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Influence of Integrated Nutrients on N and P Uptake and Biomass Production of Maize (*Zea mays* L.) in Mazimbu, Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author UKA designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author YBD analyses of the study performed the spectroscopy analysis and author JPM managed the literature searches and experimental process and author JJM identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

A screen house soil culture experiments were conducted at Teaching and Research Farm, Mazimbu campus of Sokoine University of Agriculture Morogoro City, Tanzania in 2014 and 2015 to investigate the nutrients uptake (N and P) and biomass production (DMY) of maize grown with different levels of organic and inorganic fertilizers. The treatments used were nitrogen at three levels (0, 75 and 150 kgNha^{-1}), phosphorus (0, 40 and 80 kgPha^{-1}) and Farm Yard Manure (0, 5 and 10 tFYMha^{-1}). The treatments were factorially combined and replicated three times using completely randomized design (CRD). DMY were assessed and the uptake of Nitrogen and phosphorus by maize were determined. Results of the experiments showed that, the combined rates of organic and inorganic fertilizers significantly increased Dry matter yield and N and P uptakes of maize when compared with most of the treatments and with the control. Root and shoot biomass ranged from 0.54 and 1.60 g pot^{-1} to 2.33 and 10.90 g pot^{-1} in 2014 and 3.59 and 11.52 g

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pot^{-1} to 9.28 and 24.43 g pot^{-1} in 2015 respectively. While the nutrient uptakes ranged from 1.04 and 0.089% to 2.94 and 0.37% for N and P in 2014 and 0.367 and 0.037% to 2.555 and 0.308% for N and P respectively in 2015. It was therefore concluded that the combined application of organic (FYM) and inorganic (N and P) fertilizers improved nutrients uptake and tissue nutrient contents of maize in the studied soils.

Keywords: Nitrogen; phosphorus; nutrient uptake; fertilizers.

1. INTRODUCTION

Maize is one of the highly consumed cereal crops ranked the first in terms of production and third in terms of consumption among the ten staples that feed the world [1,2] and therefore dominates agriculture in many regions of the world. Maize was introduced into Africa in 1500 s and has since become one of Africa's dominant food crops and an important staple food for more than 1.2 billion people in Sub – Saharan Africa and Latin America [3]. The declining soil fertility is widely perceived and regarded as a major limitation to increasing yields and a threat to sustainability of the maize cropping systems [4]. In Tanzania it is estimated that the annual per capita consumption of maize is over 115 kg; national consumption is projected to be three to four million tonnes per year. The popularity of maize is evidenced by the fact that, it is grown in all the agro-ecological zones in the country [5].

Due to continual removal of soil nutrients by crops, soil erosion, leaching and other processes, soils generally become deficient in one or more nutrients [6], the reaction of the farmers to the decline in soil fertility has been to practice shifting cultivation where land is not scarce or to supply additional nutrients by using fertilizers and manures. Restoring, maintaining, and increasing soil fertility are major agricultural priorities particularly in the many parts of developing world where soils are inherently poor in plant nutrients and the demand for food and raw materials is increasing rapidly [7].

Tisdale et al. [8] stated that nitrogen is an important plant nutrient and is the most frequently deficient of all nutrients. The low nitrogen supplying power of soils calls for large additions of nitrogen fertilizers to soils to meet the nitrogen needs of high yielding non legume crops [9]. Since nitrogen in the soil is normally transient after breakdown of organic matter, external supply of nitrogen is a must, except to some extent, for legumes that is not supplying, therefore, that in many developing countries (Tanzania inclusive), N fertilizer were the first to be used and are still predominant [10]. Phosphorus (P) is known as the master key to agriculture because lack of available P in the Soils limits the growth of both cultivated and uncultivated plants [11].

Nitrogen and Phosphorus have more wide spreads influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present [12].

Based upon research findings across numerous countries and diverse agro ecological zones of sub – Saharan Africa (SSA), a consensus had emerged that the highest and most sustainable gains in crop productivity per unit nutrient are achieved from mixtures of fertilizer and organic inputs [13]. The need to combine essential organic inputs with fertilizers and farmer – available organic resources are viewed as a major entry point Indeed combining mineral and organic inputs result in greater benefits then either input alone [14]. Organic and organomineral fertilizers were found to increase significantly yield of maize and vegetables as pepper, tomato, okra, melon and amaranths [15,16]. The basic concept underlying the integrated nutrient management system (INMS), nevertheless, remains the maintenance and possible improvement of soil fertility for sustainable crop productivity on long term-basis and also to reduce inorganic (fertilizer) input cost [17]. In line of the above therefore, this study was aimed at investigating the nutrient uptake (N and P) and biomass production (DMY) of maize growth with different levels of organic and inorganic fertilizers.

2. METHODOLOGY

2.1 Study Location

The study was carried out at the Teaching and Research farm and glass house of the Department of Soil Science at Faculty of Agriculture Sokoine University of Agriculture, Morogoro (Latitude 5°58''N; 10°0''S and longitude 35°25''; 35°30''E) located in the agro-ecological zone 2 of Tanzania, during the long rain seasons of 2014 and 2015. The average total annual precipitation and mean monthly temperature are about 895 mm per year and 24.0°C respectively.

2.2 Soil Sampling, Preparation and Analytical Methods

Top soil samples (0 – 30 cm) were collected from Mazimbu farm of SUA, bulked, air-dried and sieved using 6 mm and 2 mm screen for pot experiments and laboratory analysis respectively. FYM sample was collected from cattle ranch of the farm, air – dried, ground and sieved using 6 mm and 2 mm sieves for pot experiments and laboratory analysis.

Total Nitrogen was determined by Kjeldhal method [18]. Organic carbon by wet oxidation method and pH was determined potentiometrically in both water soils – solution ration of 1.2 in 0.01 MKCL by using a glass electrode pH meter. Available phosphorus (P) was determined using the Bray -1 method [19]. Exchangeable cations were extracted with IN ammonium acetate (NH_4OAC) at pH7, sodium (Na), Calcium (Ca) and K were determined using flame photometer while magnesium (Mg) was determined using the ethylenediaminetetraacetic acid (EDTA) titration method [20]. The sample of FYM was analyzed for N and P content. Total N was determined by the regular macro-Kjeldahl procedure. Particle size distribution was determined using the hydrometer method [21]. The sample of FYM was analyzed for N and P content. Total N was determined by the regular macro-Kjeldahl procedure.

2.3 Treatments and Experimental Design

The experimental design was a completely randomized design (CRD) with three replications. The treatments consisted of one source of organic manure (FYM) and two sources of inorganic fertilizers (N and P) each at three levels (N: 0, 75 and 150 $kgNha^{-1}$; P: 0, 40 and 80 $kgPha^{-1}$ and FYM: 0,5 and 10 $tFYMha^{-1}$). The total number of treatments combinations including control was twenty seven (27).

2.4 Screen House Soil Culture Experiment

A pot experiment was carried out using the bulk composite soil samples that were taken from the site. Before sowing 4 kg of the processed soil samples were thoroughly mixed with the N, P, and FYM weighed portions, except the control pots and assigned to 5 L plastic pots (according to treatments) perforated at the bottom for drainage outlets. A total of 81 green house plastic pots were used. Tap water was then added to each pot to 70% of the soil's water holding capacity to bring them to field capacity. The pots were left in the screen house for a period of 10 days to stabilize and decomposition of organic amendments (Kraal) to begin.

2.5 Planting and Agronomic Practices

After ten days, 4 maize (*Zea mays*) seeds of var. Tanzanian maize variety (TMV-1) were sown per pot and later the seedlings were thinned to 2 per pot at two weeks after sowing (WAS). Fertilizer application of P and N was done at planting followed by a split dosage of N at 2 WAS.

Weeding was carried out regularly by hand picking. Visual observation was used to identify any abnormal symptoms. The pots were maintained close to field capacity throughout the experiment. There were two experiments. In both experiments the plants were harvested at the end of four (4) weeks. Maize growth in weeks stages are shown in Flates 1-4.

2.6 Harvesting, Processing and Plant Tissue Analysis

The maize plant was grown in the screen house for 28 days (4 weeks) after which the whole maize plants above the soil level, i.e. two plants in each pot were harvested. The shoot and the root were carefully harvested by cutting the shoot above the soil level and the roots were gently uprooted from the soil. The experiment was repeated and all protocols were the same. The shoots and roots were later oven-dried in the oven at 65°C to constant weight for 2 days for the dry matter determination after which they were ground in micro – hammer stainless steel before taken to the laboratory for chemical analysis. The total N was determined using micro-Kjeldahl digestion and distillation procedures [22] while P was analyzed based on the procedures described by [23].

2.7 Statistical Analysis

The data collected were analyzed using the analysis of variance (ANOVA) and means were separated using the least significant differences (LSD) at 5% level of probability with the [24] software package.

Flate 1. Maize plant at 3 WAS in 2014

Flate 2. Maize plant at 3 WAS in 2015

Flate 3. Maize plant at 4 WAS in 2014

Flate 4. Maize plant at 4 WAS in 2015

3. RESULTS AND DISCUSSION

3.1 Soil Physico – chemical Properties

The results of the soil analysis (before sowing) used for the 2 year trials are shown in Table 1. The soils for both years were loamy sandy with pH water 7.08 and 6.96 which indicate mildly alkaline to slightly acidic in reaction. Organic carbon contents were 0.21 and 0.33%, while total N contents were 0.04 and 0.05% in 2014 and 2015 respectively. The concentrations of exchangeable bases in the soil were higher in 2015 than 2014, while micronutrients Cu, Zn and Mn were higher in 2014 than 2015 and Available phosphorus was higher in 2015 soil. The values of Soil chemical properties were low indicating that the soils were low in fertility. Therefore, there is need to apply fertilizers to the soils in order to boost their productivity. The textural class of the soil for both years was loamy sand.

3.2 Maize Biomass Yield

Maize biomass production (root and shoot DMY) were measured at the end of each green house experiment and are presented in Table 2. In both years application of different types and rates of organic and inorganic fertilizers had significant effects on the root, shoot, and dry matter yield and partitioning of maize (Table 2).

In the 2014 experiment, the highest root, shoot and DM yield were obtained from pots that received T_{27} ($N_{150}P_{80}FYM_{10}$) followed by those pots received T_{24} ($N_{150}P_{40}FYM_{10}$) which was significantly higher than the control and the pots treated with low levels of fertilizers. The highest total DM yields of 13.23 g/pot^{-1} was obtained from the plants treated with N_{150}+P_{40}+FYM_{10} at K gha^{-1} and t/ha^{-1} respectively (Fig. 1).

In the second greenhouse experiment (2015), the root, shoot and total DM yield ranged from 3.59, 11.52 and 15.26 g/pot to 9.23, 24.43 and 30.20 g/pot respectively (Table 2) with root biomass it was higher in pot received T11 followed by T8 and T14 with least value recorded from the control (3.59 g/pot). Highest shoot biomass was obtained from the plant treated with highest rates of all types of fertilizers T27 (24.43 g/pot) then followed by T14 (N75P40FYM5) and T20 (N150PoFYM5) and the control had the lower shoot biomass. In 2015 the total DM yield ranged from 15.26 to 30.20 g/pot with heavier DM produced significantly by the pot received T27 (Fig. 2).

(N150P80FYM10) then followed by T14 (N75P40FYM5) and T20 (N150P0FYM5) while the control produced significantly lower total DM value. The highest DM yield observed in the complementary used of both organic and inorganic source of fertilizers could have resulted from increased absorption of N, P, K [25] which may have contributed to the dry weight of maize.

Table 1. Physico-chemical properties of the soils used before sowing

Soil properties	Measured value	
	2014	2015
pH ($H_2$0)	7.08	6.96
pH (KCL)	5.68	5.16
Org.C (%)	0.21	0.33
Total N (%)	0.04	0.05
Avail. P.mg kg^{-1}	6.68	10.86
CEC cmol kg^{-1}	10.20	12.40
Ex.Ca cmo kg^{-1}	0.37	0.37
Ex. Mg cmol kg^{-1}	0.80	0.82
Ex. K cmol kg^{-1}	0.33	0.74
Ex. Na cmol kg^{-1}	0.20	0.32
BS (%)	16.68	18.15
Ex. Cu mg kg^{-1}	0.28	0.25
Ex. Zn mg kg^{-1}	0.19	0.12
Ex. Fe mg kg^{-1}	21.20	33.77
Ex. Mn mg kg^{-1}	31.50	27.50
Clay (%)	12.12	14.12
Silt (%)	3.64	3.68
Sand (%)	84.24	80.24
Text. Class	LS	LS

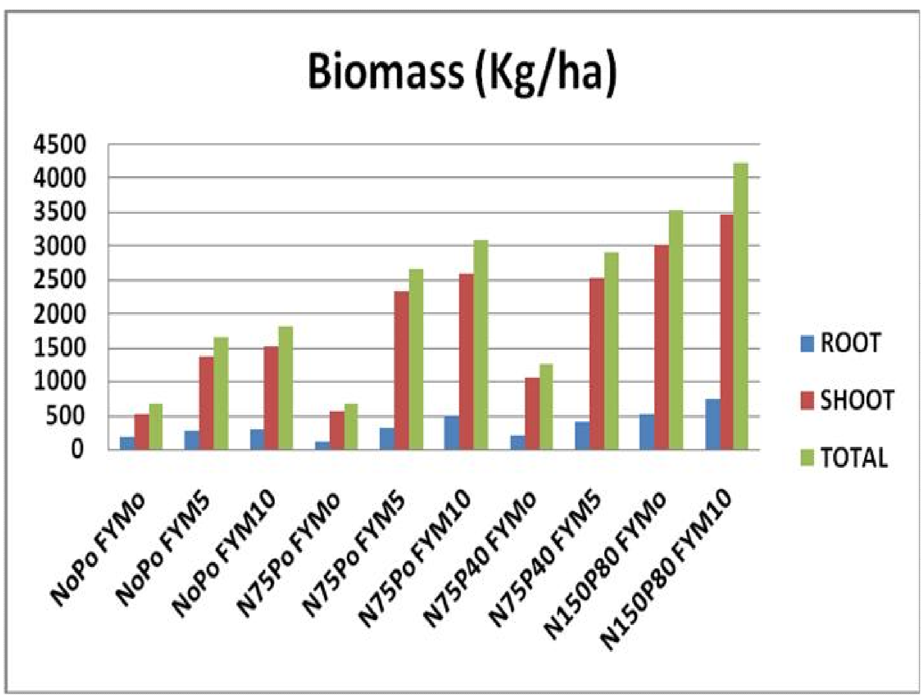

Fig. 1. Biomass yield (kg/ha) of some treatments in 2014

Table 2. Effect of rates of organic and inorganic fertilizers on Dry matter Yield at the end of the 2 experiments

S/NO	Treatments	2014			2015		
		Dry matter yield (g Pot^{-1})			Dry matter yield (g Pot^{-1})		
		Root	Shoot	Total DMY	Root	Shoot	Total DMY
1	N_oP_o FYM_o	0.536	1.59	2.14	3.59	11.52	15.26
2	N_oP_o FYM_5	0.878	4.29	5.18	4.51	14.33	18.85
3	N_oP_o FYM_{10}	0.909	4.79*	5.71	4.17	13.42	18.09
4	N_oP_{40} FYM_o	0.502	2.70	3.26	5.32	18.35	23.67
5	N_oP_{40} FYM_5	0.813	3.58	4.41	6.22	19.04	25.25
6	N_oP_{40} FYM_{10}	1.007	4.15	5.16	6.31	17.10	23.41
7	N_oP_{80} FYM_o	0.798	5.59*	6.34	6.09	18.87	24.90
8	N_oP_{80} FYM_5	0.792	4.09	4.89	7.74	19.99	27.72
9	N_oP_{80} FYM_{10}	0.976	3.99	4.97	6.01	18.70	24.71
10	$N_{75}P_o$ FYM_o	0.234	1.78	2.11	3.43	12.74	16.17
11	$N_{75}P_o$ FYM_5	0.994	7.32*	8.32	9.28	21.28	30.56
12	$N_{75}P_o$ FYM_{10}	1.517	8.14*	9.14	6.81	21.28	28.09
13	$N_{75}P_{40}$ FYM_o	0.615	3.30	4.83	6.67	20.34	27.01
14	$N_{75}P_{40}$ FYM_5	1.246	7.30*	9.16	7.50	22.19	29.68
15	$N_{75}P_{40}$ FYM_{10}	1.246	7.86*	9.11	6.31	18.92	25.23
16	$N_{75}P_{80}$ FYM_o	1.214	6.60*	7.82	6.09	19.73	25.82
17	$N_{75}P_{80}$ FYM_5	1.889	8.58*	10.47	6.25	21.13	27.38
18	$N_{75}P_{80}$ FYM_{10}	1.549	8.93*	10.49	5.61	19.75	25.37
19	$N_{150}P_o$ FYM_o	0.336	1.47	2.95	3.91	12.95	16.86
20	$N_{150}P_o$ FYM_5	1.301	7.54*	8.85	6.71	22.09	28.80
21	$N_{150}P_o$ FYM_{10}	1.428	8.23*	9.66	6.70	20.70	27.44
22	$N_{150}P_{40}$ FYM_o	1.209	8.02*	8.96	5.99	20.97	26.56
23	$N_{150}P_{40}$ FYM_5	1.418	7.94*	9.36	6.01	20.48	26.49
24	$N_{150}P_{40}$ FYM_{10}	1.647	9.60*	11.26	5.72	20.65	26.38
25	$N_{150}P_{80}$ FYM_o	1.594	9.46*	11.12	6.37	21.14	27.51
26	$N_{150}P_{80}$ FYM_5	1.667	9.49*	11.16	5.81	21.22	27.03
27	$N_{150}P_{80}$ FYM_{10}	2.328	10.89*	13.23	5.77	2.434	30.20
LSD (0.05)		**0.9227**	**2.827**	**4.103**	**2.443**	**4.700**	**6.094**
CV (%)		**39.40**	**22.10**	**15.12**	**20.0**	**12.0**	**11.9**

As presented in Figs. 1 and 2 biomass production increases with an increase FYM rate in both seasons this could be due to the fact that addition of suitable organic manure in the soil improves the soil structure and hence, encourage the plant good root and lead to higher yields.

Ahmed et al. [26] reported higher grain yields of maize with fertilizers. Also Akintunde et al. [27], reported higher nitrogen content facilities better photosynthetic activity and higher partitioning of dry matter to ears. Apart from providing organic N, the organic fertilizer could have supplied other essential nutrient elements required by the plants that may be lacking in the soils. Furthermore, the improved soil physical conditions usually associated with organic fertilizer treatments could have supported higher crop performance and grain yield where combined treatments were applied [28,29].

3.3 Effects of Treatments on Nutrient Uptake by Maize Plants

The effect of organic and inorganic based fertilizers on the uptake of N and P by maize is shown in Table 3. Plants treated with N_{150} + P_{80} + FYM_5 and N_{75} +P_{80}+FYM_5 were significantly higher in nitrogen and phosphorus uptake in 2014 while the lowest uptake values (1.04 and 0.08 %) were observed in treatments T_5 (N_0 + P_{40} + FYM_5) and control treatment respectively (Fig. 3-5).

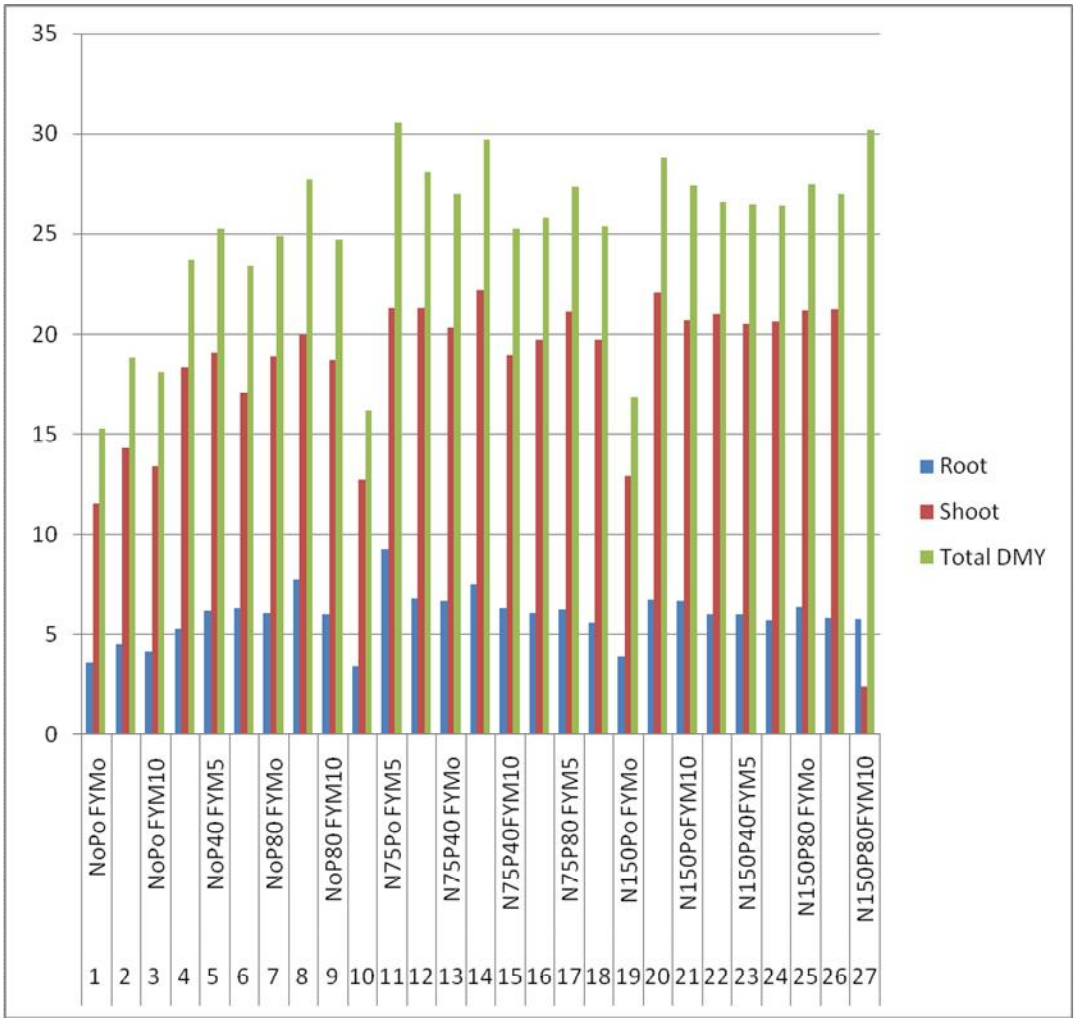

Fig. 2. Biomass yield (g/pot) of all treatments in 2015

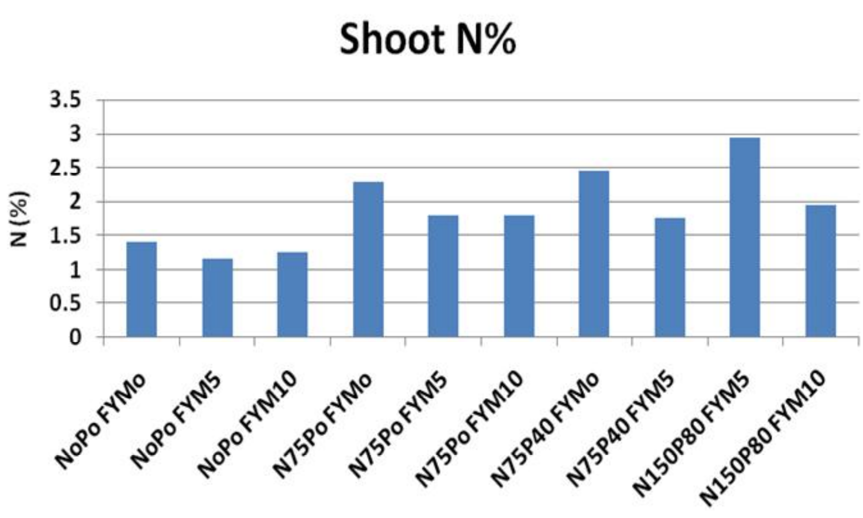

Fig. 3. Shoot N uptake of some selected treatments in 2014

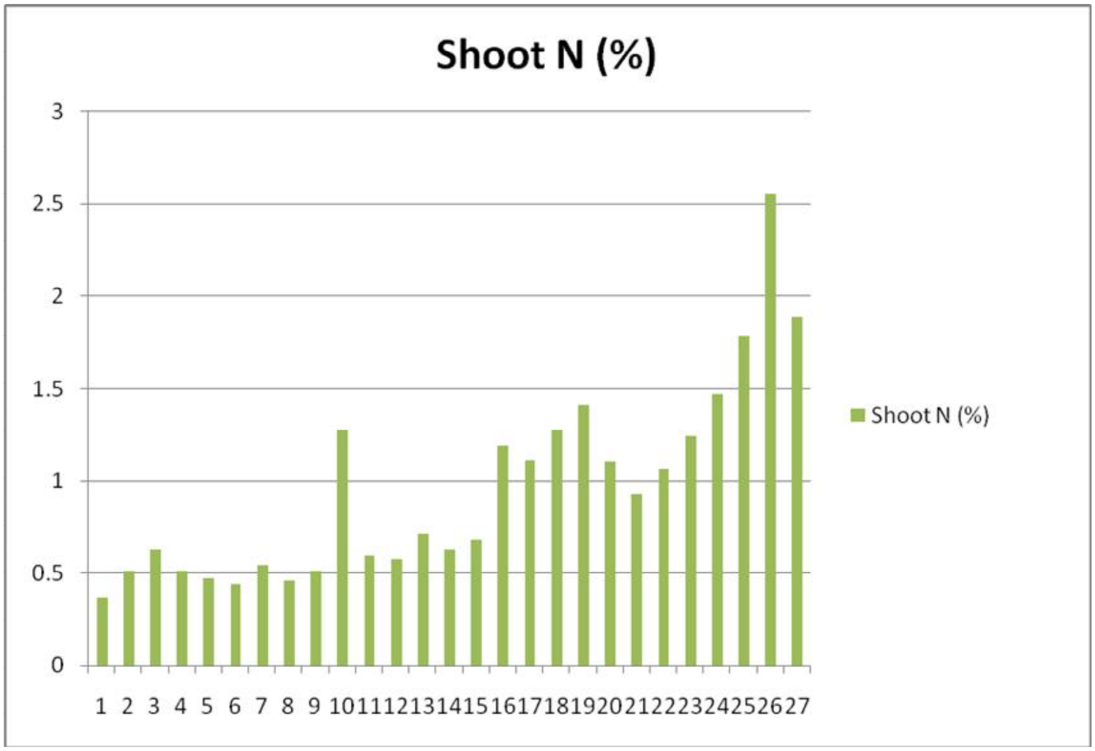

Fig. 4. Nitrogen (N) uptake of shoot as influenced by treatments in 2015

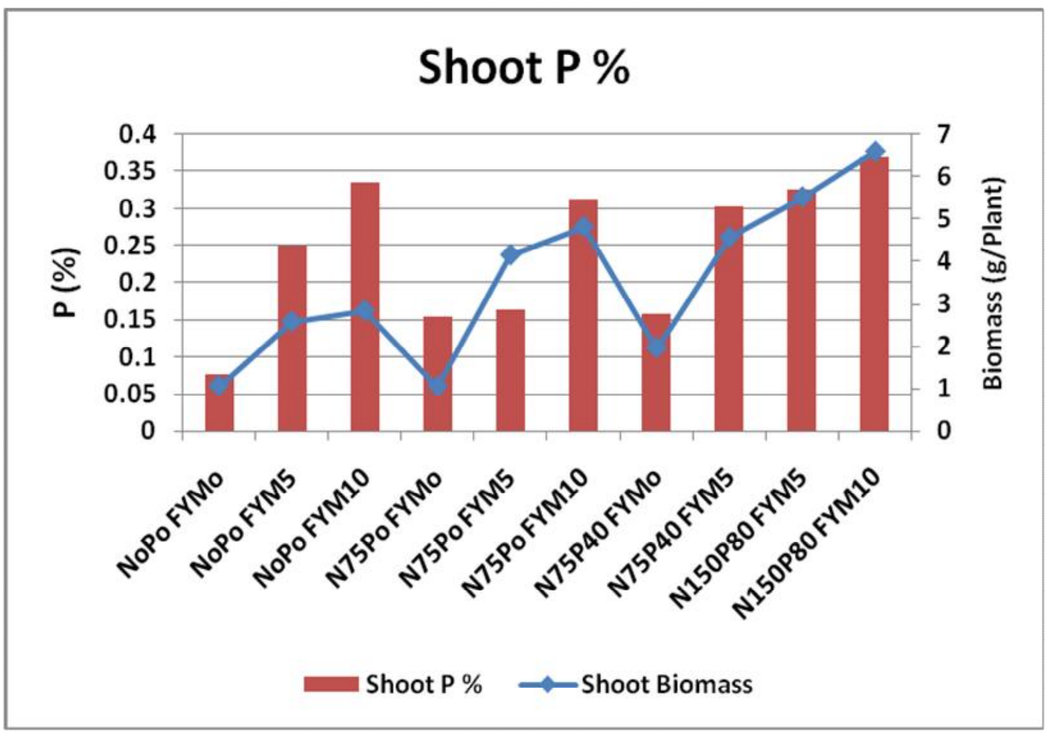

Fig. 5. Comparison of shoot P uptake and biomass yield of selected treatments in 2014

Table 3. Treatments effect on N and P uptakes on maize plant in the 2 green house experiments

S/NO	Treatments	2014		2015	
		Shoot N (%)	Shoot P (%)	Shoot N (%)	Shoot P (%)
1	N_oP_o FYM_o	1.400	0.077	0.367	0.050
2	N_oP_o FYM_5	1.155	0.249	0.507	0.091
3	N_oP_o FYM_{10}	1.260	0.336	0.630	0.140
4	N_oP_{40} FYM_o	1.260	0.250	0.507	0.095
5	N_oP_{40} FYM_5	1.032	0.201	0.472	0.147
6	N_oP_{40} FYM_{10}	1.155	0.308	0.437	0.174
7	N_oP_{80} FYM_o	1.068	0.206	0.542	0.150
8	N_oP_{80} FYM_5	1.260	0.242	0.455	0.136
9	N_oP_{80} FYM_{10}	1.225	0.369	0.507	0.119
10	$N_{75}P_o$ FYM_o	2.292	0.155	1.277	0.037
11	$N_{75}P_o$ FYM_5	1.802	0.164	0.595	0.057
12	$N_{75}P_o$ FYM_{10}	1.802	0.312	0.577	0.107
13	$N_{75}P_{40}$ FYM_o	2.450	0.158	0.712	0.053
14	$N_{75}P_{40}$ FYM_5	1.750	0.302	0.630	0.093
15	$N_{75}P_{40}$ FYM_{10}	1.907	0.337	0.682	0.126
16	$N_{75}P_{80}$ FYM_o	2.188	0.290	1.190	0.101
17	$N_{75}P_{80}$ FYM_5	1.660	0.386	1.108	0.167
18	$N_{75}P_{80}$ FYM_{10}	1.575	0.316	1.272	0.177
19	$N_{150}P_o$ FYM_o	2.188	0.164	1.412	0.042
20	$N_{150}P_o$ FYM_5	2.555	0.200	1.102	0.054
21	$N_{150}P_o$ FYM_{10}	2.345	0.306	0.928	0.133
22	$N_{150}P_{40}$ FYM_o	2.485	0.156	1.067	0.110
23	$N_{150}P_{40}$ FYM_5	2.363	0.309	1.242	0.108
24	$N_{150}P_{40}$ FYM_{10}	2.205	0.296	1.470	0.212
25	$N_{150}P_{80}$ FYM_o	2.083	0.220	1.785	0.222
26	$N_{150}P_{80}$ FYM_5	2.940	0.325	2.555	0.295
27	$N_{150}P_{80}$ FYM_{10}	1.943	0.370	1.890	0.308
LSD (0.05)		**0.4906**	**0.2001**	**0.7974**	**0.4285**
CV (%)		**13.100**	**37.500**	**40.4**	**40.4**

In 2015 screen house experiments, with exceptions of Treatments $_{19,\ 20,\ 10,\ 11}$ and $_{13,}$ Fertilizers treatments significantly (P>0.05) increased N and P uptake above the control. N uptake ranged from 1.032 and 0.36 7% to 2.940 and 2.555% in the two experiments. N uptake followed the order of fertilizer application. While P uptake ranged from 0.077 and 0.037% to 0.370 and 0.308% in 2014 and 2015 respectively.

The recorded highest nitrogen and phosphorus uptake in 2014 from combination of fertilizers treatment are similar to the findings of [30] who reported that application of fertilizers at different rates above the control resulted in highest nitrogen, phosphorus and potassium uptake by white yam. This result indicated that an integrated system of soil fertility management (ISFM) that the combine organic sources of nutrients and inorganic fertilizer are sustainable in the study area and this agrees with findings of [31-35].

4. CONCLUSION AND RECOMMENDATIONS

Soil analysis before sowing indicated that the major nutrients (N and P) were found at low levels. In addition, application of FYM showed that considerable amounts of N and P nutrients were supplied by FYM. The result indicated that integrated FYM application revealed a significant influence (P<0.05) on growth, dry matter yield and nutrient uptakes (N and P) of maize. However, it was statistically at par with inorganic fertilizer application. The low contents of the soil nutrients made the soil suitable for this study (fertilizer trial). From the results of the study, it could be concluded that at both seasons, biomass production and nutrients uptake (N and P) in maize plant were significantly higher with application of combined organic and inorganic fertilizers. Yield from application of 150 kg N^{-1}, 80 kg P^{-1} plus FYM 10 t/ha, and 75 kgN^{-1}, 40 kg P^{-1} plus FYM 5 t/ha were the best compared with 75 kgN^{-1} ,0 kg P^{-1} plus FYM 0 t/ha treatment and the control. It is therefore recommended that application of organic together with inorganic fertilizers at moderate rates (75 kgN^{-1}, 40 kg P^{-1} plus FYM 5 t/ha) would be cost effective and sufficient for maize dry matter yield and nutrient content (N and P) in the test soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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