizers applied) was carried out after the second season harvest where a composite sample of each treatment was taken from 4 replicates. The chemical analyses of soil, manure and grains were carried out according to the methods described by Chapman and Pratt (1961) and Jackson (1967). The data were statistically processed using software package (MSTAT-C, 1988). LSD 5% test was adopted of means comparison.

Results

Nutrient addition by farmyard manure

Data presented in table 3 indicated that farmyard manure applied substantial amounts of N, P and K. The calculations of macro and micronutrients applied through FYM was done on the base the nutrient analysis and FYM density (0.7). The average content was 10.99, 2.03 and 9.38 kg m^{-3} for N, P and K, respectively. FYM is a relatively rich source of K. Data presented in table 3 show the 4 key micronutrients Fe, Mn, Zn and Cu loading rates when FYM was applied. The data clearly show that FYM supplied substantial rates of Fe, Mn and Zn and Cu: 3.43 kg, 784 g, 882 g and 644 g for Fe, Mn, Zn and Cu, respectively per cubic meter. However, it seems that FYM contained the greatest Cu rates applied to the soil due to its presence in the livestock diets with high

Table 1: Chemical analysis of the experimental soil site (Units: EC as dS m^{-1}; OM and $CaCO_3$ as %; other elements as mg kg^{-1}).

pH	EC	OM	$CaCO_3$	N	P	K	Fe	Mn	Zn	Cu
8.50	0.24	0.73	5.2	1400	132	826	3694	56.8	17.08	3.78

Table 3: Macro and micronutrients addition by FYM m^{-3}.

	kg m^{-3}				g m^{-3}		
	N	P	K	Fe	Mn	Zn	Cu
Minimum	7.07	0.49	3.08	0.28	399	154	36.4
Maximum	13.72	6.86	19.46	7.07	1155	1806	1897
Mean	10.99	2.03	9.38	3.43	784	882	644

Table 2: Statistical summary of chemical properties of the farmyard manure applied to the field trial (n = 13).

Parameter	Ds (%)	VS (% ds)	OM (% ds)	pH	EC (ds m^{-1})	Total content (% ds) (Mg kg^{-1} ds)						
						N	P	K	Fe	Mn	Zn	Cu
Minimum	72.5	13.7	21.1	6.8	1.9	1.01	0.07	0.44	0.04	57	22	5.2
Maximum	96.2	54.4	44.6	8.7	8.7	1.96	0.98	2.78	1.01	165	258	271
Mean	80.6	39.6	29.3	7.7	4.6	1.57	0.29	1.34	0.49	112	126	92

(Ds: dry solids, VS: Volatile solids, OM : organic matter).

rates. Although such loading rates are relatively small but on the long term will be substantial in the case of the continues application and will be beneficial to the soil.

Regarding nutrient additions of different farm yard manure levels kg ha^{-1} it is clear that high rates of NPK were supplied by different FYM levels table 4 and Fig. 1.

Table 4: Nutrient additions of different Farm yard manure levels kg.ha^{-1}.

FYMRate m^3 ha^{-1}	Macronutrients				Macronutrients		
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
12	131.9	24.4	112.6	41.2	9.4	10.6	7.7
24	263.8	48.7	225.1	82.3	18.8	21.2	15.5
48	527.6	97.4	450.2	164.6	37.6	42.3	30.9

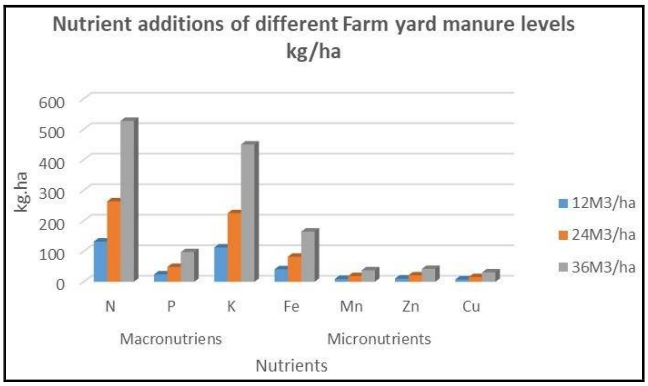

Fig. 1: Nutrient additions of different farm yard manure levels kg ha^{-1}.

Yield

Data presented in table 5 show that significant effects were detected due to treatments on maize grain yield per plant and per hectare (P<0.001) table 5. The data in the same table reveal that the maximum increase in grain yield per plant was about 50% over the control, and reached 57% per ha when the plants were fertilized with the highest rate of organic manure combined with the reduced rate of N (216 kg N) in 2019 season. The data of the same season clearly indicate that the addition of fertilizer significantly increased grain yields per hectare although there was not a significant difference between the highest rates of application. Farmyard manure applied at the lowest rate (12m^3 ha^{-1}) did not increase yields significantly over the control or the lowest rate of fertilizer. However, the yields from the higher rates of manure addition alone or combined with adjusted N rate were significantly increased to levels similar to the higher rates of inorganic fertilizer. The addition of fertilizer with FYM increased generally yields further, significantly so especially at the higher rates of manure. However, there were no significant effects of the treatments on straw and biological yields. Straw accounts for most of the total crop production (average 84%). There was no apparent relationship between grain and straw yields. Similar trend was also reported in the second season, the ANOVA showed highly significant effects of the experimental treatments on maize yields. Significant effects were reported for grain yield per plant and per ha; furthermore, straw and biological yields were significantly affected due to treatment application. Inorganic fertilizer at 216 kg ha^{-1} significantly increased grain yield by approximately (34.8%) when applied with FYM, compared to manure addition alone without mineral N Fig. 2. Straw yield was also raised by mineral N compared to plots receiving only the organic manures, this apparent response was statistically significant. On average, manure increased yield of straw and grain, and grain yield was raised with increasing rate of manure. However, there was no

Table 5: Effect of different N and manure levels on yield characters of maize grains in 2018 and 2019 seasons.

Treatment	Grain yield (g plant^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Relative yield (%)	Biological yield (t ha^{-1})
2018 season					
Control	96.3	25.37	3.82	-	25.37
180 kg N ha^{-1}	130.7	32.78	4.54	18.9	32.78
216 kg N ha^{-1}	133.7	30.86	5.216	54.7	30.86
252 kg N ha^{-1}	136.7	35.59	5.62	52.8	35.59
FYM 12 m^3 ha^{-1}	125.7	28.73	3.94	3.0	28.73
FYM 12 m^3 ha^{-1}+F	139.0	28.01	5.23	37.1	28.01
FYM 24 m^3 ha^{-1}	143.0	41.21	5.16	35.2	41.21
FYM 24 m^3 ha^{-1} + F	118.0	25.25	5.11	34	25.25
FYM 48 m^3 ha^{-1}	125.0	19.180	4.216	28.3	19.180
FYM 48 m^3 ha^{-1} + F	140.0	28.34	6.02	57.9	28.34
cv %	15.0	23.85	13.3		21.09
Probability	0.045	0.178	<0.001***		0.116
LSD at 0.05	16.2	ns	0.41		ns
2019 season					
Control	85	6.46	2.88	-	9.34
180 kg N ha^{-1}	126	8.54	5.064	75.8	13.61
216 kg N ha^{-1}	161	8.45	5.976	108	14.42
252 kg N ha^{-1}	168	8.06	6.816	136.7	14.88
FYM 12 m^3 ha^{-1}	99	7.68	3.552	23.3	11.23
FYM 12 m^3 ha^{-1} + F	156	9.02	5.832	102.5	14.86
FYM 24 m^3 ha^{-1}	172	9.60	5.856	103	15.46
FYM 24 m^3 ha^{-1} + F	197	10.08	6.888	139.1	16.97
FYM 48 m^3 ha^{-1}	219	10.18	7.056	145	17.23
FYM 48 m^3 ha^{-1} + F	209	10.56	7.608	164.1	18.17
CV %	25.0	33.85	33.3	-	27.0
Probability	0.047	0.038	<0.01***	-	0.01
LSD at 0.05	13	0.53	0.33	-	0.84

F= reduced rate of inorganic N (216 kg N ha^{-1}).

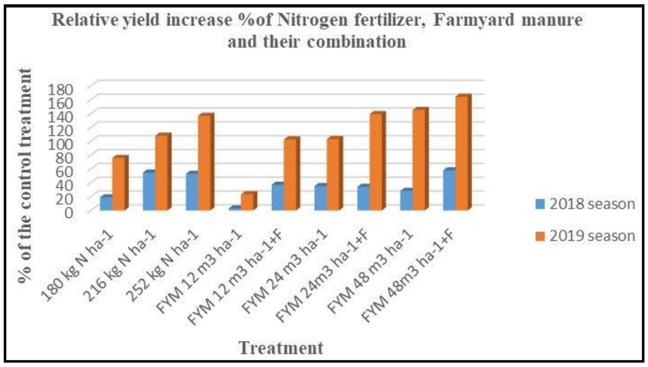

Fig. 2: Effect of Nitrogen fertilizer, Farmyard manure and their combination on relative yield increase (% of the untreated control).

significant difference in straw yield at the higher rate of manure addition of 48 $m^3 ha^{-1}$ compared with the middle rate of application of 24 $m^3 ha^{-1}$. It is well known that grain yield as well as straw and biological yields could be directly affected by most growth parameters due to the favorable nutritional conditions created from organic manures application.

Chemical constituents of grains

The chemical composition of maize grain is summarized in table 6 Figs. 3 and 4. The data revealed that no statistically significant differences in nutrient and trace element concentrations were detected by ANOVA.

Table 6: Chemical composition of maize grain (Units: nutrients as %; trace elements as mg kg^{-1}).

Treatment	N	P	K	Fe	Mn	Zn	Cu
Control	1.48	0.24	0.27	125.0	17.2	16.0	2.88
180 kg N ha^{-1}	1.74	0.28	0.32	91.7	9.0	12.3	2.05
216 kg N ha^{-1}	1.70	0.32	0.28	150.0	9.7	13.5	2.17
252 kg N ha^{-1}	1.69	0.31	0.28	158.3	12.1	15.7	2.97
FYM 12 $m^3 ha^{-1}$	2.07	0.31	0.28	166.7	13.5	14.7	2.77
FYM 12 $m^3 ha^{-1}$ + F	1.68	0.31	0.28	183.3	10.2	16.2	2.78
FYM 24 $m^3 ha^{-1}$	1.60	0.33	0.21	250.0	17.3	18.3	3.25
FYM 24 $m^3 ha^{-1}$ + F	1.73	0.34	0.28	150.0	11.8	23.0	2.40
FYM 48 $m^3 ha^{-1}$	1.43	0.29	0.27	158.3	13.0	15.5	2.30
FYM 48 $m^3 ha^{-1}$ +F	2.21	0.30	0.25	225.0	19.7	22.3	2.45
Mean	1.77	0.29	0.27	159.3	13.1	16.2	2.41
Probability	0.815	0.220	0.779	0.415	0.240	0.643	0.928
Significance	ns	ns	ns	ns	ns	ns	ns

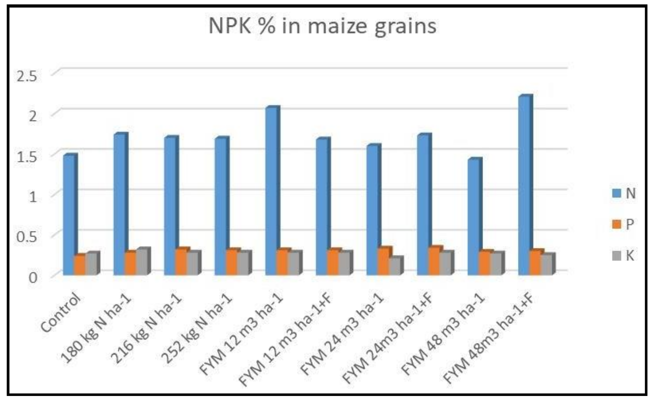

Fig. 3: Effect of soil amendments treatments on NPK in maize grains.

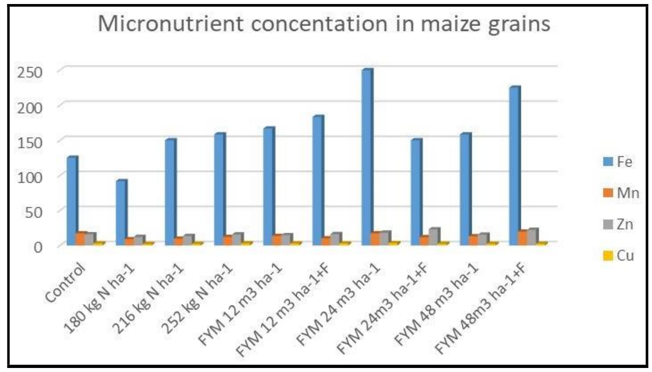

Fig. 4: Effect of soil amendments treatments on micronutrient concentration in maize grains.

Soil characteristics

Soil samples were taken for chemical analysis from selected treatments after maize harvest and the results are summarized in table 7. Significant effects were detected by ANOVA for EC, P and K. Unlike some trials where increases in soil salinity from compost or FYM addition have been detected, this trial had a highly significant decrease in EC ($P<0.001$) due to the treatments compared with the untreated control. P concentrations were significantly increased by fertilizer and K by FYM ($P=0.033$). Data presented in table 8 and Fig. 5 revealed that integrated application of FYM + 216 kg inorganic N fertilizer resulted in the greatest concentration of N, P, Fe, Mn and Zn in maize grains relative to the soil background concentrations of these nutrients.

Table 7: Chemical analysis of soil sampled after maize harvest (Units: EC as dS m^{-1}; OM as %; nutrients and other elements as mg kg^{-1}).

Treatment	pH	EC	OM	N	P	K	Fe	Mn	Zn	Cu
Control	8.23	1.13	1.24	1592	18.8	3437	21524	242	28.8	9.21
252 kg N ha^{-1}	8.13	0.96	1.25	2152	54.0	3785	35821	236	29.2	9.26
FYM 48 $m^3 ha^{-1}$	8.36	0.54	1.29	2214	97.8	3273	20391	212	25.9	8.87
Probability	0.224	<0.001	0.609	0.056	0.003	0.033	0.6545	0.412	0.211	0.493
Significance	ns	***	ns	ns	**	*	ns	ns	ns	ns
LSD at 0.05	-	0.16	-	-	34.2	335	-	-	-	-

Data presented in table 8 and Figs. 5 and 6 revealed that integrated application of FYM + 216 kg inorganic N fertilizer resulted in the greatest concentration of N, P, Fe, Mn and Zn in maize grains relative to the soil background concentrations of these nutrients. The nutrient ratios of micronutrients were greater than the macronutrients.

Discussion

Considering the fertilizer inputs saved by organic manures, Abd El Lateef *et al.*, (2019) recommended that supplementation with this major plant nutrient is recommended where the other organic fertilizers like compost or chicken manure should be frequently applied to soil to maintain crop productivity by also supplying FYM or inorganic K fertilizer in the crop rotation. However, due to the nature of bounding these nutrients in the FYM by the organic matter it is expected to slow released in the current and further subsequent seasons.

Table 8: Nutrient concentration ratio in maize grains relative to soil background concentration.

Treatment	N	P	K	Fe	Mn	Zn	Cu
Control	1.59	0.02	3.44	0.58	7.11	55.56	31.27
252 kg N ha^{-1}	2.15	0.05	3.79	0.44	5.13	53.77	32.07
FYM 48 m^3 ha^{-1} + F	2.21	0.10	3.27	1.10	9.29	86.10	27.62

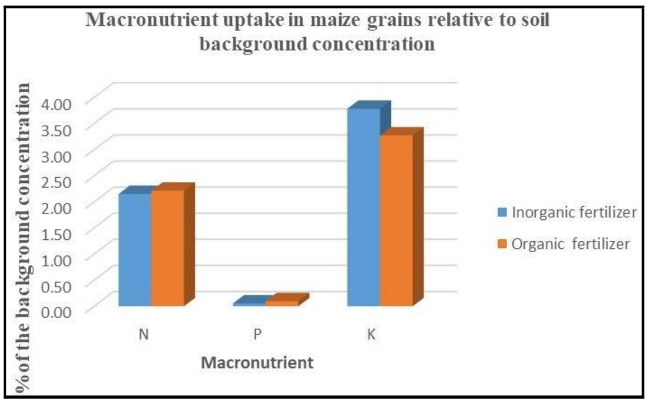

Fig. 5: The nutrient ratios of macronutrients in maize grains relative to the soil background concentrations.

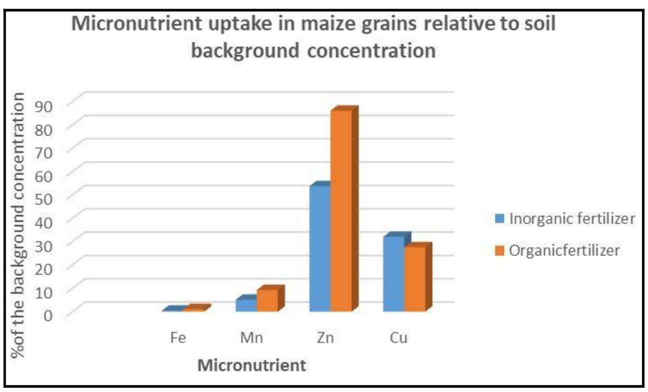

Fig. 6: The nutrient ratios of micronutrients in maize grains relative to the soil background concentrations.

The N equivalencies estimated for FYM by Abd El Lateef *et al.*, (2019) suggest that the FYM is frequently inconsistent, reflecting the more variable chemical composition of FYM. Similar results were confirmed by Abd El Lateef *et al.*, (2007).

Regarding maize yield and its components, the obtained results suggest that the most likely explanations for the high maize yield response to the applied organic materials are that: high leaching losses of soluble N supplied in the inorganic fertilizer reduced the yield response to mineral N whereas the slower release of available N from mineralization of FYM organic matter was better synchronized to the crop requirement for N. Moreover, the organic manures supplied additional growth factors, such as essential trace elements and K, which promoted crop productivity in addition to the beneficial effects of plant available N supply; also, the application of organic matter to soil in the manures improved the soil physical characters, and creating better environment for root growth and also increased soil water availability to the crop. Yadav *et al.*, (2006) demonstrated that combination of mineral fertilizers with different types of organic materials reduced rate of NPK application and sustain high crop productivity of rice. Similar results were obtained by Yang *et al.*, (2005) they reported that it is important to have balanced application of fertilizers and manure to maximize crop production and also Wang *et al.*, (2005) came to similar conclusion. Shakoor *et al.*, (2015) and Mahmood *et al.*, (2017) mentioned that integration of inorganic fertilizers with organic manures can be used with optimum rates to improve crop productivity on sustainable basis.

From the results of chemical contents of macro and micro elements it is obvious that copper concentrations were small and this essential trace element is probably deficient in the district, it should be evaluated and corrected in this district. Similar results were obtained by Porter *et al.*, 2004; Hao *et al.*, 2008; Birkhofer *et al.*, 2008 and Lima *et al.*, 2009 found that the concentrations of N, P and K in the grains inconsistently affected by manure or fer-tilizer application. On contrast Yang *et al.*, (2005) found that the combined application of NP fertilizer, corn stover and cattle manure increased either P or K uptake to the grains than the single application of each. These results are in confirmatory with Lima *et al.*, (2009) who stated that incorporation of organic manures improves soil physico-chemical properties that may have a direct or indirect effect on plant growth and yield attributes.

Several investigators reported that the soil properties are clearly affected when soil amendments were applied to the soil compared to the unlamented plots (Evans *et al*., 1977; Sutton *et al*., 1979; Culley *et al*., 1981; Chang *et al*., 1991 and Theodora *et al*., 2004). These results are in confirmatory with Lima *et al*., (2009). Munyabarenzi (2014) reported that the combined treatments generally showed significantly higher nutrient uptake and nutrient use efficiency than the sole organic and inorganic fertilizers.

Concerning the ratio of macro and micronutrients derived in grains relative to the soil background concentrations, the nutrient ratios of micronutrients were greater than the macronutrients. This may be due to the lower leachate of these nutrients where they are conjugated with the organic matter which gave maize plants the opportunity to benefit from these nutrients. The obtained results are in harmony with those obtained by Cheng (1997) and Sial *et al*., (2007). Recently, Jjagwe *et al.,* (2020) reported that, it can be concluded that treating organic materials prior to their use as crop fertilizers improves their quality in terms of the macronutrients (N, P and K). In addition, organic amendments can perform as good as inorganic fertilizers when the essential crop nutrients (N, P, K) are applied at the same rate.

In conclusion, soil incorporation of cattle organic manure, at reasonable rates combined with 85% of the recommended N rate, can enhance growth and increase grain yield at levels similar to those of inorganic N. Also, manure application can improve soil fertility, with respect to K and P, without increasing soil salinity in such sandy soil.

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