

Growth and Yield Response of Okra (*Abelmoschus Esculentus*) to the Application of Different Rates of Phosphorus in Makurdi

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Article History	Abstract
Original Research Article	<p><i>Laboratory and field experiments were carried out to determine the growth and yield response of okra (<i>Abelmoschus esculentus</i>) to the application of different rates of Phosphorus in Makurdi. Different soils were sampled at the depth of 0-20 cm, sieved using 2 mm sieve and air-dried for laboratory and field experiments respectively. Clemson spineless variety of okra seeds were planted in plots of equal measurements a total of 15. Standard agronomic practices were carried out and the okra plant was harvested 62 days after planting. Data collected include mean plant height at 4, 6, 8 and 10 weeks after planting (cm), mean pod length of okra at 4, 6, 8 and 10 weeks after planting (cm), mean pod weight of fresh okra (g) and mean number of pods. Results obtained were statistically analyzed using standard soil analytical procedures. The results indicated that there was response to the application of Phosphorus in the number of okra pods using different rates of P application and this is attributed to the fact that P is required in early growth of okra due to the redistribution or remobilization of P to the soil. However, the difference in the analytical results of plant height, pod length and fresh pod weight did not confer the difference significantly. Soil sampled showed little variations in the soil test values; the soil was low in P, N, K, CEO and O.M. This is an indication of low inherent soil fertility status which calls for improved soil management techniques. It is recommended that further studies be carried out to determine the inherent soil fertility status of Makurdi soils for enhanced specific crop requirements and sustainable production.</i></p> <p>Keywords: Growth, Yield Response, Okra (<i>Abelmoschus esculentus</i>) Phosphorus.</p>
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Introduction

Phosphorus (P) is a vital macronutrient necessary for good plant growth and development; nonetheless, it is frequently the most limited nutrient in several soil systems. Plants show a variety of physiological and metabolic changes as the amount of phosphorus changes, especially when the weather changes with the seasons. Phosphorus is not as mobile in the soil as other important nutrients, therefore plants can't take it up as easily. As a result, it is often the main thing that limits crop yield (Hinsinger, 2001). This problem is especially bad in tropical farming systems, where the native soil phosphorus levels are usually low. To keep crops growing, farmers have to use fertilisers and other outside inputs (Hinsinger, 2001).

Phosphorus is an important part of nucleic acids, phospholipids, and energy-transfer molecules like adenosine triphosphate (ATP). It is very important for plant

physiological activities. It is directly engaged in metabolic activities that store and release energy, which are necessary for cellular functioning, seed formation, and root development (Fairhurst et al., 1999). Phosphorus is also necessary for turning solar energy into chemical energy, which makes it possible to make food, fibre, and other goods from plants (Beegle and Durst, 2016). So, it is important for improving plant health, crop productivity, and overall agricultural efficiency that it is readily available.

Okra (*Abelmoschus esculentus* (L.) Moench), often known as lady's finger, is a vegetable that is very valuable and belongs to the Malvaceae family. People think that the crop came from parts of West Africa, Ethiopia, and South Asia. It is now grown all over the world in tropical, subtropical, and temperate areas (Tindall, 1983). Okra is one of the most popular vegetables in Nigeria, coming in third in both

production and consumption after tomatoes and pepper (Ibeawuchi, 2007). It is a major crop in both subsistence and commercial farming since it is important for both the economy and nutrition. This is especially true in areas where growing vegetables is a big element of food security and making money.

Objectives of the Study

This study was carried out to:

1. Determine the response of okra to different rates of P in Makurdi.
2. Determine the optimum rate of P fertilization for okra in Makurdi.

Literature Review

Phosphorus(P)

Phosphorus (P) is a necessary macronutrient that plants need in big amounts to grow and develop properly. It is an essential element in energy-carrying molecules like adenosine diphosphate (ADP) and adenosine triphosphate (ATP), which are important for storing and moving energy in the body (Olusola O. Agbede). Phosphorus is also a constituent of nucleic acids and is necessary for metabolism in cells, seed formation, and root growth (Fairhurst et al., 1999; Beegle and Durst, 2016). A good supply of phosphorus helps crops grow better by increasing grain yield, crop quality, root growth, stalk strength, and early maturity. On the other hand, a lack of phosphorus stunts growth, slows down crop development, and lowers the quality and amount of the output. It may also make the canopy close later, which can lead to soil erosion and nutrient loss, especially in tropical areas. Phosphorus is one of the least available nutrients in soils since it doesn't move around easily, which makes it a major limiting factor in agricultural output. Because of this, it has been supplemented with fertilisers in the past, first from natural sources such ground bone and then from chemically processed phosphate fertilisers (Hinsinger, 2001; Beegle and Durst, 2016).

Phosphorus doesn't escape into the air like nitrogen does, and it doesn't leach out of the root zone very often, so soil testing can give us a good idea of how much is available. But its behaviour in soil is complicated because it is mostly immobile and only occurs in very low concentrations in the soil solution, even though plants need a lot of it. The amount of phosphorus that crops may take up relies on a number of things, such as the pH of the soil, the overall amount of phosphorus in the soil, the ability of the soil to hold onto phosphorus, and how the fertiliser is applied. Phosphorus gets fixed and unavailable to plants in many soils, therefore careful management is needed to make sure there is enough of it. Symptoms of deficiency usually include slow growth, delayed maturity, and purple spots

along the edges of lower leaves, especially in young plants. Using phosphorus on crops is important for their growth, but too much of it can cause problems for the environment, like water pollution from runoff and erosion. This can lead to eutrophication, which is when aquatic plants and algae grow too much and can harm aquatic ecosystems (Beegle and Durst, 2016).

Forms and functions of phosphorus in Plants

Phosphorus is the second most essential nutrient influencing plant growth and productivity worldwide, after nitrogen. Plants absorb phosphorus from the soil solution primarily in the form of orthophosphate anions, namely dihydrogen phosphate (H_2PO_4^-) and hydrogen phosphate (HPO_4^{2-}), with the dominant form depending on the soil pH. At a pH level of approximately 7.2, both forms are present in nearly equal proportions and are equally available for plant uptake. These phosphorus forms play a vital role in supporting key physiological processes, including energy transfer, root development, and overall plant growth.

Phosphorus is an important part of plant structure and function. It makes up around 0.1–1.0% of plant tissue. It is a vital constituent of nucleoproteins in the cell nucleus that control cell growth and division. It is also a key part of deoxyribonucleic acid (DNA), which is responsible for passing on traits from one generation to the next. Phosphorus is also an important ingredient of many organic compounds in plants and animals. This is especially true for adenosine diphosphate (ADP) and adenosine triphosphate (ATP), which are used to shift energy from one form to another and provide energy for many metabolic activities. It is also a part of ribonucleic acid (RNA), which is needed to make proteins. Phospholipids, phytin, phosphorylated sugars, nucleoproteins, nucleic acids, pyridine nucleotides (TPN and DPN), and flavin nucleotides like riboflavin (vitamin B2) are all other important phosphorus-containing compounds. These show how important phosphorus is for plant growth and metabolism.

Functions of phosphorus in plants

Phosphorus compounds play significant roles in plants among which are:

Energy transfer reactions happen in a lot of different plant metabolic processes, like flowering and fruiting (including seed formation), crop maturity (where P counteracts the effects of too much nitrogen), and improving the quality of forage and the taste of vegetables. They also happen during cell division and multiplication, when fats and albumin are formed, and when starch is turned into sugar during cell respiration.

Okra

Okra (*Abelmoschus esculentus* L. Moench), colloquially known as lady's finger, is a significant and extensively

grown vegetable crop in the Malvaceae family, originating from tropical and sub-tropical parts of West Africa (Tindall, 1983). Adewole and Ilesani (2005) say that the best way to cultivate okra is to take care of the soil and nutrients so that they can support growth and yield. The crop is best in soils with a pH range of 5.8 to 6.8 and does best when it gets full sun, especially when the rows are facing east-west to catch as much light as possible (Ahmed, 2002). If the pH of the soil is too low or too high, you can change it by adding sulphur to make it more acidic (lower pH) or calcium carbonate (lime) to make it more alkaline (raise pH). It is important to add these amendments slowly and keep an eye on the soil by testing it every so often to make sure the conditions are right for growing (Adewole & Ilesani, 2005).

Okra grows best in soil that is moist, crumbly, and well-drained (Kochhar, 1986). Using both organic and inorganic fertiliser is an important part in growing okra (Palm et al., 1997). The plant can handle drought stress (Majanbu et al., 1985), but it needs extra irrigation water to grow well (Okunade et al., 2008). Okra may grow in any kind of soil, however sandy loam soils with a lot of organic matter are the best (Ibeawuchi, 2007). When planting, the seeds are directly sown into the soil at linch depth. To enhance prompt germination and emergence, okra seeds are soaked in water for several hours or overnight. Provide organic matter to serve as organic fertilizer hence poultry droppings can be effectively used or inorganic fertilizers rich in Nitrogen-Phosphorus-Potassium NPK. Before planting, soil testing using soil test kit must be done to determine the level of lime and fertilizer your soil needs for best growth, in cases where the soil is deficient in lime, Dolomite lime and NPK fertilizer must be applied. Dolomite lime is required to maintain an acidic pH which encourages high yields. (Adewole and Ilesani, 2005).

Common issues associated with Okra Farming

Curved or twisted pods are caused by sucking insects that feed directly on developing pods. Common pests include flea beetles, stink bugs, aphids, maize earworms, fire ants, and root knot nematodes (Lee et al., 1990).

Control of Diseases

To have the best okra crop, it's important to handle soil-borne illnesses well. Ahmed et al. say that pre-planting soil fumigation and the right crop rotation strategies are important for managing diseases including root-knot nematodes, stem blight, Verticillium wilt, and Fusarium wilt. Okra needs enough of the right nutrients, like nitrogen, phosphorus, potassium, calcium, sodium, and sulphur, to keep the soil fertile, help the plants grow, and increase the harvest. These nutrients have unique physiological functions that improve the availability of nutrients, the uptake of nutrients by roots, and the general growth of

plants. So, using the right amount of fertiliser at the right time is very vital for getting the most out of your plants. Phosphorus fertiliser is especially important because it has a big effect on plant growth and yield (Yogesh & Aora, 2001). Okra is very important in Nigeria, where it is the third most produced and eaten vegetable after tomatoes and peppers (Ibeawuchi, 2007).

Okra grows best in warm weather, and the best soil temperature range for germination, growth, and reproduction is 24–30°C. The main reason people grow this crop is for its tasty green pods, which can be eaten fresh or processed by freezing, canning, or drying. Okra is often used to thicken soups when it is dried (Yadav and Dhanker, 1990). Okra pods are good for you since they are high in minerals like calcium, potassium, and iron, as well as vitamins and other good nutrients (Lee et al., 1990). These traits show how important okra is as both a food and a money-making crop in tropical farming systems.

Clemson Spineless

This is an okra variety with a very wide adaptability with the pods virtually spineless, the pods are uniform, attractive, green and have good shelf life. It matures very early approximately 55-65 days post sowing, seeds are open-pollinated and the plants are self-pollinating meaning, resulting seeds can be saved planted and grown true to parent stock. The pods are pentagonal or tapered in shape with leaf size 18-20cm. The plant is tall, spreading, medium leafed and around 1.2-1.5m plant height. It has an average seed count of 160-185 seeds per gram (Majanbu et al.).

Materials and Methods

Description of Study Area

The study involved laboratory and field experiments. A piece of land measuring 30mx30m was manually cleared using a West African hoe and cutlass. Subplots measuring 4mx4m were subsequently measured out with 1m inter-plot boundary.

The study was carried out behind the University of Agriculture Makurdi Clinic.

The land lies on Latitude 7.7871° N and Longitude 8.624125° S on an Altitude of about 318feet above the sea-level.

A West African hoe was used to till the plots and a fine tilth was obtained. Composite soil samples were taken from this plot for laboratory analysis. Three okra seeds were planted per hole at a spacing of 8cm x 10cm and later thinned to two. Soil samples (0-20cm depth) were collected using a soil auger. The samples were properly labelled and immediately transported to the analytical soil science laboratory.

Sample Preparation

The samples were air-dried and mechanically pounded using a mortar and pestle, then passed through a 2 mm sieve for laboratory analysis.

Laboratory Analysis

We used both a 1:2 soil–water suspension and a 1:1 soil–KCl suspension to find out the pH of the soil. The hydrometer method as described by Bouyoucos (1951) was used to look at the distribution of particle sizes, and the chromic acid oxidation method of Walkley and Black (1934) was used to find the amount of organic carbon. Neutral ammonium acetate was used to extract exchangeable bases. Flame photometry was used to detect the quantities of sodium and potassium, and an Atomic Absorption Spectrophotometer (AAS) was used to measure the amounts of calcium and magnesium. We used 1 M KCl extraction and then titration with 0.01 M NaOH to measure exchangeable acidity. We used the Macro-Kjeldahl digestion method to find out how much nitrogen present in the soil samples.

Planting

Clemson spineless seed variety was obtained at the University of Agriculture, Makurdi Teaching and research farm and directly sown using a measuring stick at about 1.4cm deep and spaced 8-10cm apart in a single row on top of the well levelled sandy-loamy soil, the seeds germinated and emerged at 3-4 days post planting, three leaves had formed at 7-8 days, thinning was manually done using bare hands prior to weeding.

Weeding

Weeding was done using a West African hoe.

Treatment Application

Five levels of Phosphorus were applied to the plots to produce the treatments. These treatments were control (0KgPha'), 15Kg Pha, 30kg Pha^{-1} , 45KgPha and 60KgPh'. These treatments were replicated three times and the field was laid out in a Randomized Complete Block Design (RCBD). All controlled plots received an initial application of 53.3g of Urea and 40g of KCl to make up the requirement for Nitrogen and Potassium respectively. The crop was grown to maturity and the first harvest was done eight weeks after planting (8WAP). The crop was harvested at 2days interval and up to seven harvests were done.

Control

0KgPha^{-1}

T_2	15KgPha^{-1}
T_3	30KgPha^{-1}
T_4	45KgPha^{-1}
T_5	60KgPha^{-1}

Harvesting

Okra pods were harvested when the tip of the pods were observed to break easily when pressed with the fingertip (Usman, 2001), long-sleeved shirt and hand gloves were used to avoid unnecessary itching from direct contact with the okra stiff leaf hairs. The entire plots were harvested for growth and yield measurement parameters.

Data Collection

Data collected include plant height at 4, 6, 8 and 10 weeks after planting, Pod length (cm), Pod Weight after harvesting (g) and number of pods.

Statistical Analysis.

Data collected was subjected to the Analysis of Variance and means that were significant were separated using the Fischer's Least Significant Difference (FLSD).

Results

Properties of the experimental location are shown on table 1.

The pH of the site was 6.40 indicating that the soil was slightly acidic.

Clay content was found to be 12.60% and the texture was determined as sandy loam.

The organic matter (O. M) was determined as 2.84% while N was determined as 0.40%.

Phosphorus, P was determined to be 4.4 ppm whereas K was determined to be 0.3 Cmolkg^{-1} , Na was determined to be 0.28 Cmolkg^{-1} Mg was determined at 3.3 Cmol kg^{-1}

while Ca was determined to be 3.65 Cmol kg^{-1} .

Exchangeable Base (EB) was determined to be 7.53 Cmolkg^{-1} , Exchangeable Acid (EA) was determined to be 1.06 Cmol kg^{-1} while Cation Exchange Capacity (CEC) was determined as 8.59 Cmolkg^{-1} and Base Saturation (BS) was determined as 87.62%.

Mean plant height at 4, 6, 8 and 10 WAP.

The mean of P rates on plant height at 4, 6, 8 and 10 WAP are presented on Table 2. At four weeks after planting (4WAP), plant height ranged from 8.70cm with 60kg P ha to 10.10cm with 45kg P ha'. At six weeks after planting (6WAP), the least plant height (9.97cm) was obtained with 0kg Pha'(Control) while the height (11.63 cm) was obtained with 45kg P ha'. Similar results were obtained at eight weeks after planting (8WAP) where 0kg P ha (Control) recorded the least height of 11.67cm while the highest height was obtained with 15kg P ha-with 13.93 cm. However, the results at ten weeks after planting (10WAP) showed that, 0kg P ha' (Control) and 45kg P ha'-had the least height at 18.90 cm respectively while the highest height was attained at 20.90cm with 15kgPha'. There was no

significant difference in terms of plant height across the treatments.

Mean Pod length at 4,6,8 and 10 WAP.

The mean pod length at 4,6,8 and 10 is presented in Table 3.

At four weeks after planting (4WAP), the pod length ranged from 0.40 cm with 0kg P ha⁻¹ and 60kg P ha⁻¹ respectively to 0.60cm with 45kg P ha⁻¹. Also, at six weeks after planting (6WAP), the highest pod length was attained at 15kg P ha⁻¹ and 45kg P ha⁻¹ respectively with 0.80cm while the least pod length was obtained with 30kg P ha⁻¹ and 60kg P ha⁻¹ respectively at 0.67cm. Similarly at eight weeks after planting (8WAP), the least pod length was 0.93cm with 0kg P ha⁻¹ and the highest result was obtained with 15kg P ha⁻¹ at 1.16cm. However, at 10WAP, the result ranged from 1.03cm with 0kg P ha⁻¹ and 1.26 cm with 15kg P ha⁻¹ where the lowest and the highest ranges were attained respectively. There was no significant difference across the treatments.

Mean pod weight of fresh okra (g).

The mean pod weight is presented in Table 4.

At 60 days after planting, the highest weight of 305g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 304g when 30kg P ha⁻¹ was applied. 206g was obtained at 45kg P ha⁻¹ level of fertilization, 173g at 60kg P ha⁻¹ while the least value of 115g was obtained at the control. These values were however not significantly different from each other.

At 62 days after planting, the highest weight of 751g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 623g when 30kg P ha⁻¹ was applied. 515g was obtained at 45kg P ha⁻¹ level of fertilization. 303g was obtained at 60kg P ha⁻¹ while the least value of 303g was obtained at the control. These values were however not significantly different from each other.

At 64 days after planting, the highest weight of 224g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 169g when 0kg P ha⁻¹ was applied as control. 159g was obtained at 30kg P ha⁻¹ level of fertilization. 158g was obtained at 45kg P ha⁻¹ while the least value of 94g was obtained at the 60kg P ha⁻¹. These values were however not significantly different from each other.

At 67 days after planting, the highest weight of 597g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 570g when 45kg P ha⁻¹ was applied. 427g was obtained at 60kg P ha⁻¹ level of fertilization. 411g was obtained at 30kg P ha⁻¹ while the least value of 285g was obtained at the control. These values were however not significantly different from each other.

At 69 days after planting, the highest weight of 336g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 204g when 30kg P ha⁻¹ was applied. 190g was obtained at 45kg P ha⁻¹ level of fertilization. 126g was obtained at 60kg P ha⁻¹ while the least value of 111g was obtained at the control. These values were however not significantly different from each other.

At 71 days after planting, the highest weight of 314g was obtained when 15kg P ha⁻¹ was applied. This was followed by a weight of 250g when 60kg P ha⁻¹ was applied. 212g was obtained at 45kg P ha⁻¹ level of fertilization. 198g was obtained at 30kg P ha⁻¹ while the least value of 73g was obtained at the control. These values were however not significantly different from each other.

Mean number of pods of okra plant.

At 54 days after planting, the highest mean number of pods obtained was 4.60 while the lowest mean number of pods was obtained as 2.33 at 54 days after planting. At 56 days after planting, the highest mean number of pods obtained was 7.70 while the lowest mean number of pods was obtained as 3.00. At 58 days after planting, the highest mean number of pods obtained was 13.30 while the lowest mean number of pods was obtained as 4.30. At 60 days after planting, the highest mean number of pods obtained was 24.30 while the lowest mean number of pods was obtained as 10.30. At 62 days after planting, the highest mean number of pods obtained was 34.00 while the lowest mean number of pods was obtained as 17.00. At 64 days after planting, the highest mean number of pods obtained was 53.30 while the lowest mean number of pods was obtained as 28.00. At 66 days after planting, the highest mean number of pods obtained was 41.70 while the lowest mean number of pods was obtained as 30.30. At 68 days after planting, the highest mean number of pods obtained was 45.70 while the lowest mean number of pods was obtained as 27. At 70 days after planting, the highest mean number of pods obtained was 35.70 while the lowest mean number of pods was obtained as 19.00. At 72 days after planting, the highest mean number of pods obtained was 32.30 while the lowest mean number of pods was obtained as 15.30.

TABLE 1: Properties of the Experimental site

Parameter	Concentration
PH	6.4
Sand (%)	75.94
Clay (%)	12.60
Silt (%)	11.46
Texture	Sandy- loam
O.M (%)	2.84
N (%)	0.40
P (ppm)	4.4
K (C mol kg ⁻¹)	0.3
Na (C mol kg ⁻¹)	0.28
Mg (C mol kg ⁻¹)	3.3
Ca (C mol kg ⁻¹)	3.65
EB(C mol kg ⁻¹)	7.53
EA (C mol kg ⁻¹)	1.06
CEC (C mol kg ⁻¹)	8.59
BS	87.62

Table 2: Mean Plant Height (cm)

Treatment	PLTHT (4 WAP)	PLTHT (6WAP)	PLTHT (8 WAP)	PLTHT (10 WAP)
0kg P ha ⁻¹	8.87	9.97	11.67	18.90
15kg P ha ⁻¹	9.67	11.57	13.93	20.90
30kg P ha ⁻¹	9.37	11.30	13.67	19.80
45kg P ha ⁻¹	10.10	11.63	13.50	18.90
60kg P ha ⁻¹	8.70	10.20	11.97	19.80
LSD (≤ 0.05)	NS	NS	NS	NS

Table 3: Mean Plant Height (cm)

Treatment	P Length 4 WAP	P Length 6 WAP	P Length 8 WAP	P Length 10 WAP
0kg P ha ⁻¹	0.40	0.70	0.93	1.03
15kg P ha ⁻¹	0.56	0.80	1.16	1.26
30kg P ha ⁻¹	0.53	0.66	1.10	1.20
45kg P ha ⁻¹	0.60	0.80	1.13	1.23
60kg P ha ⁻¹	0.40	0.66	1.00	1.10
LSD (P ≤ 0.05)	NS	NS	NS	NS

Table 4: Mean Pod Weight of Fresh Okro (g)

TREATMENT	PW2 nd Harvest	PW 3 rd Harvest	PW 4 th Harvest	PW 5 th Harvest	PW 6 th Harvest	PW 7 th Harvest
0kg P ha ⁻¹	115	303	167	285	111	73
15kg P ha ⁻¹	305	751	224	597	336	314
30kg P ha ⁻¹	304	623	159	411	204	198
45kg P ha ⁻¹	206	515	158	570	190	212
60kg P ha ⁻¹	173	303	94	427	126	250

LSD ($P \leq 0.05$) NS NS NS NS NS NS

Table 5: Mean Plant Height (cm)

TREATMENT	54AP	56DAP	58DAP	60DAP	62DAP	64DAP	66DAP	68DAP	70DAP	72DAP
0kg P ha ⁻¹	2.33	3.00	4.30	10.30	17.00	30.30	30.70	27.30	19.00	15.30
15kg P ha ⁻¹	3.00	4.00	7.30	22.30	32.00	52.30	41.00	45.70	35.70	32.30
30kg P ha ⁻¹	4.60	7.70	13.30	24.00	34.00	53.30	36.00	33.30	24.30	20.00
45kg P ha ⁻¹	2.67	4.30	6.30	18.70	18.70	39.70	41.70	45.70	28.70	22.70
60kg P ha ⁻¹	3.33	4.00	6.00	13.70	22.30	28.00	30.30	39.70	33.00	27.70
LSD($P \leq 0.5$)	NS	1.50	2.35	5.20	10.20	20.24	10.24	13.45	10.12	5.84

Discussion

The result showed that the soil under study was slightly acidic which is suitable for effective growth of okra. This enhances conducive environment for microbial growth and performance (Draycott & Christenson, 2003). Agber and Ali et al., (2015) had earlier obtained similar pH results on studies carried out and reported for soils in Makurdi. This pH also agrees with Nolan and Pritchett (1960).

Clay in soil less than 40% are generally well-drained and good for plant growth and also determines the level at which P is absorbed by crops (Rich, 1968), this agrees with our study where the clay content is 12.60%. The amount of clay and soil organic matter highly influence the degree of K leaching.

The soil texture was found to be sandy-loam, the ability of P to be retained in the soil lies with this attribute and this determines the rate of infiltration, amount of storage and soil fertility (Gupta, 2000).

Organic carbon, nitrogen, potassium, phosphorus, sodium, magnesium, sulphur, and several microelements make up the organic matter in the soil. Soil organic matter is a big place where soil and air CO₂ can go to and come from. It helps the soil by making it more stable, holding more water, increasing the number of different types of plants and

animals in the soil, absorbing and holding onto pollutants, buffering capacity, cycling and storing plant nutrients. It is one of the most important signs of soil fertility and quality (Larson and Pierce, 1991).

The limited amount of organic matter is mostly because of the high warmth and humidity, which speed up the process of turning organic matter into minerals.

N, P, and K have a bigger effect on both the natural and agricultural ecosystems than any other important element. The P level was low. This finding corroborates the discovery by Aduayi et al. (2012) that the majority of Nigerian soils exhibit deficiencies in nitrogen and potassium. The CEC of the soil determines how well it can hold onto K that has been added. In sandy soils with a pH of 6 to 6.5, it is always possible to improve the retention of K for the best possible retention of applied K. P is the master key to agriculture since plants can't develop without enough soil P (Foth and Ellis, 1997).

Cation Exchange Capacity (CEC) is an important soil property because it shows what kind of minerals are in the soil, how well it can hold nutrients against leaching, and how fertile and environmentally friendly it is. Woldeamlak and Stroosnijder (2013) found a big difference in CEC between soils used for different types of land, with the

highest values in soils under forest and the lowest values in soils under cultivation. Soils with higher CEC levels can hold more N, P, and K, however sandy soils have a difficulty with leaching, which is what Nolan and Pritchett (1960) said.

The soil's low CEC values, which come from having low levels of organic matter and total Nitrogen, Phosphorus, and Potassium, show that the soil is not very fertile on its own. This means that better soil management methods are needed (Agber & Ali, 2012).

The findings corroborate previous observations by Agboola (1975), who indicated that African farmers necessitate sufficient soil amendments for optimal crop yield due to low intrinsic soil fertility.

The highest pod length was recorded at 1.267cm with 10WAP at 30Kg Pha1, this is because P is slowly moved into the soil but at the application of increasing levels of different rates of P fertilizers at 100Kg P ha'for sole okra plant, there was a corresponding increase in length of the pods. Ijoyah and Dzer 2012, Naik and Srinivas1992, had earlier reported similar results.

However, the lowest pod length was obtained at Okg P ha" and 60kg P ha'to be 0.40cm, this may be attributable to the slow nature at which P is absorbed in the soil and for the fact that, the no low rate of P fertilizer had been applied.

The highest pod weight was obtained at 751g with 15kg P ha' at 67days after harvesting, this was due to the application of various rates of P fertilizers. The fertilizers had been absorbed in the root nodules of the plant while the lowest pod weight of the harvest was obtained at 73g with Okg P ha'at76days after harvesting, this could be as a result of the slow movement of P into the soil.

The lowest height was 8.70 cm with 60 kg P ha at 4 WAP, while the highest height was 20.90 cm with 15 kg P ha at 10 WAP. The delayed flow of P into the soil may have caused the stunted development, while the highest height reached was owing to the movement and absorption of P in the soil. P is part of the metabolic activities that move energy around the plant. It is also very important for roots to grow and flowers to bloom. Because P flows slowly through the soil, it is vital to mix it into the soil where the roots are needed. This is why different amounts of P fertilisers are used.

It could be inferred that, the highest mean number of pods were produced as 53.30 when 15kg P ha1 and 30kg P ha'1 were applied at 64 days after planting. This could be attributed to the fact that the amount of P added made the soil P to be mobilized to the peak due to the addition of phosphate fertilizers.

However, the lowest mean number of pods was recorded as 2.33 when 0kgPha was applied at 54 days after planting. This could be due to the fact that the amount of P was not readily enough to act in synergy with the soil P to exert its mobilization in the soil, this agrees with Ijoyah and Dzer (2012) where the amount of P required to act in the soil to get soil P mobilized was studied.

Brady had told Agbede that P is involved in both active transport and Adenosine triphosphate (ATP). It also acts as a transfer reaction (TPN) in plants' metabolic activities, such as flowering, fruiting, and seed development. P also helps cells divide and grow, makes forages better for crops, and makes veggies taste better. Crop maturity in which P fights the effects of too much nitrogen being used.

Summary

Laboratory and field experiments were carried out to determine the response of okra to the application of different rates of P and the optimum rate for P fertilization for okra in Makurdi.

Data collected were statistically analyzed and the results obtained showed that there was significant difference in the mean number of pods indicating response to P fertilization.

Conclusion

It was concluded that, there was significant difference of P fertilization across the treatments. Response to P fertilization was observed across the treatments, the highest mean number of pods (53.30) was obtained at 64days after planting.

Recommendation

Therefore, it is recommended that, 30KgPha be applied to obtain optimum yield.

References

1. Adepetu, J.A., Adetunji, M. T. & Ige, D. V (2014): *Soil Fertility & Crop Nutrition*, Jumak Nig. Ltd. ISBN:978-978-944-218-8
2. Aduayi, E.A. (2002) *Fertilizer use and Management practices for crops in Nigeria*, Third edition, S.B Garko International limited 67-70
3. Agbede O. (2009), *Understanding Soil and Plant Nutrition, Phosphorus Nutrition in plants*, Salman Press & Co. Nig. Ltd, Keffi, Nasarawa state-Nigeria. First edition ISBN:978-978-900-087-6.
4. Agber, P. I & Ali A., (2002), Evaluation of the Productivity of soils in Makurdi, Southern Guinea Savannah, Nigeria, using riquier index, *Journal of Environmental Science and Water Resources* 1: (5):100-104.

5. Agrawal, P., Agrawal P., Reddy, M & Sopory, S. (2006), Role of *DREB Transcription Factors in Abiotic and Biotic Stress Tolerance in Plants*, Plant Cell Reports 25 (12):1263-1274.
6. Ahmed H, (2002). Assessment of *Spatial Variability of Some Physicochemical Characteristics of Soils under Different Elevations and Land Use Systems in the Slopes of Mount Chilalo*, (M.Sc Thesis, p.104), Alemaya University, Ethiopia.
7. Beckett P.H.T., (1964) *Studies of Soil P Confirmation of the Ratio Law; Measurement of P potential*. Journal of Soil Science. 51:1-8
8. Brady N. C., and Weil, R. R., (2002). *The Nature and properties of Soils*, Prentice-Hall, New Jersey.
9. Bolt G. H., Sumer M.E & Kamphorst, A. (1963): *A Study Between Three categories of potassium in an Illicit Soil*. Soil Science of America proceedings.27;294-299.
10. Boyle, J.R., Voight, G. K. & Sawhney, B.L(1967); *Biotite Flasks: Alteration by Chemical and Biological Treatment*. Science 155:193-195. Boyoucoucous,
11. G.J. (1951), *A Recalibration of the Hydrometer Method for Making Mechanical Analysis of Soils*. Journal of Agronomy. 3:434-438.
12. Lindsay W.L. (1979), *Chemical Equilibrium soils*, Willey Interscience.
13. Draycott A. P, Christensen, D. R (2003). *Nutrients For Sugar Beet Production: soil-Plant Relationship* CABI Publishing, Wallingford, UK.
14. Gupta P.K (2000): *Handbook of Soil Fertilizer and Manure*, Anis offset press paryapuni, New Delhi, India.431p.
15. Hayness R.J., R. S swift & R. C. Stephen (1991): *Influence of Mixed Cropping Rotations (Pasture Arables) on Organic Matter Content, Water stables Aggregations and Porosity in a group of Soils*. Soil Tillage Res.19:77-87pp.
16. Larson W. E & F. J Pierce (1991). *Conservation and Enhancement of Soil Quality* p.173-203 In: *Evaluation for Sustainable Land Management in the Developing World*, vol.,2
17. Nolan C. N. and Pritchett, W. L., (1960): *Certain Factors Affecting The Leaching of Potasuium from sandy soils*. Proceedings of Soil crop Science society of Florida, 20:139-145.
18. Page A.L., R. H Miller & D. R. Keeney (1982). *Methods of Soil Analysis., part 2; Chemical and Microbiological Properties 2nd edition*, Agronomy 9: Soil Science Society of America, Madison, USA.
19. Rich C.J. & Black, W.R (1964), *Potassium Exchangeas Affected by cation Size, pH and Mineral Structure*: soil Science 97:384-390.
20. Sadusky, M.C., Sparks, D. L., Noll, M. R. & Hendricks, G. J. (1987): *Kinetics and Mechanism of Potasium Release From Sandy Soils*. Soil Science Society of America Journal 51:1460-1465.
21. Saikh H. Varadachari, C & Ghosh, K. (1998): *changes in Carbon, Nitrogen and Phosphorus Levels due to Deforestation and Cultivation, A Case Study in Simplipal National Park, India*, Plant Soil 198: 137-145.
22. Sanchez P. A., (1978): *Properties and Management of Soils in the Tropics*, John Wiley and sons, inc., New York, USA, 618p.
23. Schroder, D. & Dummmler, H (1996): *Kalium-Nachlieferung, kalium-gestlegungung*, Dueng Bodenkd.113:213-215.
24. Sinclair, A. H., (1978) *Availabilityof Potasium in Ryegrass from Scottish Soils*, Journal of Soil Science 30:757-773
25. Tamirat, T (1992); *Vertisol of Central Highlands of Ethiopia: characterisation and Evaluation of Phosphorus Statuses*. (An M.Sc Thesis) Alemaya University, Ethiopia.
26. Walkley A. and I.A. Black (1934) *An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chronic Acid Titration Method*, Soil science 37:29-98.
27. Woldeamlak B. & Stroosnijer, L. (2003) *Effects of Agro-ecological Land Use Succession on Soil Properties in the chomoga Watershed, Blue Nile basin, Ethiopia*. Geoderma.111:85-98.
28. Yuan, L. L., Zelazny L. W. & Ratanaprasotporn A (1976) *Potasium status of selected paleudults in the Lower Coastal Plains*. Soil Science society of America Journal 40:229-23