Effects of NPK fertilizer on soil properties and prema onion *(Allium cepa L.)* performance in a humid environment at Obio-Akpa, Akwa Ibom State

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Abstract

This study was conducted in 2022/2023 planting season at the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa Campus, Oruk Anam Local Government Area, Nigeria, to determine the effects of NPK 15-15 -15 fertilizer rates on selected soil properties, growth and bulb yields of prema onion as well as the relationships between selected soil properties and bulb yields of the onion. The field experiment was laid out in a randomized complete block design (RCBD) with three replications. Four rates of the NPK fertilizer (0, 400, 600 and 800 kgha^{-1}) and prema onion were used for the experiment. Soil samples were collected before and after field experiment at 20 cm depth with a soil auger and processed for laboratory analysis. The NPK fertilizer increased soil pH, EC, total N, available P, exchangeable K, growth and bulb yield of the onion but reduced the SOM content as fertilizer rates increased. The highest mean plant height (66.79 cm), number of leaves (13.52), stem girth (1.30 cm), fresh bulb weight (19.25 tons/ha) and bulb circumference (22.3 cm/bulb) were recorded for 800 kgha^{-1}, followed by 600 kgha^{-1} and 400 kgha^{-1} in that order, whereas the lowest plant height (47.94 cm), number of leaves (10.39), stem girth (0.69 cm), fresh bulb weight (10.4 tons/ha) and bulb circumference (18.1 cm) were recorded for control plots. The 400 kgha^{-1} NPK fertilizer rate was recommended to enhance soil fertility and prema onion production in the study area considering the economic and environmental implications of using higher rates.

Keywords: NPK fertilizer, soil chemical properties, onion growth and bulb yield

Introduction

Food security continues to pose serious challenge to Nigeria and other developing African countries due to the fast increase in human population coupled with decreasing natural resources such as land and climate change effects (Sowe *et al.*, 2020). The soil being a component of the land, usually serves as a base for food production. Soil condition and weather characteristics appear to be the most influential factors affecting the growth and yield of vegetable crops such as onion, as the crop thrives optimally only on fertile, well-drained, sandy-loam with fine tilth and slightly acidic soils with pH 6.0 – 8.0 (Savva and Frenken, 2002; SHEP PLUS, 2019). Most soils in the humid parts of Nigeria are sandy and infertile, prone to excessive leaching and erosion problems occasioned mostly by torrential rainfall and their pH levels tend to be lower than the aforementioned soil pH value. As a result, there is decrease in soil fertility and productivity, scarcity and high cost of onion bulbs in the region. About 99.97% of onion consumed in Nigeria is produced in the arid northern parts of the country (including Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Nasarawa, Plateau and Sokoto States), while only 0.01 - 0.02% is produced in the humid southern parts of the country particularly Imo and Ondo States (National Bureau of Statistics, 2012; FAO, 2020). Onion is usually more sensitive to soil fertility status and weather condition than other vegetables (Boyhan and Kelly, 2008; Vijay *et al.,* 2022). Onion bulb size can be increased by the application of adequate fertilizers during the growing period (Birhanu, 2016). Hence, the need to apply the right fertilizers at the right time, right quantity and right place to ensure nutrient balance required for optimal growth and maximum bulb yield.

Adequate application of NPK fertilizers usually enhances the supply of major soil nutrients and greatly increases the growth, yield and quality of crops per unit area (Ferreira *et al.,* 2019; Al-Amri, 2021). Too high or too low fertilizer application rates may have negative influence on crop growth and development (Bai *et al.,* 2022). Excessive use of fertilizer nutrients particularly nitrogen (N) in crop production can significantly alter the soil properties resulting in soil acidification, which may reduce soil health, nutrients availability and crop productivity (Raza *et al.,* 2020; Raza *et al.,* 2021; Kuzyakov *et al.,* 2021). It also causes serious environmental threats, such as the eutrophication of surface waters, nitrate pollution of ground water and greenhouse gas emissions (Sánchez, 2010; Erisman *et al.*, 2013).

Onion (*Allium cepa* L.) is one of the most consumed vegetables and one of the most important cash-generating crops for farmers around the globe (Kassa and Ahmed, 2018). It is used in food preparations (Salad, Sauces, Fried rice, Stew, soup, Pepper soup, Bean cake, among others) mostly for its flavour and nutritional benefits (Salami and Omotoso, 2018). Onion bulbs are rich in carbohydrates, protein, vitamins (particularly vitamin C) and mineral salts such as phosphorus and calcium (Ramesh *et al.*, 2017; Adeyeye *et al.*, 2017). Onions possess essential antioxidant, anti-inflammatory, antimicrobial properties (Choi *et al.*, 2007) and have cardio-protective effects due to the presence of organo-sulfur compounds they contain (Kris-Etherton *et al.*, 2002). According to Galeone *et al.* (2006), such properties of onions may treat or prevent cardiovascular diseases, cancer and others diseases.

Even though the crop has great economic and health benefits, its production and productivity have not yet scaled to the required level especially in the humid southern parts of Nigeria. Thus, farmers in the area are yet to appreciate as well as derive enough nutritional and financial benefits from onion production. This may be due to certain factors, such as, scarcity of standard agronomic information, soil fertility status and the weather characteristics, high costs of inputs, lack of adequate storage facilities, limited access to improved seeds, fluctuation of market price, poor yield and postharvest losses (Grema and Gashua, 2014). As long as information on similar research is scarce, this study focused on generating information that may help farmers attain maximum onion production in Akwa Ibom State and other parts of the humid tropical region of the country thereby making it much more available and affordable to consumers and profitable to farmers. Thus, the objectives of this study were to determine the effects of NPK 15-15-15 fertilizer application on selected chemical properties of the soil cultivated with onion; assess the influence of NPK 15-15-15 fertilizer on growth and bulb yield of *prema* onion; determine the relationships between selected soil chemical properties and bulb yields of *prema* onion and recommend suitable rates of the NPK fertilizer for improving soil fertility, growth and bulb yields of *prema* onion in the study area.

Materials and Methods

Field study was conducted in 2022/2023 planting season at the Teaching and Research Farm Akwa Ibom State University, Obio Akpa Campus, Oruk Anam Local Government Area, Akwa Ibom State, Nigeria, which is located on latitude 5° 0' 11.8296" N and longitude 7° 46' 27.372" E. The study area has wet tropical climate that is characterized by a 7months wet season April – October and a 5months dry season November – March (Ekong and Uduak, 2014). The annual rainfall in the area varies between 2250 and 2500 mm while the mean daily temperature varies between 26 and 27°C. The vegetation in the study area is predominantly secondary forest. Soils in the area are mostly derived from coastal plain sands and are classified as Ultisols (Ibia, 2012; Uduak *et al.*, 2020). The experiment consisted of four rates of NPK 15:15:15 fertilizer (0, 400, 600 and 800 kg ha^{-1}) denoted as T_0, T_1, T_2 and T3, respectively and *prema* onion laid in a Randomized Complete Block Design (RCBD) with three replicates. Transplanting of onion seedlings was carried out seven weeks after nursery establishment. The onion seedlings were planted at a spacing of 30 cm x 30 cm (0.3 m x 0.3 m). One seedling was sown per hole at 30 different points in each of the 12 subplots measuring 2 m x 3 m each. Irrigation water was applied every other day using a calibrated watering can. The fertilizer was applied two weeks after transplanting (WAT) using ring method. The field was weeded clean at 2, 5, 8 and 11 weeks after transplanting. Data on growth were collected at 4, 6, 8, 10 and 12 WAT. Harvesting of onion bulbs was done manually by hand pulling at four (4) months after transplanting. Data on onion bulb yields were collected after harvesting. Soil samples were collected before and after the field experiment. Prior to the experiment, one composite sample of the soil was collected at 0 – 20 cm depth using a soil auger and processed for physicochemical analysis. At the end of the field experiment, four composite samples were collected at 0 – 20 cm depth from the experimental field on plot/treatment basis, processed and analyzed for selected chemical properties. The procedures reported by Udo *et al.* (2009) were used to determine particle size distribution, electrical conductivity, pH, organic matter, total nitrogen, available P, exchangeable bases, exchangeable acidity (EA), Effective cation exchange capacity (ECEC) and base saturation (BS).Analysis of variance (ANOVA) was conducted on the collected data using the GenStat 12th edition (VSN International, 2009). Mean separation was done by Fisher's protected least significant difference (F-LSD) test at 5% probability level (Ibanda *et al.*, 2018). Correlation between selected soil chemical properties and bulb yield of *prema* onion was done to determine their relationships.

Results and discussion

Physicochemical properties of the pre-experimental soil

The physicochemical properties of the pre-experimental soil (20 cm depth)are shown in Table 1. The sand, silt and clay contents of the soil were 77.00, 5.20 and 17.80 %, respectively and the distribution of these particle sizes produced the sandy loam texture for the soil layer. The soil type characterized by moderately coarse texture is capable of quickly draining excess water, but cannot hold good amounts of water and nutrients. Hence, regular application of nutrients and irrigation are important (Esu, 2010). Electrical conductivity 0.10 $dSm^{-1}$was low (Chaudhari *et al.*, 2018). Low electrical conductivity levels are often found in sandy soils whereas high EC levels are usually found in clay-rich soils (Marno, 2019). The low EC of the soil may be attributed to the leaching of salt from the top soil to the sub-soil as conditioned by soil texture and high rainfall capable of dissolving and draining excess salt down the soil profile (Chaudhari *et al.*, 2018). The pH value of the soil was 4.8 indicating very strongly acidic reaction based on the ratings reported by Adaikwu and Ali (2013). Based on the soil fertility ratings commonly used in Nigeria, the soil was found to be very low in exchangeable K and Na (Adaikwu and Ali, 2013; Michael and Sajo, 2020); low in exchangeable Ca (Adaikwu and Ali, 2013; Michael and Sajo, 2020); moderate in organic matter, available P, exchangeable Mg and ECEC (FDALR, 1990); and fairly high in total nitrogen, exchangeable acidity and base saturation (FDALR, 1990; Adaikwu and Ali, 2013).These results agree with the reports of Ekong and Uduak (2014) and Itakufok *et al.* (2020). The low levels of nutrients obtained in the pre-experimental soil indicate low fertility status and may be attributed to high temperature, high rainfall and inappropriate agricultural practices which characterize the tropical areas (Osodeke, 1996). It could also be attributed to continuous cropping which necessitates the need for an additional supply of nutrients. High rainfall causes water erosion and leaching losses in these areas, particularly where soils are left bare. High temperature is associated with high rates of organic matter decomposition and volatilization of some plant nutrients (including nitrogen and sulphur). Inappropriate agricultural practices such as slash and burn, clean weeding, overgrazing, conventional tillage and intensive cropping are known to deplete soil nutrients and water (NRCS, 2011).

Effects of NPK fertilizer rates on selected soil properties at Harvest

The selected soil chemical properties at harvesting as influenced by the NPK fertilizer application are shown in Table 2. The highest EC (0.17 dSm^{-1}) was observed in T_3, followed by T_2 and T_1 in that order whereas the least EC (0.11 dSm^{-1}) was recorded in T_0 (control). The highest pH value was recorded in T_3 and lowest in T_0 (control).Soil organic matter (SOM) contents varied from 2.98% to 3.01%. T_0 (control) recorded the highest soil organic matter content, while the lowest value was recorded for T_3. Total N, available P and exchangeable K contents of the soil were the highest in T_3, followed by T_2 and T_1, while the lowest was recorded in T_0 (control). Increase in soil pH indicated noticeable effects of NPK fertilizer application rates on the pH of the soil at harvesting. Yang *et al.* (2007) and Gu *et al.* (2009) reported that NPK fertilizer had no effect on soil pH, whereas Shen *et al.* (2010) and Hu *et al.*(2011) reported that NPK fertilization had significant effects on soil pH. These inconsistent results could be due to differences in soil types, NPK fertilizer quality, climate and duration of the experiment, among other factors. The NPK fertilizer rates of application had significant effects ($P < 0.05$) on the electrical conductivity, pH, total N, available P and exchangeable K with non-significant effects ($P > 0.05$) on the soil organic matter contents of the experimental soil. Obviously, the much greater increase in soil chemical fertility, recorded in T_3 and T_2 could be attributed to higher rates of NPK fertilizer application compared to T_1 and T_0 (control).

Effects of NPK fertilizer rates on the growth of

Prema onion

Results presented in Table 3 shows the effects of NPK 15-15-15 fertilizer rates on the growth of *prema* onion. The 800 kgha^{-1}(T_3) of NPK fertilizer treated soil produced the highest effects on mean plant height (66.79 cm) per plant, number of leaves (13.52) per plant and stem girth (1.30 cm) per plant, closely followed by T_2(600 kgha^{-1}) and T_1(400 kgha^{-1}),whereas the lowest effects on mean plant height, number of leaves and stem girth were recorded in T_0 (control plots) that received 0 kgha^{-1} NPK fertilizer. The fertilizer rates of application had significant effects ($P<0.05$) on all the growth indices of *prema* onion. The increase in growth of the onion crops that received higher rates of NPK fertilizer than the control could be due to the quantity and rate of release of the major plant nutrients present in the inorganic fertilizer thereby providing better growth and development of the plants. This result is similar to the results of Abdelrazzag (2002), Ayoola and Adeniyan (2006) and Neihikhere (2019), who reported that different rates of NPK 15:15:15 fertilizer applied had different effects on crop growth, thereby making its application necessary especially in poor soils, where there is too much rainfall and inappropriate agricultural practices such as bush burning, clean weeding, overgrazing, conventional tillage, continuous cropping and intensive cropping. Jeyathilake *et al.* (2006) stated that onion is a heavy feeder of nutrients and that the nutrients play important role in boosting growth, productivity and quality of onion. The least effects on the crop growth indices recorded in the control plots could be due to the fact that no fertilizer was applied to the plots and so the crops had to depend on the inherent soil nutrients for their growth and development. This trend was similar to the result reported for edible pea by Kulsum *et al.* (2007).

Effects of NPK15:15:15fertilizer rates on the bulb yields of Prema onion

Figure 1 shows the effects of NPK fertilizer rates on bulb yield of *prema* onion. The maximum fresh bulb weight (19.25 tons/ha) was produced with T_3(800 kgha^{-1}), followed by T_2 (17.03 tons/ha), T_1 (16.26 tons/ha) and T_0 (10.4 tons/ha). Maximum bulb circumference (22.3 cm) was also obtained with T_3 compared to T_2 (18.2 cm), T_1 (19.3 cm) and T_0 (18.1 cm). This result agrees with Ayoola and Adeniyan (2006) and Neihikhere (2019), who reported that different rates (300, 600, 800 and 1000 kg ha^{-1}) of NPK 15:15:15 fertilizer applied had different effects on crop yield. The highest fresh bulb weight recorded inT_3 (800 kgha^{-1}) plots could be due to the rate of NPK fertilizer applied and so the crops had to efficiently use the nutrients for formation and development of superior bulbs. Abdelrazzag (2002) found that the yield indices of onion (*Allium cepa*) increased with increase in the application rate of NPK 15:15:15 fertilizer. This trend was similar to the result reported for edible pea (Kulsum *et al.*, 2007). They recommended that relatively high level of nutrients is required for optimum development and yield of crops.

Relationships between selected soil properties and yields of Prema onion

As shown in Table 4, the soil electrical conductivity (r = 0.915 and r = 0.624), pH (r = 0.897 and r = 0.765), total nitrogen (r = 0.991 and r = 0.678), available phosphorus (r = 0.934 and r = 0.701) and exchangeable potassium (r = 0.969 and r = 0.763) showed positive relationships with the fresh bulb weight and bulb circumference yield components of *prema* onion while the soil organic matter (r = 0.513) showed a positive relationship with fresh bulb weight but negatively (r = -0.150) related with the bulb circumference yield component of *prema* onion. However, it was observed that only total N (r = 0.991**)and exchangeable K (r = 0.969*) showed significant statistical relationships with fresh bulb weight. This trend is similar to studies by Lawlor (2002), Ghaffoor *et al.* (2003), Vance *et al.* (2003) and Wang *et al.* (2013) who reported that crop growth is significantly influenced by the availability of nutrients majorly: nitrogen, phosphorus and potassium.

Conclusion and recommendation

The study investigated the effects of NPK 15-15-15 fertilizer rates on selected soil properties and performance of *prema* onion at Obio Akpa, Akwa Ibom State, Nigeria. NPK 15:15:15 fertilizer contains major soil nutrients that are useful in optimizing or raising the fertility status of poor unproductive soils. In this study, the application of NPK 15:15:15 fertilizer significantly ($P<0.05$) increased the soil electrical conductivity, pH, total nitrogen, available P and exchangeable K. Organic matter content of the experimental soil at harvest decreased with increase in the NPK fertilizer rates. Although 800 $kgha^{-1}$ recorded the highest effects on growth and bulb yields of *prema* onion, followed by 600 $kgha^{-1}$, 400 $kgha^{-1}$ seemed to produce the most economical effects on growth and bulb yield as well as environmental-friendly effects, whereas the least effects on growth and bulb yield were recorded for the control plots. Soil total nitrogen and exchangeable K had significant relationship with onion fresh bulb weight whereas pH and available phosphorus showed significant relationships with the onion bulb circumference ($P<0.05$). Based on the findings of this study, it was recommended that NPK fertilizer can be used solely, to optimize soil fertility as it contains nutrients that would help raise the soil fertility status and crop performance. It was recommended that relatively high level of nutrients is required for optimum growth and development of the crop. The application of NPK 15: 15: 15 fertilizer at the rate of 400 $kgha^{-1}$was recommended for the improvement of soil fertility and *prema* onion production in the study area considering the economic and environmental implications of using higher rates.

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Table 1: Physicochemical properties of pre-experimental soil

Soil Property	Value
Sand (%)	77.00
Silt (%)	5.20
Clay (%)	17.80
Textural Class	SL
Electrical conductivity (dSm^{-1})	0.10
pH (H_2O)	4.80
OM (%)	4.46
TN (gkg^{-1})	0.6
Av. P ($mgkg^{-1}$)	12.17
Exchangeable Ca ($cmolkg^{-1}$)	4.01
Exchangeable Mg ($cmolkg^{-1}$)	2.33
Exchangeable K ($cmolkg^{-1}$)	0.13
Exchangeable Na ($cmolkg^{-1}$)	0.08
EA ($cmolkg^{-1}$)	1.89
ECEC ($cmolkg^{-1}$)	8.44
BS (%)	77. 60

SL = sandy loam, OM = organic matter, TN = total nitrogen, Av.P = available P, EA = exchangeable acidity, ECEC = effective cation exchange capacity, BS = base saturation

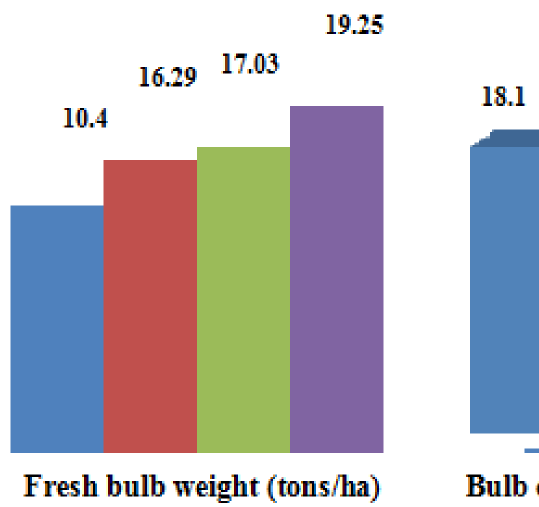

Fig. 1: Effects of NPK fertilizer application rates on fresh bulb weight and b

Table 3: Effects of NPK fertilizer rates on the growth of *prema* onion

Treatment (kgha^{-1})	4WAT	6WAT	8WAT	10WAT	12WAT
			Plant height (cm/plant)		
T_0	43.98	45.37	47.56	47.85	47.94
T_1	50.35	51.82	54.11	55.88	55.96
T_2	52.20	53.72	56.04	60.98	61.05
T_3	53.70	57.04	61.00	66.57	66.79
LSD ($p<0.05$)	5.66	5.09	5.03	4.90	4.94
			Number of leaves		
T_0	6.57	7.47	8.28	10.33	10.39
T_1	8.13	9.10	10.23	12.30	12.38
T_2	8.45	9.03	10.37	12.38	12.56
T_3	9.32	9.93	11.13	13.40	13.52
LSD ($p<0.05$)	1.07	1.04	0.86	0.59	0.62
			Stem girth (cm/plant)		
T_0	0.44	0.57	0.65	0.68	0.69
T_1	0.53	0.64	0.75	0.80	0.83
T_2	0.73	0.83	1.00	1.09	1.12
T_3	0.86	1.05	1.18	1.27	1.30
LSD ($p<0.05$)	0.11	0.17	0.21	0.19	0.19

T_0 = 0 kgha^{-1}, T_1 = 400 kgha^{-1}, T_2 = 600 kgha^{-1}, T_3 = 800 kgha^{-1}, WAT = weeks after transplanting

Table 4: Correlation matrix between selected soil properties and bulb yields of *prema* onion

	Fresh weight	Bulb circumference	EC (dsm^{-1})	pH	OM (%)	TN (%)	Av. P ($mgkg^{-1}$)	Ex.K ($mgkg^{-1}$)
Fresh weight	1							
Bulb circumference	0.693	1						
EC	0.915	0.624	1					
pH	0.897	0.765	0.977*	1				
OM	0.513	-0.150	0.679	0.516	1			
TN	0.991**	0.678	0.961*	0.940	0.584	1		
Av. P	0.934	0.701	0.994**	0.991**	0.600	0.972*	1	
Ex. K	0.969*	0.763	0.970*	0.978*	0.512	0.987*	0.988*	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)