ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF
AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 14 (4): 203-211, 2015
ISSN 1812-5379

ansinet
Asian Network for Scientific Information

RESEARCH ARTICLE **OPEN ACCESS**

DOI: 10.3923/ja.2015.203.211

Effects of NPK Single Fertilizers on Relative Growth Performances of Two Cycles of Maize (*Zea mays* L.) Grown in a Degraded Soil of Southwest Nigeria

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ARTICLE INFO

Article History:
Received: July 03, 2015
Accepted: August 27, 2015

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ABSTRACT

The balanced use of inorganic amendments to enhance effective crop production for developing world economies like Nigeria is paramount to achieve her Millennium Development Goals (MDGs) for its teeming population. Thus this study was carried out to assess the relative growth performances of a major food crop under different regimes of fertilizer application. Field and Green House experiments were carried out to assess the relative growth performances of two Cycles of *Zea mays* L. (LNTP-W C_0 and C_3) used as test crops for the amendment of degraded soil using N, P and K single fertilizers. The single fertilizers (treatments) used were Urea, Single Super Phosphate (SSP) and Muriate of Potash and the study was carried out in the Department of Botany, University of Ibadan, Nigeria. The experiment consisted of 4 treatments applied at 2 levels (C_0 and C_3) and replicated three times in a Completely Randomized Design (CRD) to give a total of 48 experimental units. The application of Nitrogen (N) was done at four levels (0, 30, 60 and 90 kg ha^{-1}), while the Phosphorous (P_2O_5) and Potassium (K) were applied at a constant rate of about 60 kg ha^{-1} for all the pots except for the experimental control pots. The design was adopted for both Green House and Field experiments. The results from the study showed that C_3 performed better than C_0 in Field and Green House experiments with respect to their relative performances of the growth parameters; plant height (cm), stem diameter (mm), number of leaves, leaf length (cm) and leaf width (cm) measured within the Pre-flowering period of 8 weeks. The treatment combination of 90 kg ha^{-1} N, 60 kg ha^{-1} P and 60 kg ha^{-1} K gave the best performance in this study. The study also revealed that the growth rate of the maize plant was directly proportional to the level of N applied with constant levels of P and K providing the basis for developing optimum NPK fertilizer level for the amendment of degraded soil for higher productivity using maize with tolerance to low soil Nitrogen. The study showed that more derelict soils can be put to good use with the appropriate level of NPK Fertilizer application optimum for the right crop, thus aiding the use of hitherto abandoned degraded land and putting more land under cultivation.

Key words: *Zea mays* L., eroded soil, fertilizer application, performance

INTRODUCTION

The quality and productivity of many farmlands in Nigeria has been lost through a combination of human-induced and natural processes, which affects the capacity of the soil to function optimally. Wind or water erosion induced by tillage and poor soil management, acidification from improper use of acid-forming nitrogenous fertilizers, soil contamination by indiscriminate industrial effluent discharge are among factors responsible for this level of soil degradation. However, the productivity of degraded and eroded soils can be restored using organic amendments, such; as manure and improved crop and soil management (Mikha *et al*., 2010). Other means usually employed for amending derelict soils include techniques such as; use of chemical amendments, phytoremediation, bioremediation and natural attenuation.

Fertilizers may be generally referred to as mineral components often added to the soil to supply one or more elements required for plant growth and productivity. The three major elements found in fertilizers are nitrogen, potassium and phosphorus, while the secondary elements include calcium, sulphur and magnesium. Other elements are boron, manganese, iron, zinc, copper and molybdenum. Fertilizers enhance the natural fertility of soil or replace the chemical elements extracted from the soil via crop harvesting, grazing, leaching or erosion. Organic and inorganic fertilizers are the common fertilizer types used for soil amendment in Nigeria. These fertilizers are designed to provide nutrients and chemical compounds that plants require to grow, when those elements are lacking in the soil. Bowyer (2010) opined that fertilizers are compounds, which are used to produce an overall effective increase in crop yield, or they can be single nutrient which means they are used to replenish a single type of mineral that is lacking in the soil. Fertilizers have played a key role in helping farmers achieve their high level of production by providing essential plant nutrients which are indispensable for producing sufficient and healthy food for the world’s expanding population (Khaskheli, 2011). However, one of the factors responsible for stagnating yields and decreasing fertilizer use efficiency is the current unbalanced fertilizer use. Khaskheli (2011) also identified several problems encountered in balanced and efficient fertilizer use including non-availability of specific fertilizers at the right time, ever-increasing prices, improper application methods and time, lack of knowledge among farmers about the need for balanced fertilizer applications, adulteration and inadequate grant of soft loans especially for the small farmers, who actually constitute about 75% of the farming community. He also stated that nutrient balances for many cropping systems are negative of which nitrogen and phosphorus are the most limiting nutrients to crop production but their sufficient use by majority of the small-holder farmers become limiting due to their high costs. Consequently, a substantial number of farmers do not use fertilizers and the ones who use fertilizers apply below the recommended rates.

Maize is regarded as one of the most important cereal crops in Sub-Saharan and Saharan Africa (IITA., 2007) and considered as the most important cereal crop in humid and sub humid savanna of West and Central Africa (Oyetunji *et al*., 2001). Maize has been reported to respond positively to fertilizer application in terms of crop yield or productivity. Smaling *et al*. (1992) reported a positive yield response of maize to fertilizers and manure application under different agro-ecological conditions in Kenya. They emphasized the need for recommending fertilizers according to the agro-ecological diversity of agricultural land and support systems of integrated nutrient management, particularly in areas of low soil fertility. Davis and Westfall (2011) reported that nitrogen is the most limiting nutrient for maize production and the application of nitrogen fertilizers should be at rates based on expected crop yields minus credits for residual soil nitrates, estimated nitrogen mineralized from soil organic matter, previous legume crop residues and manure or other organic wastes and nitrogen present in irrigation water, while phosphate and zinc fertilizers should be applied at rates based on soil test results.

The concept of balanced fertilization is a very important phenomenon in soil and crop management, thus, this study was carried out to investigate how degraded soil can be remediated using NPK single fertilizers at optimal levels and to demonstrate its positive effect on the growth, development and yield of the maize crop in order to demonstrate how a degraded soil can be amended using the NPK fertilizer and the subsequent effects on the maize crop used as the test crop. The specific objectives of this study were to determine the effects of different levels of NPK fertilizer application on the performance of maize on a degraded soil. Also, to determine the relative performance of two Cycles of maize (LNTP-W C_0 and C_3) improved for tolerance to low soil Nitrogen in both Green House and field conditions.

MATERIALS AND METHODS

Description of study area: The study area was located at the Green House and Nursery farm in the Department of Botany, University of Ibadan, Ibadan (Oyo State), Nigeria. This area lies between latitude 3° 53' E and longitude 17° 26' N and altitude of 185 m above sea level (Akin-Oriola, 2003), with a mean daily temperature of 24.6°C and mean rainfall range above 1300 mm.

Soil sample preparation and analysis: Five hundred kilograms of severely eroded sandy soil was collected and thoroughly mixed together for uniformity of constituents. Forty-eight experimental pots (10 L) with perforated bases were filled with the degraded soil of equal weight (10 kg) and then separated into two groups (24 pots on the Field and 24 pots in the Green House). The experimental pots were perforated in order to allow excess water to drain out. The pots in each group were then sub-divided into three units to give 8 pots in each unit. The soil in each pot was further watered with 30 L of tap water. The soil samples were sundried and analysed at the International Institute of Tropical Agriculture (IITA), Ibadan-Nigeria to determine its physicochemical constituents before planting. Two cycles of maize seeds (already improved for tolerance to low soil Nitrogen, LNTP-W C_0 and C_3) were obtained from IITA, Ibadan-Nigeria and used as test crops for the study. Ten maize seeds were sown per pot in both Green House and Field experimental set-up. The Green House pots were watered at alternate days with 250 mL of tap water, while the Field experiment were left under rainfall conditions since the experiment was conducted during the rainy season and observations on both experiments were recorded for a pre-flowering period of about 8 weeks.

Experiment design and set-up: The pots were replicated three times in a Completely Randomized Design (CRD) for each treatment giving rise to a total of 48 experimental units. The treatments used were Urea for Nitrogen, Single Super Phosphate (SSP) for Phosphorus, Muriate Of Potash (MOP) for Potassium and Control (zero amendment). The application of Nitrogen (N) was done at four levels (0, 30, 60 and 90 kg ha^{-1}), while the Phosphorous (P_2O_5) and Potassium (K) were applied at a constant rate of about 0.26 g fertilizer/pot (equivalent of 60 kg ha^{-1}) for all the pots except for the experimental control pots. The experimental setup was uniform for both Green House and Field locations.

Treatments were applied 21 Days After Planting (DAP) and this was done after the plant growth parameters have been measured for week 0 (that is, 3 weeks after planting). The four treatment level combinations were: (i) 0 kg N, 60 kg P, 60 kg K; (ii) 30 kg N, 60 kg P, 60 kg K; (iii) 60 kg N, 60 kg P, 60 kg K and (iv) 90 kg N, 60 kg P, 60 kg K.

Subsequently, measurements of growth parameters were taken on weekly basis for about 5 weeks and the real values showing the actual effect of the treatment levels and combinations on the plants were calculated as: Week_x-Week_0. Where Week_x = Week 1, Week 2 up to Week 5. The following plant growth parameters were taken for a pre-flowering period of 8 weeks: number of leaves, stem diameter, plant height, leaf length and leaf width.

Statistical analysis: All data generated during the experiment were analysed using the two way analysis of variance (ANOVA) with the aid of the SPSS Version 16. Significant means between the two maize cycles were separated using the t-test at 0.05 level of significance ($p \leq 0.05$).

RESULTS AND DISCUSSION

Table 1 shows the soil type as predominantly sandy, slightly alkaline, low in fertility (minimal N and OC values) with very high iron content. These characteristics are typical of infertile, lateritic soils found in many parts of South Western Nigeria. Thus this soil type cannot ordinarily support growth of agricultural crops without adding some form of amendments to the soil to boost its nutritive values.

Percentage germination index: Maize seeds of both cycles LNTP-W C_0 and C_3 started germination on the 4th day after planting in both Green House and Field Experiments and the emergence counts taken on the 5, 7 and 9th Days After Planting (DAP) were used to calculate the Percentage Emergence (%E) and Emergence Index (EI) (Table 2).

Table 1: Physical and chemical properties of the soil used for the study

Parameters	Values
Physical properties	
Sand (%)	82.00
Clay (%)	12.00
Silt (%)	6.00
Chemical properties	
Fe (ppm)	162.06
Mn (ppm)	20.22
Cu (ppm)	2.82
Zn (ppm)	28.45
N (%)	0.042
pH (H_2O)	7.80
P (g kg^{-1})	0.014
Ca (cmol kg^{-1})	7.09
Mg (cmol kg^{-1})	0.37
K (cmol kg^{-1})	0.19
Na (cmol kg^{-1})	0.09
O.C (%)	0.51

Table 2: Mean Percentage Emergence (%E) and emergence indices of C_0 maize cycle (C_0) and C_3 maize cycle (C_3) in Green House and field experiment

	Green House		Field	
Maize cycle	E (%)	EI	E (%)	EI
C_0	26.7	7.3	12.5	7.7
C_3	69.2	6.3	56.7	6.3

The Table 2 shows that C_3 had greater %E than C_0 in both Field and Green House Experiments. In the Field, %E for C_3 is 56.7%, while C_0 is 12.5% and in Green House, C_3 recorded 69.2%, while C_0 had 26.6%. This may serve as, a tool for predicting the relative performances of the two maize cycles as reported by Crosbie *et al.* (1980) in their study on two maize populations. The higher %E and EI for C_3 in both Field and Green House experiments corresponds with the better performance observed compared to C_0 maize cycle.

The C_3 maize cycle in Field and Green House experiments had the same EI of 6.3 indicating that it took an average of 6 days for all the seeds to emerge in both Field and Green House experiments. The C_0 maize cycle in Field and Green House experiments were 7.7 and 7.3, respectively, showing that it took an average of 7 days for the seeds to germinate. Crosbie *et al.* (1980) used EI to predict the relative performance of two maize populations and the values reported in this study corresponds with the relative performances of the two maize cycles studied.

Table 3 shows the effects of the treatment levels on C_0 maize cycle plant height in the field.

Analysis of variance showed significant differences with treatments on C_0 maize cycle ($p<0.05$). The treatment combination of N_{90} (Nitrogen 90 kg ha^{-1}) performed best followed by N_{60}, N_{30} and N_0 (control) and this showed that crop growth can be improved with the aid of fertilizers as reported by Smaling *et al.* (1992). The result also showed that degraded soil can be amended using appropriate fertilizer

Table 3: Effects of treatment levels on C_0 maize cycle (C_0) mean plant height (cm) in the Field

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	2.07±0.03^a	5.27±0.52^a	9.30±1.05^a	31.37±3.92^a	63.07±4.42^a
C_0N_{30}	5.07±0.97^b	9.13±0.49^b	16.83±1.64^b	53.23±3.60^b	101.33±8.60^b
C_0N_{60}	7.13±0.03^c	11.20±0.60^c	22.07±1.16^b	65.40±2.90^c	126.07±5.07^c
C_0N_{90}	9.20±0.15^d	16.93±0.44^d	35.27±2.49^c	82.33±3.20^d	145.17±3.40^d

Means on the same column with the same letters are not significantly different ($p<0.05$), C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 4: Effects of treatment levels on C_3 maize cycle (C_3) mean plant height (cm) in the Field

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	3.73±0.18^a	8.73±0.30^a	13.20±1.15^a	47.60±5.29^a	98.20±4.70^a
C_3N_{30}	7.10±0.15^b	13.50±0.40^b	28.43±0.52^b	70.43±0.52^b	124.73±3.90^b
C_3N_{60}	9.13±0.15^c	16.67±0.50^c	35.63±2.28^c	85.13±1.08^c	146.77±1.77^c
C_3N_{90}	11.70±0.17^d	24.13±0.52^d	47.90±1.01^d	96.73±0.95^d	159.73±1.03^d

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 5:Effects of treatment levels on C_0 mean plant height (cm) in the Green House

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	7.00±1.31^a	13.40±2.94^a	27.10±6.71^a	60.13±13.51^a	72.03±15.60^a
C_0N_{30}	14.03±0.41^b	28.90±1.44^b	55.73±6.27^b	73.63±24.66^a	162.63±10.62^b
C_0N_{60}	17.27±0.75^b	39.67±3.09^c	73.70±6.09^{bc}	125.17±4.54^b	196.43±4.28^c
C_0N_{90}	21.73±1.33^c	49.03±0.93^d	91.77±1.47^c	149.73±1.86^b	220.80±1.35^c

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 6: Effects of treatment levels on C_3 mean plant height (cm) in the Green House

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	11.03±0.87^a	22.17±1.13^a	45.70±2.07^a	83.63±8.37^a	134.07±19.77^a
C_3N_{30}	15.97±0.48^b	36.53±0.75^b	65.60±10.75^b	116.40±1.94^b	179.50±1.56^b
C_3N_{60}	22.10±0.81^c	49.37±1.22^c	91.27±1.75^c	149.10±3.64^c	224.70±5.81^c
C_3N_{90}	25.33±0.32^d	57.90±2.29^d	113.53±3.55^d	182.40±2.25^d	253.77±6.18^d

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

treatment combinations. Table 4 shows the effects of the treatment levels on C_3 in the Field with respect to the plant height (cm). Analysis of variance shows significant differences ($p<0.05$) with treatment on C_3 maize cycle with treatment combination of N_{90} being the best followed by N_{60}, N_{30} and N_0 in that order.

Table 5 shows the effects of the treatment levels on C_0 plant height (cm) in the Green House. Analysis of variance shows significant differences with treatment levels and Control ($p<0.05$) and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Table 6 shows the treatment effects on C_3 plant height (cm) in the Green House. Analysis of variance shows significant differences with treatment levels ($p<0.05$) and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0 in that order.

Tables 3-6 show that as nitrogen level increases, the heights of the plants increase and this showed that plant growth is dependent on an adequate Nitrogen (N) supply or availability in the soil, which leads to amino acids, proteins, nucleic acids synthesis and other cellular constituents (Vincentz *et al*., 1993; Migge and Becker, 1996; Atilio and Causin, 1996). It was observed that increase in nitrogen level gave rise to increase in growth rate. This is in line with the report of Mattson *et al*. (1991) who stated that plant growth and yield are dependent on nitrogen supply. Khaskheli (2011) likewise reported an increase in growth, yield and quality of fodder maize grown with fertilizers. Ojeniyi *et al*. (2012) and Zerihun *et al*. (2013) who reported similar findings in their studies on crop yield as influenced by integrated fertilizer applications. The C_3 maize cycle performed better than C_0 maize cycle under Field and Green House experiments with respect to treatments throughout the period of study. This shows that C_3 maize cycle has higher nitrogen use efficiency (in terms of biomass produced per unit nitrogen) than C_0 maize cycle and this was observed in all the growth parameters studied.

Performances of the maize test plants in the Green House were observed to be much higher than field. This could be as a result of environmental factors, such as; rainfall, wind, pests, high light intensity etc. which were controlled in the Green House and thus impacted negatively on the crops in the field under extreme conditions. The plants in the Green House had adequate water supply of about 250 mL at alternate days and wind/light/pests were controlled. This is in line with Pimentel *et al*. (1995) who reported that when rain does not fall for a long time, the water use efficiency (amount of dry matter produced or CO_2 fixed per unit water transpired) of the plant is limited.

Table 7 shows the effects of the treatment levels on the number of leaves of C_0 maize cycle in the field. Analysis of variance shows significant differences with treatment levels ($p<0.05$) after the first week and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Table 8 shows the effects of the treatment levels on the number of leaves of C_3 maize cycle in the field and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels and control ($p<0.05$) for the weeks studied, except for the 1st week where there was no significant difference between N_{30} and the control. Table 9 shows the effects of the treatment levels on number of leaves of C_0 maize cycle in the Green House. Analysis of variance shows significant differences with treatment levels ($p<0.05$) for the 4 and 5th weeks and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Table 10 shows the effects of the treatment levels on C_3 in the Green House with respect to the Number of Leaves and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels and control ($p<0.05$) except for N_{30}. The effects of treatment levels on the mean number of leaves showed that increase in nitrogen level increased the number of leaves in the maize cycles studied (Table 9 and 10).

In summary, C_3 was observed to perform better than C_0 in Field and Green House experiments with respect to all

Table 7: Effects of treatment levels on mean number of leaves (Field) of C_0 maize cycle

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	1.00 ± 0.33^{a}	2.00 ± 0.33^{a}	3.00 ± 0.33^{a}	4.00 ± 0.58^{a}	5.00 ± 0.58^{a}
C_0N_{30}	1.00 ± 0.00^{a}	2.00 ± 0.00^{ab}	3.00 ± 0.00^{ab}	4.00 ± 0.33^{a}	6.00 ± 0.57^{ab}
C_0N_{60}	1.00 ± 0.33^{a}	3.00 ± 0.33^{b}	4.00 ± 0.33^{b}	5.00 ± 0.33^{ab}	7.00 ± 0.33^{bc}
C_0N_{90}	2.00 ± 0.33^{a}	4.00 ± 0.33^{c}	5.00 ± 0.00^{c}	6.00 ± 0.33^{b}	8.00 ± 0.33^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 8: Effects of treatment levels on mean number of leaves (Field) of C_3 maize cycle

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	1.00 ± 0.00^{a}	2.00 ± 0.00^{a}	3.00 ± 0.33^{a}	4.00 ± 0.33^{a}	6.00 ± 0.58^{a}
C_3N_{30}	1.00 ± 0.33^{a}	3.00 ± 0.33^{b}	4.00 ± 0.33^{ab}	5.00 ± 0.33^{ab}	7.00 ± 0.33^{ab}
C_3N_{60}	2.00 ± 0.33^{ab}	4.00 ± 0.33^{bc}	5.00 ± 0.58^{b}	6.00 ± 0.33^{b}	8.00 ± 0.33^{b}
C_3N_{90}	2.00 ± 0.33^{b}	4.00 ± 0.33^{c}	7.00 ± 0.33^{c}	9.00 ± 0.33^{c}	10.00 ± 0.00^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 9: Effects of treatment levels on mean number of leaves (Green House) of C_0 maize cycle

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	1.00 ± 0.33^{a}	2.00 ± 0.33^{a}	3.00 ± 0.33^{a}	4.00 ± 0.58^{a}	6.00 ± 0.03^{a}
C_0N_{30}	2.00 ± 0.33^{ab}	2.00 ± 0.33^{a}	4.00 ± 0.33^{b}	5.00 ± 0.33^{a}	7.00 ± 0.58^{ab}
C_0N_{60}	2.00 ± 0.58^{ab}	4.00 ± 0.33^{b}	5.00 ± 0.00^{c}	7.00 ± 0.00^{b}	8.00 ± 0.33^{bc}
C_0N_{90}	2.00 ± 0.33^{b}	5.00 ± 0.33^{b}	6.00 ± 0.33^{d}	8.00 ± 0.58^{b}	9.00 ± 0.58^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 10: Effects of treatment levels on mean number of leaves (Green House) of C_3 maize cycle

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	1.00 ± 0.33^{a}	3.00 ± 0.33^{a}	5.00 ± 0.67^{a}	6.00 ± 0.33^{a}	8.00 ± 0.33^{a}
C_3N_{30}	3.00 ± 0.33^{ab}	4.00 ± 0.33^{ab}	6.00 ± 0.33^{ab}	8.00 ± 0.33^{ab}	9.00 ± 0.33^{a}
C_3N_{60}	3.00 ± 0.58^{b}	5.00 ± 0.88^{ab}	7.00 ± 0.67^{b}	8.00 ± 0.67^{b}	10.00 ± 0.00^{b}
C_3N_{90}	3.00 ± 0.58^{b}	6.00 ± 0.88^{b}	9.00 ± 0.58^{c}	11.00 ± 0.33^{c}	12.00 ± 0.58^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 11: Effects of treatment levels on stem diameter (mm) of C_0 maize cycle (Field)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	0.69 ± 0.13^{a}	0.89 ± 0.14^{a}	2.38 ± 0.13^{a}	2.89 ± 0.13^{a}	3.32 ± 0.17^{a}
C_0N_{30}	1.77 ± 0.12^{b}	2.50 ± 0.19^{b}	3.04 ± 0.10^{b}	3.84 ± 0.21^{a}	4.75 ± 0.79^{a}
C_0N_{60}	2.41 ± 0.31^{c}	2.97 ± 0.27^{b}	4.02 ± 0.09^{c}	5.40 ± 0.19^{b}	7.15 ± 0.14^{b}
C_0N_{90}	3.21 ± 0.10^{d}	3.83 ± 0.11^{c}	4.95 ± 0.13^{d}	7.35 ± 0.56^{c}	8.94 ± 0.57^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 12: Effects of treatment levels on stem diameter (mm) of C_3 maize cycle (Field)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	1.97 ± 0.13^{a}	2.12 ± 0.11^{a}	2.58 ± 0.26^{a}	3.44 ± 0.27^{a}	4.34 ± 0.39^{a}
C_3N_{30}	2.70 ± 0.11^{b}	3.04 ± 0.06^{b}	$3.97\pm0.04a^{b}$	5.98 ± 0.13^{b}	7.03 ± 0.16^{b}
C_3N_{60}	3.26 ± 0.10^{c}	4.16 ± 0.42^{c}	5.04 ± 0.87^{b}	7.03 ± 0.66^{b}	9.00 ± 0.47^{c}
C_3N_{90}	3.93 ± 0.10^{d}	5.14 ± 0.09^{d}	7.06 ± 0.08^{c}	9.03 ± 0.02^{c}	10.83 ± 0.40^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 13: Effects of treatment levels on stem diameter (mm) of C_0 maize cycle (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	1.36 ± 0.30^{a}	2.15 ± 0.18^{a}	2.74 ± 0.15^{a}	3.46 ± 0.11^{a}	3.92 ± 0.12^{a}
C_0N_{30}	2.11 ± 0.02^{ab}	2.92 ± 0.08^{b}	3.18 ± 0.15^{a}	4.34 ± 0.25^{a}	4.84 ± 0.24^{a}
C_0N_{60}	2.77 ± 0.22^{b}	3.60 ± 0.07^{c}	4.49 ± 0.31^{b}	5.50 ± 0.36^{b}	6.50 ± 0.52^{b}
C_0N_{90}	3.68 ± 0.39^{c}	4.60 ± 0.30^{d}	5.92 ± 0.42^{c}	6.87 ± 0.42^{c}	8.00 ± 0.48^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 14: Effects of treatment levels on stem diameter (mm) of C_3 maize cycle (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	2.03 ± 0.04^{a}	2.36 ± 0.12^{a}	2.91 ± 0.07^{a}	3.74 ± 0.10^{a}	4.10 ± 0.10^{a}
C_3N_{30}	2.30 ± 0.07^{a}	3.32 ± 0.050	4.09 ± 0.04^{ab}	4.87 ± 0.08^{a}	5.41 ± 0.25^{a}
C_3N_{60}	3.30 ± 0.284	4.31 ± 0.36^{c}	5.48 ± 0.76^{b}	6.69 ± 0.78^{b}	7.68 ± 1.06^{b}
C_3N_{90}	4.47 ± 0.29^{c}	6.10 ± 0.17^{d}	7.57 ± 0.35^{c}	8.79 ± 0.26^{c}	10.58 ± 0.34^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

treatment levels throughout the period of study. The C_3 showed higher nitrogen use efficiency (i.e., biomass produced per unit nitrogen in a plant) than C_0.

Table 11 shows the effects of the treatment levels on C_0 in the field with respect to the stem diameter and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels and Control at a 0.05 level of significance. Table 12 shows the effects of the treatment levels on C_3 in the field with respect to the stem diameter and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 13 shows the effects of the treatment levels on C_0 in the Green House with respect to the stem diameter and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels except for N_{30} and N_0, at a 0.05 level of significance. Table 14 shows the effects of the treatment levels on C_3 in the Green House with respect to the stem diameter and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels except for N_{30} and N_0 ($p<0.05$).

The relative effects of treatment levels on the mean stem diameter showed that increase in nitrogen level gives rise to increase in stem diameter with age. The results obtained in the field were similar to that of Green House, but the performances observed in the Green House experiment were much higher than field. C_3 performed better than C_0 in field and Green House experiments with respect to all treatment levels for all weeks. This shows that C_3 has higher nitrogen use efficiency (i.e., biomass produced per unit nitrogen in a plant) than C_0.

Table 15 shows the effects of the treatment levels on C_0 in the Field with respect to the Leaf width and treatment

Table 15: Effects of treatment levels on the leaf width (cm) of C_0 maize cycle (Field)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	0.20 ± 0.06^{a}	0.40 ± 0.06^{a}	0.70 ± 0.06^{a}	1.13 ± 0.07^{a}	1.67 ± 0.09^{a}
C_0N_{30}	0.57 ± 0.03^{b}	1.07 ± 0.03^{b}	1.50 ± 0.06^{b}	2.10 ± 0.06^{b}	2.87 ± 0.07^{b}
C_0N_{60}	0.77 ± 0.03^{c}	1.60 ± 0.06^{c}	2.43 ± 0.09^{c}	2.97 ± 0.09^{c}	3.53 ± 0.12^{c}
C_0N_{90}	0.97 ± 0.07^{d}	2.30 ± 0.10^{d}	3.10 ± 0.06^{d}	3.60 ± 0.10^{d}	4.13 ± 0.09^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 16: Effects of treatment levels on the leaf width (cm) of C_3 maize cycle (Field)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	0.37 ± 0.03^{a}	0.67 ± 0.03^{a}	1.03 ± 0.09^{a}	1.47 ± 0.12^{a}	2.13 ± 0.15^{a}
C_3N_{30}	0.77 ± 0.03^{b}	1.40 ± 0.06^{b}	1.90 ± 0.06^{b}	2.37 ± 0.07^{b}	3.30 ± 0.06^{b}
C_3N_{60}	1.00 ± 0.06^{c}	2.00 ± 0.06^{c}	2.70 ± 0.06^{c}	3.17 ± 0.03^{c}	3.77 ± 0.15^{c}
C_3N_{90}	1.27 ± 0.09^{d}	2.63 ± 0.07^{d}	3.30 ± 0.06^{d}	3.83 ± 0.03^{d}	4.23 ± 0.03^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 17: Leaf width (cm), effects of treatment levels on C_0 (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	0.17 ± 0.03^{a}	0.60 ± 0.06^{a}	0.97 ± 0.03^{a}	1.50 ± 0.12^{a}	1.93 ± 0.12^{a}
C_0N_{30}	0.67 ± 0.03^{b}	1.53 ± 0.03^{b}	2.03 ± 0.03^{b}	2.57 ± 0.09^{b}	3.13 ± 0.12^{b}
C_0N_{60}	0.97 ± 0.07^{c}	2.23 ± 0.09^{c}	2.67 ± 0.12^{c}	3.20 ± 0.06^{c}	3.90 ± 0.15^{c}
C_0N_{90}	1.50 ± 0.15^{d}	3.03 ± 0.15^{d}	3.50 ± 0.15^{d}	4.03 ± 0.13^{d}	4.83 ± 0.13^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 18: Leaf width (cm), effects of treatment levels on C_3 (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	0.33 ± 0.07^{a}	0.87 ± 0.09^{a}	1.37 ± 0.15^{a}	1.87 ± 0.12^{a}	2.33 ± 0.15^{a}
C_3N_{30}	0.73 ± 0.03^{b}	1.70 ± 0.06^{b}	2.20 ± 0.06^{b}	2.83 ± 0.03^{b}	3.50 ± 0.06^{b}
C_3N_{60}	1.37 ± 0.22^{c}	2.80 ± 0.30^{c}	3.40 ± 0.45^{c}	3.90 ± 0.50^{c}	4.43 ± 0.38^{c}
C_3N_{90}	1.93 ± 0.03^{d}	3.53 ± 0.15^{d}	4.23 ± 0.12^{d}	4.67 ± 0.12^{c}	5.03 ± 0.09^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 16 shows the effects of the treatment levels on C_3 in the Field with respect to the leaf width and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance.

Table 17 shows the effects of the treatment levels on C_0 in the Green House with respect to the leaf width (cm) and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 18 shows the effects of the treatment levels on C_3 in the Green House with respect to the Leaf width (cm) and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels at a 0.05 level of significance.

The mean Leaf width values represented in the tables illustrate the relative effects of the treatment levels and showing that increase in Nitrogen level gives rise to increase in growth rate. The results obtained in the field were similar to the Green House when compared, but performances observed in the Green House experiment were much higher than field. C_3 performed better than C_0 in field and Green House experiments with respect to all treatment levels for all weeks. This shows that C_3 has higher nitrogen use efficiency (i.e., biomass produced per unit nitrogen in a plant) than C_0.

Table 19 shows the effects of the treatment levels on C_0 in the field with respect to the leaf length and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 20 shows the effects of the treatment levels on C_3 in the Field with respect to Leaf length diameter and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and

Table 19: Leaf length (cm), effects of treatment levels on C_0 (Field)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	1.70 ± 0.06^{a}	3.33 ± 0.15^{a}	5.70 ± 0.32^{a}	7.80 ± 0.23^{a}	10.07 ± 0.69^{a}
C_0N_{30}	6.20 ± 0.40^{b}	8.83 ± 2.04^{b}	14.67 ± 2.67^{b}	17.70 ± 3.10^{b}	21.83 ± 3.43^{b}
C_0N_{60}	7.47 ± 0.18^{c}	13.67 ± 0.57^{c}	21.73 ± 0.95^{c}	25.37 ± 0.81^{c}	31.23 ± 1.86^{c}
C_0N_{90}	9.87 ± 0.23^{d}	18.53 ± 0.81^{d}	28.27 ± 1.00^{d}	33.30 ± 0.91^{d}	41.53 ± 0.99^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 20: Leaf length (cm), effects of treatment levels on C_3 (Field)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	2.60 ± 0.48^{a}	5.50 ± 0.95^{a}	8.20 ± 1.27^{a}	12.13 ± 2.46^{a}	17.30 ± 3.81^{a}
C_3N_{30}	7.47 ± 0.33^{b}	15.27 ± 0.33^{b}	21.00 ± 0.40^{b}	24.40 ± 0.47^{b}	30.43 ± 0.42^{b}
C_3N_{60}	9.97 ± 0.26^{c}	18.33 ± 0.50^{c}	26.97 ± 1.56^{c}	31.20 ± 2.28^{c}	37.93 ± 2.54^{b}
C_3N_{90}	12.80 ± 0.25^{d}	24.43 ± 1.04^{d}	36.23 ± 0.92^{d}	40.07 ± 0.95^{d}	48.27 ± 1.24^{c}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

Table 21: Leaf length (cm), effects of treatment levels on C_0 (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_0N_0	5.30 ± 0.46^{a}	7.27 ± 0.38^{a}	8.93 ± 0.47^{a}	10.83 ± 0.46^{a}	12.37 ± 0.50^{a}
C_0N_{30}	11.13 ± 0.23^{b}	15.93 ± 0.43^{b}	19.07 ± 0.65^{b}	23.70 ± 0.72^{b}	26.97 ± 0.85^{b}
C_0N_{60}	14.27 ± 0.56^{c}	23.20 ± 0.78^{c}	30.77 ± 0.69^{c}	34.33 ± 1.13^{c}	41.07 ± 1.51^{c}
C_0N_{90}	16.90 ± 0.60^{d}	28.70 ± 0.70^{d}	40.00 ± 0.95^{d}	42.57 ± 1.67^{d}	50.03 ± 0.92^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_0N_0: C_0 maize cycle with no nitrogen treatment, C_0N_{30}: C_0 maize cycle with 30 kg ha^{-1} nitrogen, C_0N_{60}: C_0 maize cycle with 60 kg ha^{-1} nitrogen and C_0N_{90}: C_0 maize cycle with 90 kg ha^{-1} nitrogen

Table 22: Leaf length (cm), Effects of treatment levels on C_3 (Green House)

	Weeks				
Treatments	1	2	3	4	5
C_3N_0	7.83 ± 0.90^{a}	11.17 ± 1.80^{a}	13.60 ± 1.89^{a}	15.53 ± 1.94^{a}	17.97 ± 2.48^{a}
C_3N_{30}	12.63 ± 0.24^{b}	22.90 ± 0.451^{b}	26.33 ± 0.47^{b}	30.37 ± 0.67^{b}	33.83 ± 0.78^{b}
C_3N_{60}	16.37 ± 0.98^{c}	27.97 ± 1.56^{c}	37.37 ± 2.64^{c}	40.77 ± 3.07^{c}	44.93 ± 4.50^{c}
C_3N_{90}	19.37 ± 0.43^{d}	32.13 ± 1.13^{c}	44.63 ± 1.11^{d}	49.77 ± 2.16^{d}	56.40 ± 1.91^{d}

Means on the same column with the same letters are not significantly different ($p<0.05$). C_3N_0: C_3 maize cycle with no nitrogen treatment, C_3N_{30}: C_3 maize cycle with 30 kg ha^{-1} nitrogen, C_3N_{60}: C_3 maize cycle with 60 kg ha^{-1} nitrogen and C_3N_{90}: C_3 maize cycle with 90 kg ha^{-1} nitrogen

N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 21 shows the effects of the treatment levels on C_0 in the Green House with respect to the leaf length and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels, at a 0.05 level of significance. Table 22 shows the effects of the treatment levels on c_3 in the Green House with respect to the leaf length and treatment combination of N_{90} performed best followed by N_{60}, N_{30} and N_0. Analysis of variance shows significant differences with treatment levels at a 0.05 level of significance.

The C_3 performed better than C_0 in field and Green House experiments with respect to all treatment levels for all weeks. This shows that C_3 has higher nitrogen use efficiency (i.e., biomass produced per unit nitrogen in a plant) than C_0. The results obtained in the field were similar to the Green House when compared, but performances observed in the Green House experiment were much higher than Field.

In summary, the significant differences between the treatment levels and control had shown that an eroded soil can be a mended by the application of appropriate dosages of NPK single fertilizers. The results showed that higher amounts of treatments applied resulted to greater values for the growth parameters measured and this generally shows that fertilizer application can improve the performance of maize crop in terms of growth and productivity.

The results also show that plant growth rate is proportional to nitrogen availability in the soil and this was clearly showed by the difference in the effects of the treatment levels recorded for both Field and Green House experiments with respect to the growth parameters measured. The values obtained were directly proportional to the level of nitrogen treatment applied, whereby the treatment combination of N_{90} performed best followed by N_{60} and N_{30}. This was observed for both field and Green House experiments. Among the two maize cycles (C_0 and C_3) used for the experiment, C_3 performed best with respect to all the growth parameters measured in both Green House and Field experiment.

CONCLUSION

The relative performances of two populations of maize could be predicted using their Percentage Emergence (%E) and Emergence Index (EI). Between the two maize cycles (C_0 and C_3) used for the experiment, C_3 performed better in both field and Green House experiments and the general performance recorded for Green House was better than field experiments. The treatment combination N90 performed best. Other treatment combinations performed better than control.

Finally, with respect to the specific objectives of the study, the treatment combination of 90 kg ha^{-1} N, 60 kg ha^{-1} P and 60 kg ha^{-1} K gave the best performance, while C_3 performed better than C_0. Therefore mineral fertilizers can be recommended according to the agro-ecological diversity of agricultural area, with support systems of integrated nutrient management, particularly in areas of low soil fertility.

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