GROWTH AND UPTAKE IN MAIZE AS INFLUENCED BY NPK FERTILIZER IN GREEN HOUSE EXPERIMENT

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Abstract

It is important to explore varying supply of nitrogen (N), phosphorus (P) and potassium (K) for sustainable production of maize in green house environment. This necessitated the study to determine the effect of these nutrients on growth and nutrient uptake in maize. In this study, three separated pot experiments were conducted in a complete randomized block design with three replications. Treatments consisted of N,P, K as 0, 30, 60, 90, 120, 150, 180 kg N ha^{-1}, 0, 30, 60, 90, 120, 150, 180 kg P ha^{-1} and 0, 30, 60, 90, 120, 150, 180 kg K ha^{-1} for the first, second and third experiment, respectively. Maize seeds of variety Swam 1 were sown in pots and N, P and K fertilizer treatments were applied two weeks after planting (WAP). Data of growth parameters of maize were collected fortnightly on plant height, stem girth, number of leaves, leaf length, width and area for 8 weeks; dry matter yield and uptake were determined at the end of the experiments. The result showed that application of N at 120 kg ha^{-1} significantly increased plant height (66%), leaf number (96%) and dry matter accumulation in maize, whereas leaf area and P concentration (157%) significantly increased with 150 kg N ha^{-1}. Significant increases in plant height (26%), girth, leaf area, leaf number (54%), shoot dry weight and N concentration were recorded with 60 kg P ha^{-1}. However, the application of K at 180 kg ha^{-1} increased the plant height (16%), girth (61%), leaf number, leaf area (24%), leaf length (10 %), leaf width (10%), concentration and uptake of N and K. It was concluded that maize growth and uptake was greatly influenced by N,P,K applications at 120 to 150 kg N ha^{-1}, 60 kg P ha^{-1} and 180 kg K ha^{-1}.

Keywords: Growth parameters, maize, N, P, K fertilizer, nutrient concentration, and nutrient uptake

1. INTRODUCTION

The demand for food is increasing because of increasing population; the problem of food scarcity is increasing. Maize (*Zea mays L.*) as an important crop in Nigeria is a better option to mitigate the threat of food shortage, as it is a high yielding crop that provides food and forage. It is Nigeria's third most important cereal crop after sorghum and millet [1]. However, a major reason for low yields in maize production is the poor organic matter and available nutrients of most soils in the humid tropics as a result of continuous cropping, and consequently to reduction in sustainable soil productivity [2]. Long term cultivation has further depleted the organic-matter content and fertility status of the soils [3]. This phenomenon is amidst other constraints like drought, poor crop management, diseases and pest. Efforts aimed at obtaining high yield of maize would necessitate the augmentation of the nutrient status of the soil to meet the crop's requirements for optimum productivity and also maintain the soil fertility [4]. The nutrient status of the soil may be achieved by boosting the soil nutrient content with the use of inorganic fertilizers such as NPK.

The maize crop requires an adequate supply of nutrients particularly nitrogen, phosphorus and potassium for optimum growth and yield [4]. Nitrogen, phosphorus, potassium, and other nutrient elements play great physiological importance in formation of chlorophyll, nucleotides, phosphotides and alkaloid as well as in many enzymes, hormones and vitamins for optimum grain yield [4]. Nitrogen deficiency could exert a particularly marked effect on maize crop yield as the plant would remain small and rapidly turn yellow if sufficient nitrogen is not available for the construction of protein and chlorophyll [6].

Phosphorus is also essential for maize for growth, being an essential component of nucleic acid, phosphorylated sugar, lipids and protein plays a vital role in grain production [7]. It is important because it forms phosphate bonds with adenine, guanine and uridine, which act as carriers for biological process. In plants, phosphorus is a common component of organic compounds. It was noticed that nitrogen and phosphorus application increased the green fodder yield of maize while Phosphorus application enhanced the crop to reach 50% tasseling and silking earlier [8, 9].

Potassium is one of the important macronutrients next to N and P. This nutrient is one of the essential nutrients whose deficiency affects the crop growth and production. Potassium is an activator of many plant enzymes. Potassium has important functions in plant water relations where it regulates ionic balances within cells. Potassium regulates the leaf stomata opening and subsequently the rate of transpiration and gas exchange. Plants also need K for the formation of sugars and starches, for the synthesis of proteins and cell division. It increases the oil content of pistachios and contributes to its cold hardiness [10]. Under K deficient conditions photosynthesis is depressed as a consequence of sucrose accumulation in the leaves and its effect on gene expression [11]. Maize is the most important cereal in the world after wheat, its nutritional values cannot be over emphasized and the rate at which it is being consumed and used industrially is increasing daily thereby making its production throughout the year a major concern. It is therefore pertinent to explore varying supply of nutrients particularly nitrogen, phosphorus and potassium needed for good growth and high yield of maize for sustainable production in screen house environment. This necessitated the study to determine the effect of nitrogen, phosphorus and potassium on growth, dry matter yield and nutrient uptake of maize.

2. MATERIALS AND METHODS

2.1 SOIL COLLECTION AND SOIL ANALYSIS

The top soil (0-20 cm) was collected from the University farms, Federal university of Agriculture Abeokuta, Ogun state. The soil was air dried, and sieved through 2mm mesh sieve. Sub sample of the soil were collected and analyzed for the following properties: Soil pH was estimated in 1:2 (soil: water) using glass electrode pH meter. Particle size was determined according to hydrometer method. Soil was digested and total nitrogen content was analyzed using kjeldahl method. Available phosphorus was determined with Bray-1 and available P by a modified single solution method. Exchangeable cations were extracted with 1N ammonium acetate, Na and K in the extract were determined by flame photometry, and Ca and Mg were determined by atomic absorption spectrophotometer.

2.2 EXPERIMENTAL DESIGN

The experiments were conducted in completely randomized design with three replications. Treatments for experiment 1 included varying levels of nitrogen (0, 30, 60, 90, 120, 150 and 180 kg K ha^{-1}) and constant levels of potassium and phosphorus at 90 kg N ha^{-1} and 15 kg P ha^{-1}, respectively. Treatments for experiment 2 included varying levels of phosphorus (0, 30, 60, 90, 120, 150 and 180 kg K ha^{-1}) and constant levels of nitrogen and potassium at 90 kg N ha^{-1} and 15 kg P ha^{-1}, respectively . Treatments for experiment 3 were varying levels of potassium (0, 30, 60, 90, 120, 150 and 180 kg K ha^{-1}) and constant levels of nitrogen and phosphorus at 90 kg N ha^{-1} and 15 kg P ha^{-1}, respectively.

2.3 **SCREEN HOUSE EXPERIMENT**

Five kilograms of soil was dispensed into each experimental pot with each treatment applied separately into the pot. The soil in the pots was watered and maize seeds (Swam 1) were sown at 3 seeds per pot. The thinning was done to maintain to one plant per pot after two weeks. The plants were watered in the screen house for eight weeks i.e. at tassel stage. Growthdata including plant height, stem girth, leaf length, leaf width and number of leaves were recorded forth nightly. The leaf area was also measured. Maize plants were harvested at the end of the 8th week. The root and shoot components were separated, cleaned, placed in to neatly labeled envelopes and dried to constant weight. The oven dried shoots were milled and analyzed for potassium and nitrogen concentration. Similar procedure as carried out in experiment 1 was done simultaneously in experiments two and three only that the target nutrient analyzed were different, phosphorus and nitrogen in experiment 2, and potassium and nitrogen in experiment 3.

2.4 STATISTICAL ANALYSIS

Data collected were analyzed for their variance by using the software package SAS (1999). Mean comparison among the treatments was performed using LSD at 5 % level of probability.

3. RESULTS

3.1 SOIL CHARACTERISTICS

The soil had a pH of 6.20, organic carbon, total nitrogen and available P of 0.65 % and 0.04 % and 3.01mgkg^{-1} respectively. It contained 4.41 cmol$_{(+)}$kg^{-1}, 1.16 cmol$_{(+)}$kg^{-1}, 0.64 cmol$_{(+)}$kg^{-1} and 0.24 cmol$_{(+)}$kg^{-1} of calcium, magnesium, sodium and potassium, respectively (Table 1).

3.2 EFFECT OF N, P AND K APPLICATION ON PLANT HEIGHT AND STEM GIRTH OF MAIZE

Table 2 shows that application of nitrogen did not lead to significant increase in plant height at 2 and 6 WAP (weeks after planting), although the tallest plants were recorded with nitrogen application at rates of 150 kg ha^{-1} and 120 kg ha^{-1}. At 4 WAP, maize height was significant with a highest increase of 66 % above the control with 150kg N ha^{-1}. There was no significant difference among the control, 30 kg and 180 kg N at 4 WAP. Application of 120 kg N ha^{-1} led to increase in maize height at 8 WAP relative to the control and other application rates. The application of 120 kg N ha^{-1} significantly increased maize height by 134 % when compared to the application of 30 kg N ha^{-1}. Maize stem girth was narrowest with N rate of 30 kg ha^{-1}. There was no significant difference among the control, 30 kg N ha^{-1} and 180kg N ha^{-1} in terms of stem girth at 2 WAP. However, at 4 WAP stem girth was wider with 150 kg N ha^{-1} compared to the control although significant differences were not observed with other application rates. Stem girth was similar for all the treatments at 6 and 8 WAP despite the fact that the widest girth at 6 and 8 WAP were recorded with application of 90 kg N ha^{-1} and 120 kg N ha^{-1}.

All the application rates of phosphorus with the exception of 30 kg ha^{-1} and 120 kg ha^{-1} resulted in increased maize height at 2 WAP, although not significant with respect to the control. Similar responses were reported at 4 WAP. However, the application rates of 30 kg P ha^{-1}, 60 kg P ha^{-1} and 120 kg P ha^{-1} had similar effect on maize height despite the fact that a highest significant increase of 26 % was recorded from the application of 60 kg P ha^{-1} relative to 30 kg P ha^{-1}. The height of maize was similar for the control and P application rates at 6 WAP. A significant reduction in maize height was noted in control, 30 kg P ha^{-1} and 150 kg P ha^{-1} compared to 60 kg P ha^{-1} at 8 WAP. All P rates except 60 kg P ha^{-1} had similar effect on height of maize at 8 WAP. There was no significant difference in stem girth at 2 WAP. Stem girth increased with increasing P up to 60 kg ha^{-1} where as application rate below 60 kg ha^{-1} led to significant reduction in stem girth at 4 WAP. The application of 60 kg P ha^{-1} led to significant increase in stem girth when compared to other rates except 120 kg P ha^{-1} and 150 kg P ha^{-1} but the highest significant increase of 28 % was recorded. Similar response was observed at 6 WAP only that widest stem girth produced with 60 kg P ha^{-1} did not significantly differ from P rates above 60 kg ha^{-1}. At 8 WAP all P application rates did not differ from each other although significant increases in stem girth were produced by 120 kg P ha^{-1}, 150 kg P ha^{-1} and 180 kg P ha^{-1}.

The application of 60 kg K ha^{-1} produced significantly taller plants than the control although there was no significant difference in the height of maize with the application of potassium at the varying rates at 2 WAP (Table 2). At 4 WAP significant increase in height was noted with K at 180 kg ha^{-1} even though this did not differ from 120 kg ha^{-1} and 150 kg ha^{-1}. There was no significant difference in maize height at 6 WAP but highest increase was noted with 60 kg K ha^{-1} and 90 kg K ha^{-1}. All the potassium application rates except 180 kg K ha^{-1} and the control stimulated similar maize height at 8 WAP. However, application rate of 180 kg ha^{-1} significantly increased the plant height to 16 % of the control. The stem girth of maize was higher with the application of potassium; significant difference was not recorded at 2 WAP. Applying potassium at rate of 180 kg K ha^{-1} widened the stem of maize at 2 WAP in comparison to the control by 61 %. The application of K at 30 kg K ha^{-1}, 60 kg K ha^{-1}, 90 kg K ha^{-1} led to similar response in stem girth when compared to the control at 2 WAP, however, stem girth of maize was observed to increase with increasing application rates of potassium. At 6 and 8 WAP, there was no significant difference in stem girth with the application of K at 30 kg ha^{-1}. However maize stem widened with increasing potassium rates at 6 and 8WAP. The application of 180 kg K ha^{-1} produced the widest stem girth relative to the application of other rates at 6 and

8WAP. Application of 90 kg K ha^{-1} and 120 kg K ha^{-1} had similar effect on stem girth while 150 kg K ha^{-1} produced a wider stem girth than 120 kg K ha^{-1} at 6 WAP.

3.3 EFFECT OF N, P AND K APPLICATION ON LEAF LENGTH AND WIDTH OF MAIZE

Leaf length of maize significantly increased with the application of nitrogen fertilizer of 120 kg N ha^{-1} at 2 WAP in comparison with the control while the other application rates did not differ considerably (Table 3). At 4 and 6 WAP, no significant increase was observed in leaf length though application of N fertilizer increased leaf length when compared to the control. The highest increase in leaf length was recorded with 120 kg N and 90 kg N ha^{-1} at 4 and 6WAP respectively. Significant increase in leaf length was recorded with the application 150 kg N ha^{-1} relative to control at 8 WAP. With the exception of the observation made at 4WAP, leaf width did not significantly differ following the application of nitrogen fertilizer as shown in Table 3. At 4 WAP the highest significant increase was brought about by N application rate of 120 kg N ha^{-1} and 150 kg N ha^{-1} in relative to the control.

There was increase in leaf length of maize as the weeks progressed for all phosphorus treatments. No significant effect was recorded among the treatments from 2-8 WAP despite the highest leaf length from the application of 60 kg P ha^{-1} for all the weeks and the lowest was recorded with P rate of 30 kg ha^{-1} for all weeks except 2 WAP. There was no significant difference in leaf width during the period of observation though application rate of 90 kg P ha^{-1} produced the widest leaf at 2 and 8 WAP.

Leaf length of maize was significantly longer by 10 % with the application of 60 kg K ha^{-1} relative to the control (Table 3). However, leaf length was similar for all the application rates of potassium at 2 WAP. Significant increase was only noted with the application of 180 kg K ha^{-1} in relation to other application rates and the control at 4 WAP. All application rates of potassium resulted in significantly longer leaves than the control at 6 WAP. The highest increase in leaf length was recorded following the application of 150 kg K ha^{-1} even though it did not significantly differ from that of 180 kg K ha^{-1} at

6 WAP. Increasing potassium rates also increased the leaf length at 8 WAP wherein the longest leaf was recorded under the 180 kg K ha^{-1} treatment. All potassium rates produced significantly longer leaves than the control, with the highest increase in leaf length from the application rate of 180 kg K ha^{-1} at 8 WAP. Maize leaf width was similar for the control, 30 kg K ha^{-1} and 60 kg K ha^{-1}. Application of 180 kg K ha^{-1} significantly increased the leaf width when compared with 90 kg K ha^{-1}, 120 kg K ha^{-1} and 150 kg K ha^{-1} at 2 WAP. Application rates of 60 kg ha^{-1} and 180 kg K ha^{-1} resulted in similar leaf width, which was significantly higher than the control and the other application rates at 4 WAP. Significantly, wider leaves were observed with the application of 150 kg K ha^{-1} and 180 kg K ha^{-1} relative to the control even though 180 kg K ha^{-1} did not differ from the other application rates except for 30 kg K ha^{-1} at 6WAP and 30 and 60 kg K ha^{-1} at 8 WAP.

3.4 EFFECT OF N, P AND K APPLICATION ON LEAF NUMBER AND LEAF AREA OF MAIZE

The leaf area of maize increased with N application rate of 120 kg ha^{-1} and a decrease was recorded for the control (Table 4), no significant differences were observed at 2 and 6 WAP. At 4 WAP, N application rate of 120 kg ha^{-1} increased the leaf area by 96 %. However, at 8 WAP there was no significant difference in leaf area with application rate of 30 kg N ha^{-1} relative to the control, significant increases were only observed with application rate of 150 kg N ha^{-1} when compared to the control. Application of N fertilizer did not result in significant increases in number of leaves at 2, 6 and 8 WAP although the least number of leaves were recorded with application rates of 60 kg N ha^{-1}, 180 kg N ha^{-1} and 30 kg N ha^{-1} at 2, 6 and 8 WAP respectively. At 4 WAP, application of nitrogen rates of 90 kg ha^{-1}, 120 kg ha^{-1} and 150 kg N ha^{-1} significantly increased number of leaves than the control.

The application of P fertilizer increased number of leaves from 2 to 8 WAP. At 2 WAP, all P application rates with the exception of 30 kg ha^{-1} and 150 kg ha^{-1} resulted in an increase in the number of leaves. Similar response was observed at 4 WAP wherein all P rates except 30 kg ha^{-1} and 120 kg ha^{-1} resulted in similar number of leaves. When application rate of 90 kg P ha^{-1} was compared to 30 kg P ha^{-1} at 4 WAP, a highest increase of 54 % was recorded. The number of leaves significantly increased with the application of all P fertilizer rates with the exception of 30 kg ha^{-1} at 6 WAP. Application rate of 60 kg ha^{-1} P significantly increased the number of leaves relative to the control and 30 kg P ha^{-1}. Leaf area of maize was observed to increase with increasing weeks though no significant effect was recorded with the application of all P rates during the period of observation.

There was no significant difference in the number of leaves in maize (Table 4) at 2 WAP though similar number of leaves was recorded with the control and all potassium rates except 60 kg K ha^{-1} . At 4 WAP, number of leaves did not differ for the control, 30 kg K ha^{-1}, 90 kg K ha^{-1} and 180 kg K ha^{-1} while significant decreases were observed with application rates of 60 kg K ha^{-1} and 150 kg K ha^{-1}. The application of 180 kg K ha^{-1} and 150 kg K ha^{-1} resulted in the highest number of leaves at 6 WAP. However, number of leaves was significantly lesser with the control and potassium rates of 30 – 90 kg K ha^{-1}. Leaf area was similar for all potassium rates; moreover, the application of potassium fertilizer increased the area of leaf significantly above the control with the highest leaf area produced with 90 kg K ha^{-1} at 2 WAP. At 4 WAP, application rate of 180 kg K ha^{-1} resulted in the bigger leaf area at 4 WAP though this did not differ from 60 kg K ha^{-1} K and 90 kg Kha^{-1}. The control and application rates of 30 kg K ha^{-1}, 90 kg K ha^{-1}, 120 kg K ha^{-1} and 150 kg K ha^{-1} significantly decreased the leaf area when compared to 180 kg K at 4 WAP. Maize leaf area was significantly increased at 6 WAP with the application of all potassium rates with the exception of 30 kg K ha^{-1}. At 8 WAP maize leaf area was observed to increase with increasing potassium rates and significantly lower area was observed in the control. Highest leaf area was produced with K rate of 180 kg ha^{-1}.

3.5 EFFECT OF N, P and K APPLICATION ON DRY MATTER, NUTRIENT CONCENTRATION AND UPTAKE BY MAIZE

Shoot dry weight and root dry weight increased with the application of nitrogen fertilizer though increases were not significant as shown in Table 5. Dry weight was heaviest with N application rate of 120 kg ha^{-1}. Nitrogen concentration and uptake did not significantly differ for all the rates and even the control despite the fact that N uptake was observed to increase with increasing rate up to 150 kg ha^{-1}. A highest increase in K concentration of 157 % more than the control was observed with application rate of 150 kg N ha^{-1}.

The application of phosphorus fertilizer had significant effect on the shoot dry weight. All phosphorus rates except 30 kg P ha^{-1} resulted in significant increases in shoot dry weight relative to the control. Shoot dry weight was significantly decreased with P application rate of 30 kg ha $^{-1}$ relative to the control. Root dry weight did not significantly increase with the application of all P rates. Phosphorus concentration was lowest in maize grown on control soil while the highest was observed with 60 kg P ha^{-1} even though increase was not significant. Nitrogen concentration in plant was highest and only significant with P rate of 60 kg P ha^{-1} when compared to the control, N concentration was also observed to decrease with increasing P application rates above 30 kg P ha^{-1}. Phosphorus and nitrogen uptake were not significantly affected with application of all P rates although the greatest uptake of these nutrients was recorded with 60 kg P ha^{-1}.

Shoot dry weight was significantly increased with potassium rate of 180 kg ha^{-1} relative to the control and K application rates below 90 kg ha^{-1}. No significant difference was observed in root dry weight even though the heaviest was produced with 180 kg K ha^{-1}. The application of potassium significantly increased N concentration although all application rates with the exception of 60 kg ha^{-1} resulted in similar N concentration. Potassium concentration significantly increased with the 180 kg K ha^{-1} when compared to other application rates and control. It was also observed that K concentration increased with increasing K application. Potassium application above 60 kg ha^{-1} increased K uptake significantly more than the control.

4. DISCUSSION

The soil used for the study was slightly acidic. It was low in organic carbon, available phosphorus, calcium, sodium and potassium. Its total nitrogen was very low, while magnesium was medium. It was a sandy soil with poor nutrient status: hence was expected to respond well to fertilizer application.

The result obtained from this study showed that different levels of nitrogen significantly improved maize growth, dry matter yield and nutrient uptake. It was reported [8] that nitrogen and phosphorus application increased the green fodder yield of maize. Growth was mostly supported with application levels of 120 kg N ha^{-1}. This was evident in the plant height, number of leaves and dry matter yield. These results were similar to the findings of [13] who reported that increasing supply of N improved growth of corn. It was also observed that number of leaves per plant tended to increase as nitrogen application rate increased. Maximum numbers of leaves were produced with the application of 120 kg N ha^{-1}. This could be attributed to the fact that nitrogen promoted vegetative growth in maize. Some researchers [e.g., 14] have reported similar results. Leaf area was also affected by levels of nitrogen application. There was increase in leaf area with increased rate of nitrogen application. The application of 150 kg N ha^{-1} resulted in significantly higher leaf area and P concentration in the plant. This result is in agreement with the findings of [15] who reported that higher rates of nitrogen promote leaf area during vegetative development and help to maintain functional leaf area during the growth period. The significant increase in phosphorus concentration with increased N fertilization could be attributed to the fact that nitrogen plays a major role in the formation of nucleotides and phosphatides thereby increasing the concentration of phosphorus in the plant. This is in agreement with the findings of [16] who reported that increased P accumulation in leaves and kernels of two corn cultivars were due to urea application.

Phosphorus fertilization led to increase in maize growthparameters, dry weight and nitrogen concentration. It was revealed [17] that application of phosphorous fertilizer significantly increased plant height. However, among all P application rates, application of 60 kg P ha^{-1} significantly increased plant height, stem girth, leaf area and leaf number than the control. The significant increase in the above-mentioned parameters could be because phosphorus is a major component of

Adenosine triphosphate involved in respiration process thus increasing the leaf area and rate of photosynthesis. Furthermore, application at 60 kg P ha^{-1} could have initiated the actions of microorganisms directly involved in nutrient mineralization and availability thereby increasing plant growth (plant height, stem girth, leaf area and leaf number). This supports the findings of [18] that solubility of insoluble phosphates by phosphorus solubilizing microorganisms and the secretion of growth enhancers such as auxin, gibberellins and cytokinin by such organisms increased the root growth and consequently the crop growth. The significant increase in shoot dry weight with the application of 60 kg P ha^{-1} is in conformity with [19] who reported that dry matter yield increased with increasing P up to 60 kg P ha^{-1}.

The significant increases in plant height, stem girth and leaf length of maize with the application of 180 kg K ha $^{-1}$ signifies that increased level of K led to higher plant height and girth. This could be attributed to the fact that potassium is responsible for maintaining proper water potential, turgid pressure and promoting cell elongation in the leaves. This supports the findings of [20], who reported that one of the more visually obvious consequences on plant growth from insufficient levels of plant potassium is a reduction in plant stature. Maize leaf area was significantly increased with the application of 180 kg K ha^{-1}, potassium rate below 180 kg ha $^{-1}$ did not lead to significant increase. Insufficient K levels reduced leaf area expansion leading to reduced leaf size in maize [21]. The increased concentration and uptake of potassium with increasing potassium in soil could be because soil responded well to K fertilization thereby increasing the rate of K uptake from the soil. This is in conformity with the findings of [22] that potassium concentration increased because of K fertilization. Potassium influences the uptake and transport of nitrate within the plant [23]. This could have been the reason for the increased concentration and uptake of nitrogen with the application of 180 kg K ha^{-1}. The trans-port of amino acids was reported to be enhanced by higher K levels, especially the transport of amino acids to developing seeds [24].

5. CONCLUSION

Growth parameters (plant height, number of leaves, leaf area), dry matter yield and phosphorus concentration were affected by N application. However, nitrogen concentration, shoot dry matter and growth parameters except leaf area and breadth were considerably influenced by P fertilization. Application of potassium to maize grown in screen house affected plant height, girth, leaf number area, length and breadth. Furthermore, increasing potassium rate was equivalent to increasing those parameters, concentration and uptake of N and K in maize. It is therefore recommended that 120 to 150 kg N, 60 kg P and 180 kg K ha^{-1} should be applied for sustainable maize production in screen house.

Table 1. Some chemical characteristics of experimental soil

	pH	Ca	Mg	Na	K	Avail P	Total N	Total C	Texture
		.... cmol kg^{-1}		....		mg kg^{-1}	............%............		
Soil	6.20	4.41	1.16	0.64	0.24	3.01	0.04	0.65	Sandy

Table 2. Effect of N, P and K application on plant height and stem girth of maize

Treatment	**...........**	**Plant**	**Height**	**(cm)**	**..........**	**Stem**	**Girth**	**(cm)**
(ha-1)	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**2WAP**	**4WAP**	**6WAP**	**8WAP**
0 kg N	16.2a	19.2d	23.8a	31.2ab	0.2bcd	0.35b	0.27a	0.49a
30 kg N	15.5a	22.3bcd	25.4a	27.5b	0.13d	0.39b	0.33a	0.45a
60 kg N	15.9a	27.4abc	30.3a	50.0ab	0.28ab	0.61ab	0.39a	0.69a
90 kg N	17.3a	30.7a	39.9a	54.3ab	0.23abc	0.53ab	0.52a	0.77a
120 kg N	18.5a	30.1ab	46.3a	64.3a	0.29a	0.59ab	0.45a	0.83a
150 kg N	19.9a	31.9a	40.0a	52.7ab	0.18cd	0.72a	0.47a	0.67a
180 kg N	16.5a	20.5cd	29.7a	34.3ab	0.22abc	0.53ab	0.33a	0.41a
0 kg P	15.5ab	21.0b	29.0ab	42.7c	0.13a	0.20d	0.26c	0.35b
30 kg P	13.7b	21.17b	26.8a	44.1c	0.14a	0.22cd	0.27bc	0.47ab
60 kg P	19.67a	26.8a	37.0a	67.5a	0.15a	0.50a	0.57a	0.65a
90 kg P	15.7ab	22.3b	33.5a	62.4abc	0.17a	0.25bcd	0.40abc	0.63ab
120 kg P	14.7b	21.5b	31.5a	55.0abc	0.15a	0.27bcd	0.35abc	0.63ab
150 kg P	17.50ab	24.3ab	30.8a	48.0bc	0.16a	0.45ab	0.55a	0.70a
180 kg P	17.0ab	23.7ab	31.2a	51.7abc	0.12a	0.42abc	0.50ab	0.77a

0 kg K	30.0b	80.3d	100.0a	116.6b	0.15a	0.24d	0.60e	0.64e
30 kg K	31.3ab	82.3cd	103.3a	122.6b	0.15a	0.28cd	0.63e	0.67e
60 kg K	33.0a	84.0bc	110.0a	116.6b	0.17a	0.28cd	0.69d	0.75cd
90 kg K	30.6ab	84.0bc	110.0a	123.3b	0.17a	0.30cd	0.76c	0.80c
120 kg K	32.3ab	87.0ab	103.3a	120.0b	0.17a	0.33c	0.78c	0.94b
150 kg K	31.6ab	86.6ab	100.0a	117.6b	0.17a	0.55b	0.85b	0.98ab
180 kg K	31.0ab	87.6a	103.3a	135.6a	0.16a	0.70a	0.91a	1.07a

Mean with the same alphabet in each treatment section did not differ significantly across the column at (*P* = .05)

WAP- weeks after planting

Table 3. Effect of N, P and K application on Leaf length and Leaf width of maize

Treatment	**..........**	**Leaf**	**Length**	**(cm)**	**..........**	**Leaf**	**Width**	**(cm)**
(K ha^{-1})	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**2WAP**	**4WAP**	**6WAP**	**8WAP**
0 kg N	25.4b	32.2a	45.9a	72.0b	4.0a	3.6b	4.0a	5.0a
30 kg N	35.6ab	46.4a	63.4a	74.6b	4.3a	4.3ab	4.0a	4.0a
60kg N	72.6ab	78.9a	104.3a	101.9ab	3.3a	5.0ab	4.7a	6.7a
90 kg N	77.6ab	97.1a	120.5a	131.8ab	4.0a	5.3a	5.0a	8.0a
120 kg N	90.3a	98.9a	120.1a	146.6ab	4.3a	5.7a	5.0a	8.0a
150 kg N	66.0ab	83.7a	117.1a	176.9a	4.3a	5.7a	5.0a	6.7a
180 kg N	47.4ab	60.7a	91.4a	92.8ab	4.3a	4.0ab	3.7a	5.0a
0 kg P	19.0a	38.3a	44.6a	46.8a	1.55a	1.70a	2.1a	2.2a
30 kg P	19.0a	33.7a	40.2a	44.3a	1.50a	1.80a	2.2a	2.6a
60 kg P	19.7a	54.7a	65.6a	67.3a	1.73a	2.4a	3.0a	3.2a
90 kg P	18.7a	49.1a	58.0a	64.3a	1.83a	2.4a	2.7a	3.6a
120 kg P	17.7a	39.5a	48.5a	54.6a	1.63a	2.1a	2.6a	2.7a
150 kg P	17.5a	41.1a	52.0a	54.7a	1.65a	2.5a	2.8a	2.6a
180 kg P	19.3a	48.4a	56.6a	61.5a	1.63a	2.0a	3.2a	2.2a
0 Kg K	29.6b	56.67b	67.6d	77.0f	1.9ab	4.1b	5.5c	5.6c
30 kg K	31.0ab	58.0ab	69.6c	80.0e	2.1ab	4.3ab	5.6bc	5.7bc
60 kg K	32.6a	58.0ab	72.3ab	83.0d	2.1ab	4.5a	5.7ab	5.8a
90 kg K	31.3ab	57.6ab	71.6b	85.3c	2.2a	4.4b	5.7ab	5.8ab
120 kg K	32.3ab	56.0b	72.3ab	88.0b	2.3a	4.1b	5.6ab	5.6c
150 kg K	31.6ab	57.3ab	73.6a	88.3b	2.3a	4.1b	5.8a	5.8a
180 kg K	30.3ab	59.0a	73.3a	90.6a	1.7b	4.5a	5.8a	5.9a

Mean with the same alphabet in each treatment section did not differ significantly across the column at (P = .05) WAP- weeks after planting

Table 4. Effect of N, P and K application on number of leaves and Leaf area of maize

Treatment	**..........**	**Leaf**	**number**	**.........**	**...........**	**Leaf**	**Area**	**(cm^2)**
(K ha-1)	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**2WAP**	**4WAP**	**6WAP**	**8WAP**
0 kg N	4.0a	3.7b	4.0a	5.0a	32.2a	25.4b	45.9a	72.1b
30 kg N	4.3a	4.3ab	4.0a	4.0a	46.4a	32.6ab	63.4a	74.6b
60 kg N	3.3a	5.0ab	4.6a	6.7a	78.9a	72.6ab	104.3	101.9ab
90 kg N	4.0a	5.3a	5.0a	8.0a	97.1a	77.6ab	120.5	131.8ab
120 kg N	4.3a	5.6a	5.0a	8.0a	98.9a	90.3a	120.1a	146.6ab
150 kg N	4.3a	5.6a	5.0a	6.7a	83.7a	66.0ab	117.1a	176.9a
180 kg N	4.3a	4.0ab	3.7a	5.0a	60.7a	47.0ab	91.4a	92.8ab
0 kg P	3.5ab	4.5c	3.5c	6.0b	21.7a	46.6a	68.8a	76.6a
30 kg P	3.0b	3.7b	4.3bc	6.0b	21.3a	45.8a	64.9a	87.0a
60 kg P	4.0a	5.0abc	5.7ab	8.0a	25.7a	100.2a	150.3a	163.2a
90 kg P	4.0a	5.7a	5.7ab	7.3ab	21.7a	88.0a	119.2a	171.6a
120 kg P	4.0a	4.7a	6.0a	7.7ab	21.7a	64.0a	96.1a	112.7a
150 kg P	3.5ab	5.5ab	5.0ab	7.5ab	21.7a	76.8a	108.9a	128.1a
180 kg P	4.0a	5.0abc	5.7ab	8.0a	24.3a	78.2a	142.1a	182.a
0 Kg K	4.0a	6.3a	9.0c	9.7b	43.5b	175.7c	282.5d	321.5d
30 kg K	4.0a	6.0ab	9.3bc	10.0ab	50.5a	187.1bc	290.8cd	340.0c
60 kg K	3.7a	5.0c	9.0c	9.3b	50.6a	197.2ab	311.0ab	363.2b
90 kg K	4.0a	6.0ab	9.0c	9.7b	52.5a	188.7abc	306.3ab	371.3b
120 kg K	4.0a	5.7b	9.7ab	10.0ab	50.4a	180.6c	301.9bc	367.3b
150 kg K	4.0a	5.0c	10.0a	11.0a	50.5a	177.8c	318.6a	386.5a
180 kg K	4.0a	6.0ab	10.0a	11.0a	38.8a	200.6a	314.2ab	399.0a

Mean with the same alphabet in each treatment section did not differ significantly across the column at (P = .05)

WAP- weeks after planting

Table 5. Effect of N, P and K application on dry matter, nutrient concentration and uptake in maize

Treatment (ha^{-1})	Shoot dry wt $gpot^{-1}$	Root dry wt. $gpot^{-1}$	Conc.	Conc.	Uptake Per pot	Uptake Per pot
			N (%)	**P (mg kg^{-1})**	**N(g)**	**P(mg)**
0 kg N	1.07a	0.36a	0.36a	70.0b	0.27a	90.0a
30 kg N	0.94a	0.44a	0.44a	70.0b	0.28a	90.0a
60 kg N	2.10a	0.31a	0.31a	100.0ab	0.31a	250.0a
90 kg N	2.98a	0.42a	0.42a	130.0ab	0.55a	400.0a
120 kg N	3.45a	0.48a	0.48a	150.0ab	0.82a	610.0a
150 kg N	3.00a	0.44a	0.43a	180.0a	0.93a	590.0a
180 kg N	1.70a	0.27a	0.27a	90.0ab	0.34a	210.0a
			P (mg kg^{-1})	**N (%)**	**P (g)**	**N (g)**
0 kg P	4.50c	0.55a	400.8a	1.76b	0.73a	0.79a
30 kg P	3.67d	0.33a	687.1a	3.60ab	1.97a	1.32a
60 kg P	5.00abc	0.75a	1164.3a	5.95a	7.03a	2.97a
90 kg P	5.67a	0.72a	458.1a	4.24ab	2.02a	2.40a
120 kg P	4.67bc	0.53a	668.0a	3.60ab	1.93a	1.68a
150 kg P	5.50ab	0.54a	1145.2a	3.65ab	3.36a	2.00a
180 kg P	5.00abc	0.87a	591.7a	3.18ab	2.05a	1.59a
			K (%)	**N (%)**	**K(g)**	**N(g)**
0 Kg K	6.66bc	0.84ab	2.34c	0.9c	0.15c	0.06b
30 kg K	6.05c	0.82b	2.61c	1.06ab	0.15c	0.07b
60 kg K	6.39c	0.81b	2.84bc	0.98bc	0.18bc	0.06b
90 kg K	8.41abc	0.97ab	3.57ab	1.10a	0.30ab	0.09ab
120 kg K	10.37ab	1.10ab	2.90bc	1.15a	0.30ab	0.12a
150 kg K	10.39ab	1.10ab	3.07abc	1.15a	0.33a	0.12a
180 kg K	10.58a	1.14a	3.77a	1.06ab	0.38a	0.11a

Mean with the same alphabet in each treatment section did not differ significantly across the column at (P = .05)

wt.- weight Conc. - concentration

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