*Bionature*

***Volume 44, Issue 2, Page 31-53, 2024; Article no.BN.1658***
***ISSN: 0970-9835 (P), 0974-4282 (O)***

# Impact of NPS Fertilizer Rates on Okra Growth, Yield, and Quality

**Sarose Sababa [a], Tiru Tesfa [b], Shibru Zerihun [a] and John Barnabas [a*]**

[a] *College of Agriculture and Natural Resource Management, Gambella University, Gambella, P.O. Box- 126, Ethiopia.*
[b] *College of Agriculture and Environmental Sciences, University of Gondar, P.O. Box -196, Gondar, Ethiopia.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. The research conceptualization, methodological refining, analytical software choice, data curation, analysis, investigation, and writing were handled by author SS. Visualization, reviewing, and supervision were carried out by authors SZ and TT, both of who are the principal and co-supervisors. Author JB contributed in manuscript writing, editing, commenting, and corresponding the publication. All authors read and approved the final manuscript.*

***Article Information***

DOI: https://doi.org/10.56557/bn/2024/v44i22041

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.globalpresshub.com/review-history/1658

***Original Research Article***

***Received: 03/07/2024***
***Accepted: 05/09/2024***
***Published: 05/09/2024***

## ABSTRACT

Okra (*Abelmoscus esculentus* (L) Moench) is widely known and utilized vegetable crop in tropical and sub-tropical parts of the world. In Ethiopia, including Gambella, okra production and yield improvement have not been attained due to a lack of appropriate production practices, including fertilizer use recommendations. Hence, this experiment was conducted to evaluate the effect of NPS fertilizer rates on growth, yield, yield components, and quality of okra. The treatments were laid out in a randomized complete block design (RCBD) with three replications with eight levels of NPS fertilizer application rates. Data collection and measurement was done according to scientific

*Corresponding author: Email: johnbarnabas@gmail.com;

***Cite as:*** *Sababa, Sarose, Tiru Tesfa, Shibru Zerihun, and John Barnabas. 2024. "Impact of NPS Fertilizer Rates on Okra Growth, Yield, and Quality". BIONATURE 44 (2):31-53. https://doi.org/10.56557/bn/2024/v44i22041.*

recommendation for each parameter; data analysis was done using statistical analysis software version 9.3 (SAS, 2008). Results indicated that the NPS fertilizer had a significant influence on the growth, yield, yield components, and quality parameters of okra. The maximum number of branches (4.2), leaf area (890 $cm^2$), number of pods per plant (7.6), pod length (30.9 cm), individual pod weight (18.0 g), fresh biomass yield (814.2 g), dry biomass yield (248.7 g), number of seeds per pod (96.3), total soluble solute (4.9), and pod yield per hectare (15.9t $ha^{-1}$) were obtained from the NPS rate of (75-90-16.5) kg $ha^{-1}$. The highest pod diameter (2.7cm) was obtained from NPS fertilizer rate of 50–60–11 kg $ha^{-1}$ which was statistically similar with (2.4cm) at NPS rate of 75–90–16.5 kg $ha^{-1}$. Similarly, the maximum pod dry matter content (27.1) was obtained from NPS fertilizer rate of 100–120–22 kg $ha^{-1}$ which was also statistically on par with (25.9) at NPS rate of 75–90–16.5 kg $ha^{-1}$. The economic feasibility analysis showed that the maximum net benefit (Birr 232740.4 $ha^{-1}$) with highest MRR (3625.53%) was obtained from application of 75kgN-90kg$P_2O_5$-16.5kgS per hectare, whereas the lowest (Birr 118500 $ha^{-1}$) was obtained from the unfertilized. Application of NPS fertilizer resulted to gain (114240.4 Birr $ha^{-1}$) more compared unfertilized. Therefore, NPS fertilizer rate of 75–90–16.5 kg $ha^{-1}$ appears to be the optimum practice for higher yield and is economically feasible with maximum net benefit (Birr 232740.4 $ha^{-1}$) and the highest MRR (3625.53%) of the local cultivar okra in the Abobo area. Further increase in NPS rate above (75-90-16.5) kg $ha^{-1}$ did not bring about significant changes in yield, suggesting that NPS (75-90-16.5) kg $ha^{-1}$ is the optimum rate to obtain the highest green pod yield of okra.

*Keywords: NPS fertilizer; okra; growth; yield; yield components; quality.*

## 1. INTRODUCTION

Within the family Malvaceae, okra (*Abelmoschus esculentus*) is one of the most popular and commonly used species [1]. Growing in tropical and sub-tropical regions of the world, this vegetable crop is highly significant [2]. It is widely dispersed over Africa, Asia, Southern Europe, the Mediterranean, and all of America, having originated in Ethiopia [3, 4, and 5] and [6]. It is extremely diverse throughout the nation, especially in the south-western lowlands (550–650 masl) areas [7]. Due to the multiple uses for its fresh leaves, buds, blooms, pods and stems, and seeds, okra is considered a versatile crop [8]. Its leaves are also consumed as a vegetable. A non-caffeinated alternative is made from its seeds [9] According to Abbas *et al* [10], the immature fruits, or pods, of the plant are also eaten as vegetables and can be added to salads, stews and soups, fresh or dry, raw or cooked. According to Habtamu Fekadu *et al.* [11], it is essential to the human diet since it provides essential nutrients including protein, lipids, minerals, and vitamins that are typically lacking in other food types. It contains about 88.6g of water, 8.20g of carbohydrates, 2.10g of protein, 0.2g of fat, 1.70g of fibers, 0.084 g of calcium, 0.090g of phosphorous, 0.0012g of iron, 0.047g of ascorbic acid, and a sizable amount of riboflavin and carotenes are present in the 100g of edible portion [1].

Okra grow at ideal temperature between 21 and 30 degrees Celsius, with 18 and 35 degrees Celsius serving as the minimum and maximum values [12]. For optimal productivity, it needs full light; warm, humid weather is necessary for an abundant crop [13]. Although it may grow in a variety of soil types, well-drained soil—especially with a lot of organic matter—is ideal for its growth [14].

According to FAOSTAT [15], 9.95 million tons of okra were produced worldwide in 2019. As per FAO [16], Asia has emerged as the primary producer, trailed by Africa and North America.

Ethiopia's production and consumption is disregarded, and it is only recognized and farmed in a few areas, such as Benshangul Gumuz, Humera, and Gambella. Despite this, it is among the most significant crops grown in the Gambella Regional States, right after sorghum and maize [17].

Increasing the NPK application levels was found by several researchers to enhance plant development and yield [18]. Bruce & Rayment [19] state that the soils have very little nitrogen. The soils had 5.3 ppm of available phosphorus. The amount of phosphorus in the soil is low, according to Hazelton & Murphy [20].

To alleviate soil fertility problems appropriate fertilizer application is a very important activity in okra production for yield and quality improvement. Poor management and the low fertility status are limiting factors for okra growth, yield and quality [21]. Hence application of appropriate rate of fertilizer on okra is mandatory to boost the production of Okra.

Many researches have reported on the impact of fertilizer on okra growth and output. According to Uka *et al*. [22], fertilizer application resulted in noticeably greater values for plant height, fresh weight, leaf area, and dry weight when compared to once without fertilization. Similarly, Agbede & Adekiya [23] found that fertilizer application enhances the chemical characteristics of the soil, as well as the growth, yield, total nutrient content, and mineral composition of the okra plant.

The average production of okra in the Abobo district, which is traditionally grown by farmers, has been estimated to not surpass 9.5 t ha$^{-1}$. Reports from Pakistan, however, indicate that improved okra yields of 16.73 t/ha and 15.77 t/ha were achieved following the application of 100 kg N/ha and 120 kg $P_2O_5$/ha, respectively [24].

Thus, improper fertilizer rate application may be the cause of the low okra output in the Abobo district. Okra, on the other hand, is widely known to improve the economy of the community, especially in the research domain. Although the crop didn't reach its full potential nationally, especially in the Abobo district, it still has a great deal of promise to reduce hunger and ease food poverty in Ethiopia. This is because proper fertilizer recommendations were lacking. Thus, the study was conducted with the objective of testing different rates of NPS fertilizer for enhanced okara crop's growth, yield, and quality.

## 2. MATERIALS AND METHODS

### 2.1 Description of Experimental Site

The experiment was conducted in Abobo district, Gambella region in 2021 during the rainy season. Situated at a height of 526 meters above sea level and in latitude 8° 60’ N and longitude 34° 39’ 0" E in Ethiopia, the place is 821 kilometers southwest of the country's capital, Addis Ababa. Within the district ranges were 17˚C to 29˚C () for the mean lowest and maximum yearly temperatures. The long-term average of 1400 mm represents the range of mean annual rainfall (800 mm to 1500 mm).

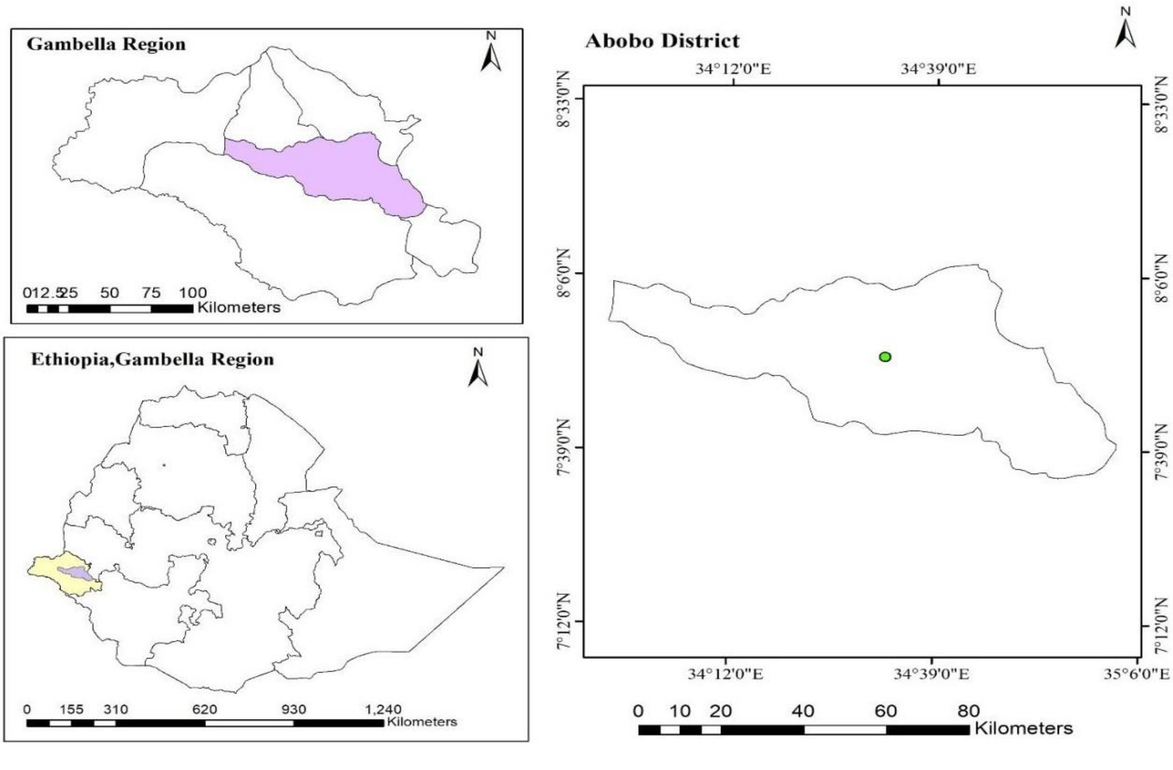


**Fig. 1. Map of study area**

**Table 1. Treatments levels used in study**

| Treatments | Description {N-P-S (kg)} |
|---|---|
| T1 | 0-0-0 |
| T2 | 25-30-5.5 |
| T3 | 50-60-11 |
| T4 | 75-90-16.5 |
| T5 | 100-120-22 |
| T6 | 125-150-27.5 |
| T7 | 150-180-33 |
| T8 | 175-210-38.5 |

## 2.2 Experimental Material

The local okra cultivar known as "Amula" was utilized for planting purposes. Growers in the area have been using the cultivar, which takes 55 to 75 days to mature in Abobo conditions. Compared to other cultivars, this short/dwarf kind of okra is prized for its excellent production capacity. Because of its high-yielding nature and short days to mature this cultivars is more preferred by growers than other available cultivars. Application of blended NPS fertilizers is also encouraged by Minster of agriculture of Ethiopia and it improves crop yields, soil pH, total nutrient content and nutrient. But there was no recommendation on fertilizer application in study area. However, reports are available in Pakistan for better yield of okra that showed obtaining of (16.73 t/ha) and (15.77 t/ha) after the application of 100kg N/ha and120kg $P_2O_5$/ha respectively [24]. This is equivalent to 100kgS-120kg$P_2O_5$-22kgS. Starting from this baseline the treatment is leveled with the rate of 25kg up and down. The recommended nitrogen ratio was corrected by using a blended level NPS fertilizer (19%N-38%$P_2O_5$-%S) and urea (46%N).

## 2.3 Experimental Treatment and Design

Eight levels of N, P2O5, and S fertilizer rates per acre made up the experiment (Table 1). Three replications were used in the Randomized Complete Block Design (RCBD) experiment. Plot dimensions were 1.8 m × 1.5 m (2.7 $m^2$). Five 1.5-meter-long seed rows were sown, with 0.3 meters separating each plant and 0.45 meters between rows. Blocks and plots were separated by 1 m width between blocks and 0.5 m width within a block. The experiment's total area measured 9.45 x 5.4 m, or 51 $m^2$ (Fig. 1).

## 2.4 Experimental Procedure and Crop Management

The experimental field was manually tilled, and ridges were made by hand. In July 2021, Okra seeds were planted in the prepared plots by scattering two to three seeds per hole. One robust plant was placed in each hole once the seedlings emerged, and the blended NPS fertilizers were sprayed at the time of planting. A month following germination, urea was added as nitrogen. Every agronomic technique was used consistently across all plots in accordance with recommendations. When the fruit was bright green, the pod was meaty, and the seeds were small, the okra crop was collected.

## 2.5 Soil Sampling and Analysis

Before the crop was sown, soil samples and analysis were conducted. Using an auger, soil samples were taken in a zigzag pattern from six spots at a depth of 0 to 30 cm throughout the entire experimental site. Subsequently, all of the samples were combined to create a single composite sample that weighed one kilogram to determine soil parameters. To analyse the pH and texture, the sample was dried and ground up so that it could fit through a 2 mm screen. A 1 mm pore size sieve was used to filter the soil sample in order to measure the amount of total nitrogen and organic carbon. Soil texture, pH, organic carbon, total N, available P, and CEC determinations were conducted at Jimma University Soil Laboratory.

## 2.6 Data Collection and Measurement

### 2.6.1 Phenology and growth parameters

**Days 50% flowering:** Days to flowering is the number of days counted from planting to the date on which 50% of plants produce at least their first flower ([25].

**Days to pod setting:** The total number of days were taken from emergence to the stage at which 50% of the plants in each experimental plot set at least one pod per plant [25].

**Plant height (cm):** Plant height was measured at the last picking of the fruit from ten randomly selected plants in each plot from the central rows using a measuring tape from the soil surface to the tip of the plant [25,26].

**Leaf area ($cm^2$):** Leaf area was calculated as per Aikins et al [27]; leaf area per plant ($cm^2$) calculated as length of leaf (cm) x width of leaf (cm) x correction factor (0.75)

**Length of pod bearing zone (cm):** was measured to the length of stem from the point of first pod set to the point where pod formation ends using tap Metter [25,26].

**Number of branches per plant:** Total number of branches was counted from 10 randomly selected plants from the central rows and then mean was calculated at the final harvest [25,26]

**Number of leaves per plant:** The total number of leaves was recorded by counting the number of leaves per plant until the final harvest. Leaves were counted from the same ten randomly selected plants, which was selected for the measurement of plant height [25,26]

**2.6.2 Yield and yield components**

**Number of green pods per plant:** The number of green pods per plant was counted at every picking day from ten randomly selected and tagged plants in each plot. The total number of pods obtained from the selected plant was divided to get the average number of pods per plant [25,26]

**Length of green pod (cm):** The length of 10 green marketable pods collected from sample plants were measured and averaged [25].

**Individual pod weight (g):** The Weight of 10 green marketable pods collected from sample plants were measured and averaged.

**Pod diameter (cm):** Pod diameter was measured using a vernier caliper and averaged.

**Above ground fresh biomass yield (g $plant^{-1}$):** The sum of above ground parts of 10 selected plants along the pods were weighed and averaged.

**Above ground dry biomass yield (g $plant^{-1}$):** The sum of above ground parts of 10 selected plants along the pods were weighed and averaged after oven-drying to a constant weight.

**Total green pod yield ($tha^{-1}$):** Yield obtained at each harvest from the net plot area was summed up as marketable and unmarketable yield and converted to a hectare basis.

**2.6.3 Quality**

**Pod dry matter content**: Five pods from each treatment of different plot was ground on forced air oven for 24 to 48 hours and percent of dry matter was determined as dry matter is equal to dry sample weight over wet sample weight times 100%

**Total soluble solids**: Brix percentage was measured by Portable refractometer at room temperature. Five pods from each treatment of different plots were laid in a blender and 2-3 drops of filtered juice was collected to measure Brix.

## 2.7 Data Analysis

All data were subjected to analysis of variance (ANOVA) to check the presence of variation among the varieties for tested traits using statistical analysis software version 9.3

## 2.8 Partial Budget Analysis

As farmers attempt to evaluate the economic benefits of shift in practice, partial budget analysis was done to identify the economic feasibility of the treatments. The average open market price of okra crop and the local prices of seed was 25 Birr $kg^{-1}$ during the time 21 of harvest, Urea (19.04 Birr $kg^{-1}$) and blended NPS (19.04 Birr $kg^{-1}$) used for analysis. A Treatment was considered worth to farmers when it's minimum acceptable rate of return (MAR) is100 % [28], which is suggested to be realistic. This enables farmer to make recommendations from marginal analysis.

The economic analysis was based on the formula developed by CIMMYT [28] and is shown as follows:

Gross average yield (GAY) (kg $ha^{-1}$): is average yield of each treatment Adjusted yield (AJY): AJY = GAY - (GAY × 0.1)

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell at Abobo town market during the month of June 2021.

It was calculated as:

GFB = AJY× field/farm gate price of a crop per 100 kg
Total cost (TC): Prices of Urea (19.04 Birr $kg^{-1}$) and blended NPS (19.04 Birr $kg^{-1}$) were taken at the time of sowing.

Net benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment.

NB = GFB – TC

Marginal rate of return (MRR): was calculated as change of net benefit divided by change of total variable cost as described by CIMMYT [28] was applied on the yield results. To identify treatments with maximum return to the farmer's investment marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a valuable option to farmers, the MRR needs to be at least between 50% and 100% [28].

However, researchers in Ethiopia suggested MRR of 100% as realistic [29]

Marginal rate of return (%) = Change in net benefit over Change in total cost times 100

## 3. RESULTS AND DISCUSSION

### 3.1 Soil Physiochemical Properties of Experimental Site

An examination of the soil texture revealed that the experimental site's soil was a clay loam with 45% sand, 34.5% clay, and 30.5% silt. Day (1965) used the Bouyoucous hydrometer method to corroborate this conclusion. The soil has a low organic matter concentration of 2.67%. provided confirmation of this outcome. The soils had 5.3 ppm of available phosphorus.

The experimental soil has little accessible sulfur, according to [30] findings (Table 2). It was discovered that the experimental soil was generally favourable for growing okra.

### 3.2 Crop Phenology Parameters

#### 3.2.1 Days to 50% flowering

Table 3 shows that NPS fertilizers had a highly significant ($P<0.001$) impact on the number of days until 50% of okra plants flowered. In okra plants treated with NPS (175-210-38.5) kg ha-1, the largest number of days to 50% flowering (49.3 days) was observed; in contrast, the lowest number of days to 50% flowering (45.3 days) was observed in unfertilized plots (Table 3) [25].

The days to 50% flowering were extended by applying NPS fertilizer. The higher rates of NPS fertilizer linked to rapid vegetative growth may cause delayed flowering, as it leads to prolonged photosynthesis.

The current results were consistent with those of Nardos, Mulugeta [31], who found that 160 kg $ha^{-1}$ NPS fertilizer rate increased tomato flowering duration to a maximum of 57 days. Similarly, days to blooming were delayed by the application of NP fertilizer rates, according to reports from Sayed & Said [32] and Geremew Taye [33].

**Table 2. Initial physicochemical properties of soil**

| No | Parameters | Values | Rating for soil |
|---|---|---|---|
| 1 | pH | 6.8 | Neutral |
| 2 | OM % | 2.67 | Low |
| 3 | TN % | 0.04 | Very low |
| 4 | Av.p (ppm) | 5.3 | Low |
| 5 | Av. S (ppm) | 16 | Low |
| 6 | Salt% | 45 | |
| | Clay% | 34.5 | |
| | Silt % | 30.5 | |
| | Textural class | Clay loam | |

*Where pH = hydrogen power, % OM = percent of organic matter, %TN = Percent of total nitrogen, Av. S (ppm), available sulphur in parts per million. Av.p.ppm = available phosphorus in parts per million, CEC = Cation exchange capacity*

**Table 3. Effect of NPS fertilizers on phenology of okra**

| Treatments N-P-S (kg) | Days to 50% flowering | Days to first pod setting |
|---|---|---|
| 0-0-0 | 45.3[e] | 47.3[e] |
| 25-30-5.5 | 45.7[e] | 47.7[e] |
| 50-60-11 | 46[ed] | 48[ed] |
| 75-90-16.5 | 46.6[dc] | 48.7[dc] |
| 100-120-22 | 47[cd] | 49[cb] |
| 125-150-27.5 | 47.7[b] | 49.7[b] |
| 150-180-33 | 48.7[a] | 50.6[a] |
| 175-210-38.5 | 49.3[a] | 51.3[a] |
| Significance | *** | *** |
| **LSD (5%)** | **0.87** | **0.89** |
| **CV (%)** | **1.1** | **1.0** |

*Means in the column followed by the same letter(s) are not significantly different at p<0.05: ns=non- significant, *, **, ***= significant at p<0.05, p<0.01 and p<0.001, respectively*

#### 3.2.2 Days to 50% pod setting

The analysis of variance revealed that the NPS fertilizers had a substantial (p<0.001) impact on the days to 50% pod setup (Table 3). The okra plant's maximum days to 50% pod setting (51.3 days) were observed when NPS (175-210-38.5) kg $ha^{-1}$ was applied, whereas the minimum days to 50% pod setting (47.3 days) was observed when unfertilized (Table 3). The days until pod setting increased when NPS fertilizer was applied. Like-wise, Yitbarek Abrham and Geletaw Kebede, [34] reported increase in NPS application rate from 0 to 150 kg NPS $ha^{-1}$ led to a significant increase in the number of days required to reach physiological maturity.

### 3.3 Growth Parameters

#### 3.3.1 Leaf area

Analysis of variance results revealed that NPS fertilizers had a substantial (p<0.05) impact on leaf area (Table 4). The application of (75-90-16.5) kg $ha^{-1}$ produced the maximum leaf area (890 $cm^2$) and the unfertilized plot produced the lowest (390 $cm^2$).

The leaf area increased after NPS fertilizer was applied. A sufficient supply of nutrients from the NPS may be the cause of the largest leaf area, which can be ascribed to cell division, tissue growth, increased leaf length, and leaf width. In line with Khandaker et al, [35] reported the maximum leaf area NPK fertilizer application (170 kg/ha, 190 kg/ha and 210 kg/ha) respectively.

#### 3.3.2 Plant height

The results of the analysis of variance showed that the NPS fertilizers had no discernible effect on plant height (P>0.05) (Table 4). Plant height was not greatly boosted by NPS fertilizer application. The diminutive size of the okra cultivar (Amola) employed as planting material. may be the cause of the non- significant effect on plant height. The crop's vigor and leaf size increased as the amount of NPS fertilizer rose. The result was in line with Shambel Aseffa, [36] reported non-significant differences were observed due to interaction effect of nitrogen and phosphorus levels on plant height of okra.

#### 3.3.3 Length of pod bearing zone

NPS fertilizers did not substantially alter the length of the pod bearing zone, according to analysis of variance (P>0.05) (Table 4). This is a result of the dwarf okra cultivar (Amola) that is utilized as planting material. Amanga Okelo [17] found, in contrast to this outcome, that applying a nitrogen rate lengthens the pod bearing [25,26].

#### 3.3.4 Number of branches per plant

The results of the analysis of variance indicated that NPS fertilizer had a statistically significant (p<0.01) effect on the number of branches per plant (Table 4). The application of (75-9-16.5) kg $ha^{-1}$ produced the largest branch (4.2) and the minimum branch (1.3) from the control unfertilized plot.

**Table 4. Effects of NPS fertilizers on growth parameter of okra**

| Treatments N-P-S (kg) | PH (cm) | LPBZ (cm) | NBPP | LA (cm) | NLPP |
|---|---|---|---|---|---|
| 0-0-0 | 54.4 | 36.3 | $1.3^{b}$ | $390^{b}$ | 10.0 |
| 25-30-5.5 | 61.9 | 45.9 | $1.8^{cd}$ | $710^{a}$ | 12.3 |
| 50-60-11 | 61.3 | 47.7 | $3.4^{ba}$ | $860^{a}$ | 14.1 |
| 75-90-16.5 | 73.8 | 51.7 | $4.2^{a}$ | $890^{a}$ | 15.0 |
| 100-120-22 | 70.9 | 51.0 | $2.6^{bc}$ | $790^{a}$ | 15.4 |
| 125-150-27.5 | 70.5 | 53.3 | $2.3^{c}$ | $780^{a}$ | 14.8 |
| 150-180-33 | 68.7 | 45.2 | $1.7^{cd}$ | $680^{a}$ | 12.7 |
| 175-210-38.5 | 63.8 | 46.1 | $1.6^{cd}$ | $660^{a}$ | 11.8 |
| Significance | NS | NS | ** | * | NS |
| **LSD (5%)** | **16.4** | **14.9** | **1.04** | **240** | **3.4** |
| **CV (%)** | **14.1** | **18.1** | **21.6** | **19.3** | **14.5** |

*Means in the column followed by the same letter(s) are not significantly different at p<0.05: ns=non-significant, *, **, ***= significant at p<0.05, p<0.01 and p<0.001, respectively*

The number of branches per plant rose with the application of blended NPS fertilizer. This increase in branches per plant that is correlated with the administration of NPS fertilizer may be caused by the availability of nitrogen. This result was fpund in agreement with Yitbarek Abrham and Geletaw Kebede, [35] who reported that an increasing NPS fertilizer level from 80kg NPS/ha to 240kg NPS/ha increased primary branch.

### 3.3.5 Number of leaves

According to the analysis of variance, NPS fertilizers had a statistically non-significant impact on leaf number ($P > 0.05$) (Table 4). This suggests that varying NPS fertilizer rates had no effect on the quantity of leaves. The dwarf okra cultivar (Amola) of the crop, which produces almost stable leaf numbers instead of increasing leaf area and size, is the reason for the non-significant effect of NPS. Similarly Yebirzaf Yeshiwas, [37] reported non-significant effect of inorganic fertilizer on leaves number of cabbages.

## 3.4 Yield and Yield Parameters of Okra

### 3.4.1 Number of pods per plant

The results of the analysis of variance indicated that NPS fertilizers had a substantial ($p<0.01$) impact on the number of pods per plant, as shown in Table 5. The application of NPS (75-90-16.5) kg ha$^{-1}$ produced the maximum number of pods (7.6) per plant, which was statistically similar to the (6.6) pods per plant obtained from the application of NPS (50-60-11) kg ha$^{-1}$. On the other hand, the unfertilized plot produced the lowest number of pods (4.4) per plant (Table 5).

The number of pods per plant rose with the application of NPS fertilizer. The use of NPS fertilizer may have increased the number of pods per plant, possibly as a result of the phosphorus nutrient's role in cell division and balance nutrition, which improved the okra crop's development and reproductive capabilities. There may be an increase in the number of pods per plant as a result of NPS's ability to promote the growth of more branches and buds. This result is in agreement with Sajid et al. [38] reported the maximum number of pods (10.69) plant$^{-1}$ with application of N and P fertilizer at the rate of 150 kg N/ha and 90 kg P/ ha.

### 3.4.2 Length of green pod

The analysis of variance revealed that NPS fertilizers had a substantial ($p<0.001$) impact on the length of the green pod. The application of NPS (75-90-16.5) kg ha$^{-1}$ resulted in green pods with a maximum length of 30.9 cm, while unfertilized plots produced green pods with a minimum length of 21.0 cm (Table 5). The length of the green pod increased after the administration of NPS fertilizer using 100 kg ha$^{-1}$ of NPS. In line with Addisu Ebbisa and Tadele Amdemariam [38] who reported the significant effect of NPS fertilizer on the length of green pods and highest pod length (6.92) with NPS 100 kg ha$^{-1}$.

### 3.4.3 Pod diameter

The result of the analysis of variance showed that the pod diameter was high and hence significantly affected by the NPS fertilizers ($p<0.01$) (Table 5). The maximum pod diameter (2.7) was obtained from the application of NPS (50-60-11) kg ha$^{-1}$ which was statically similar to

(2.4) which is obtained from (75-90-16.5) kg $ha^{-1}$, whereas the minimum pod diameter (1.7) was obtained from the unfertilized plot (Table 5). Similarly, Amanga Okelo [17] reported the increment of pod diameter of okra with application of N rate of 46 kg.

### 3.4.4 Individual pod weight

Analyses of variance revealed that NPS fertilizers had a highly significant ($p<0.001$) impact on the weight of individual pods (Appendix Table 5). The application of NPS (75-90-16.5) kg ha-1 produced the maximum individual pod weight of 18.0g, whereas unfertilized produced the lowest individual pod weight of 14.1g (Table 5). In line with Shambel Aseffa [36] reported that the application N and P2O5 at the rate of 50 and 37.5 kg/ha produced 28.06 percent average weight of each individual pod on clay soil.

### 3.4.5 Above-ground fresh biomass yield

The application of NPS fertilizers had a substantial impact on the above-ground fresh biomass output ($P<0.001$), according to the analysis of variance (Appendix Table 5). While the unfertilized plot yielded the lowest biomass production (582.6g), the application of NPS (75-90-16.5) kg $ha^{-1}$ produced the maximum above-ground fresh biomass yield (814.2g) (Table 5).

### 3.4.6 Above-ground dry biomass yield

The above-ground dry biomass output was also highly affected ($P<0.001$) by the NPS fertilizers, according to the results of the analysis of variance (Table 5). The unfertilized plot yielded the lowest above-ground dry biomass yield (144.3g), whereas the highest dry biomass yield (248.7g) was produced from an NPS rate of (75-90-16.5) kg $ha^{-1}$. In line with Belay Mekuannet and Kiya Adare [39] who reported the maximum above ground biomass yield (17.1 t $ha^{-1}$) with application of NPS at the rate 150 kg $ha^{-1}$.

### 3.4.7 Number of seeds per pod

According to Table 5, the analysis of variance revealed that the NPS fertilizers had a significant impact on the quantity of seeds per pod ($P<0.01$). Applying (75-90-16.5) kg $ha^{-1}$ resulted in the greatest number of seeds per pod (96.3), whilst the unfertilized plot produced the lowest number of seeds per pod (61.0) (Table 5). Similarly, Zainab et al [40] reported the highest number of seeds obtained of okra with 150 kg $ha^{-1}$ and 170 kg $ha^{-1}$ of NPK fertilizer.

### 3.4.8 Total green pod yield

An analysis of variance resulted in a very high significant influence ($p<0.001$) of NPS application on okra pod yield per hectare (Table 5). When compared to the pod yield from the unfertilized plot, the application of NPS fertilizers at the rates of (50-60-11) kg $ha^{-1}$ and (75-90-16.5) kg $ha^{-1}$ greatly enhanced the green pod yield by approximately 40.5% and 101.3%, respectively (Table 5). Increases in NPS rate beyond (75 -90 -16.5) kg $ha^{-1}$ did not result in appreciable yield variations, indicating that this rate is optimal for okra green pod production in the research region on clay loam soil

**Table 5. Effects of NPS fertilizers on yield and yield component parameters of okra**

| Treatments N-P-S (kg) | NPPP | PL (cm) | PD (cm) | APW (g) | NSPP | FBY (g) | DBY(g) | FPY(t$ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 0-0-0 | 4.4$^{d}$ | 21.0$^{d}$ | 1.7$^{d}$ | 14.1$^{e}$ | 61.0$^{d}$ | 582.6$^{g}$ | 144.3$^{f}$ | 7.9$^{f}$ |
| 25-30-5.5 | 5.4$^{bcd}$ | 21.8$^{cd}$ | 1.8$^{cd}$ | 14.8$^{de}$ | 69.7$^{bcd}$ | 629.9$^{f}$ | 156.9$^{f}$ | 9.2$^{def}$ |
| 50-60-11 | 6.6$^{ab}$ | 28.8$^{b}$ | 2.7$^{a}$ | 16.7$^{b}$ | 85.0$^{ab}$ | 790.7$^{b}$ | 229.9$^{b}$ | 14.3$^{b}$ |
| 75-90-16.5 | 7.6$^{a}$ | 30.9$^{a}$ | 2.4$^{ab}$ | 18.0$^{a}$ | 96.3$^{a}$ | 814.2$^{a}$ | 248.7$^{a}$ | 15.9$^{a}$ |
| 100-120-22 | 5.5$^{bcd}$ | 24.4$^{bc}$ | 2.3$^{b}$ | 15.9$^{bc}$ | 85.7$^{ab}$ | 742.2$^{c}$ | 214.4$^{c}$ | 11.1$^{c}$ |
| 125-150-27.5 | 5.8$^{bc}$ | 23.6$^{cd}$ | 2.2$^{b}$ | 15.6$^{cd}$ | 83.3$^{ab}$ | 731.4$^{cd}$ | 209.3$^{c}$ | 10.5$^{cd}$ |
| 150-180-33 | 5.3$^{bcd}$ | 22.6$^{cd}$ | 2.2$^{b}$ | 14.8$^{de}$ | 66.7$^{cd}$ | 717.4$^{de}$ | 190.2$^{d}$ | 9.6$^{cde}$ |
| 175-210-38.5 | 4.7$^{bc}$ | 20.7$^{d}$ | 2.1$^{bc}$ | 14.2$^{e}$ | 66.3$^{cd}$ | 707.4$^{e}$ | 194.2$^{e}$ | 8.8$^{ef}$ |
| Significance | ** | *** | ** | *** | ** | *** | *** | *** |
| **LSD (5%)** | **1.4** | **3.1** | **0.33** | **0.92** | **18.1** | **20.6** | **11.9** | **1.6** |
| **CV (%)** | **14.1** | **7.3** | **8.5** | **3.3** | **13.5** | **1.7** | **3.5** | **8.3** |

*Means in the column followed by the same letter(s) are not significantly different at p<0.05: ns=non-significant,*, **, ***= significant at p<0.05, p<0.01 and p<0.001, respectively*

**Table 6. Effect of NPS on quality parameters of okra**

| Treatments N-P-S (kg) | TDMC (%) | TSS (Brix) |
|---|---|---|
| 0-0-0 | 20.3$^{c}$ | 2.8$^{c}$ |
| 25-30-5.5 | 24.8$^{b}$ | 3.6$^{b}$ |
| 50-60-11 | 24.9$^{b}$ | 4.7$^{b}$ |
| 75-90-16.5 | 25.9$^{ab}$ | 4.9$^{a}$ |
| 100-120-22 | 27.1$^{a}$ | 3.8$^{a}$ |
| 125-150-27.5 | 25.1$^{ab}$ | 3.6$^{b}$ |
| 150-180-33 | 23.8$^{b}$ | 3.5$^{b}$ |
| 175-210-38.5 | 20.5$^{c}$ | 3.6$^{c}$ |
| Significance | ** | *** |
| **LSD (5%)** | **2.7** | **0.5** |
| **CV (%)** | **6.3** | **7.8** |

*Means in the column followed by the same letter(s) are not significantly different at p<0.05; ns=non significant, *, **, ***= significant at p<0.05, p<0.01 and p<0.001*

(75 -90 - 16.5) kg ha$^{-1}$. When NPS fertilizers were applied, the overall pod yield generally increased in comparison to control treatments. Likely, Shambel Aseffa [36] reported the application of nitrogen and phosphorus fertilizer rates up to a 50kg N and 37.5kg $P_2O_5$ results in higher pod yield of okra.

## 3.5 Quality Parameter of Okra

### 3.5.1 Pod dry matter content

Pod dry matter content was found statistically extremely significant (P<0.001) when NPS fertilizer was applied, according to the results of the analysis of variance (Table 6). The application of NPS (100-120-22) kg ha$^{-1}$ produced the highest pod dry matter content (27.1g), which was statistically comparable to the pod dry matter contents of NPS (75-90-16.5) kg ha$^{-1}$ and (125-150-27.5) kg ha$^{-1}$, respectively. Conversely, the unfertilized plot yielded the lowest pod dry matter content (20.3g) (Table 6). In line with Endris Solomon et al. [41] reported the higher dry matter production with blended fertilizer application at the rate of 34.58 kg N, 69 kg $P_2O_5$, and 12.75 kg S ha$^{-1}$.

### 3.5.2 Total soluble solute

The application of NPS fertilizer had a substantial impact on the total soluble solute, as demonstrated by the analysis of variance result (p<0.001) (Table 6). The application of NPS (75-90-16.5) kg ha$^{-1}$ produced the largest soluble solute (4.9%), whereas the unfertilized plot produced the minimum soluble solute (2.8%) (Table 6). Similarly, Ahmad et al. [42] reported the highest TSS (5.60%) obtained from tomato plant that received NPK at the rate of 90 kg ha$^{-1}$.

## 3.6 Correlation Analysis of Growth and Yield Related Parameters of Okra

To characterize and quantify the degree and direction of the relationship between variables, correlation is utilized. highly positive or highly negative associations are shown by the correlation coefficient (r) value that is closest to +1 or -1, respectively. On the other hand, a weakly positive or negative correlation is indicated by a correlation coefficient (r) value that approaches zero.

The culmination of numerous intricate morphological and physiological processes that take place during the crop's growth and development is the total pod yield. Total pod yield showed a strong positive correlation (p≤0.01) with dry biomass yield (r = 0.86***), fresh biomass yield (r = 0.81***), and number of seeds per pod (r = 0.76***), according to the correlation coefficient (r) analysis. Pod yield also showed a positive significant association (p≤0.01) with leaf area (r = 0.64**), number of leaves per plant (r = 0.53**), number of pods per plant (r = 0.59**), individual pod weight (r = 0.58**), and number of branches per plant (r = 0.64**). There was a positive significant correlation (p≤0.0 5) between pod yield and the leaf bearing zone (r = 0.44*), pod length (r = 0.52*), and pod diameter (r = 0.51*).

The application of NPS fertilizers improved okra yield, yield components, and quality, which eventually boosted yield in the research site. This was evidenced by the presence of a strong and positive correlation with growth parameters, with the exception of days to 50% maturity and days to pod setting. This indicated that higher growth factors and yield components were contributing to higher yields of okra.

**Table 8. Partial budget analysis for okra yield as influenced by NPS fertilizer rates at Abobo district in 2021 cropping season**

| Treatments N-P-S (kg) | FPY ($tha^{-1}$) | APY ($tha^{-1}$) | TGB ($Birrha^{-1}$) | TVC ($Birrha^{-1}$) | NB ($Birrha^{-1}$) | MRR (%) | Rank |
|---|---|---|---|---|---|---|---|
| 0-0-0 | 7.9 | 7.1 | 106500 | 0 | 105500 | 0.00 | |
| 25-30-5.5 | 9.2 | 8.3 | 124500 | 3932.6 | 120567.4 | 383.14 | 3rd |
| 50-60-11 | 11.1 | 10.0 | 150000 | 5827.0 | 144173 | 1246.07 | 2nd |
| 75-90-16.5 | 15.9 | 14.3 | 214500 | 7769.6 | 206740.4 | 3237.47 | 1st |
| 100-120-22 | 14.3 | 12.9 | 193500 | 9654.1 | 183845.9 | D | |
| 125-150-27.5 | 10.5 | 9.5 | 142500 | 11586.7 | 130913.3 | D | |
| 150-180-33 | 9.6 | 8.6 | 129000 | 13481.0 | 115519 | D | |
| 175-210-38.5 | 8.8 | 7.9 | 118500 | 15413.7 | 103086.3 | D | |

*Note: NPS=blended Fertilizer; ETB= Ethiopian Birr; APY=Adjusted Pod Yield; TGB= Total Gross benefit; TVC = Total variable cost; NB = Net benefit; D=Dominated treatments, MRR = Marginal rate of return, Price of NPS = 19birr $kg^{-1}$, Price of Urea = 19birr $kg^{-1}$*

### 3.7 Economic Feasibility Analysis

As presented in Table 8, the economic feasibility analysis demonstrated that the application of NPS (75-90-16.5) kg $ha^{-1}$ yielded the highest maximum net benefit (Birr 232740.4 $ha^{-1}$) with the highest MRR (3625.53%), while the unfertilized produced the lowest (Birr 118500 ha-1). The application of NPS fertilizer produced 114240.4 Birr $ha^{-1}$ more by the treatment than by unfertilized (Table 8). The second acceptable net benefit 144173 Birr $ha^{-1}$ with MRR (1246.07%) was produced from application of (50-60-11) kg $ha^{-1}$, which were likewise approximately 44173 Birr $ha^{-1}$ higher net benefits than the control treatments.

Furthermore, the application of NPS (100-120-22) kg $ha^{-1}$ produced the next maximum net benefit of 183845.9 Birr $ha^{-1}$ with an unacceptable MRR (dominated treatment), Applications of NPS (75-90-16.5) kg $ha^{-1}$ were the most recommended and economically possible for okra production, according to the CIMMYT [28] guideline for economic analysis. This yielded a net benefit of (232740.4 Birr $ha^{-1}$) with an acceptable MRR (3625.53%). Further increase in rate of NPS level produced no change in marginal rate of return.

This suggests that increasing soil fertility and crop output requires applying the right amount of NPS fertilizer. The outcome was consistent with the findings of Khandaker *et al*. [35], Mal et al.[43], and Ngbede *et al*. [44], who indicated that when applying inorganic fertilizer to okra crops, the net benefit income and cost benefit ratio increased as opposed to when applying either organic or inorganic fertilizer alone [45].

## 4. CONCLUSIONS

The application of NPS fertilizers at the rate of NPS (50-60-11) kg $ha^{-1}$ and (75-90-16.5) kg $ha^{-1}$ greatly enhanced the green pod yield by 40.5% and 101.3%, respectively, as compared to unfertilized once. Increases in NPS rate beyond (75-90-16.5) kg $ha^{-1}$ did not provide appreciable yields, indicating that NPS (75-90-16.5) kg $ha^{-1}$ is the best rate to achieve the largest yield of green pods on clay loam soil.

Because total yield has a significant impact on farmers' net benefit gain per hectare, it has received attention in okra improvement programs. With the local okra cultivar's net benefit (232740.4 Birr $ha^{-1}$) and MRR (3625.53%), the highest yield (15.9 t $ha^{-1}$) was achieved from 75-90-16.5 kgNPS $ha^{-1}$. This greater total yield is positively connected with all growth, yield, and quality characteristics with the exception of days to 50% flowering and 50% pod setting.

Applying the right amount of NPS fertilizer to the soilsolve fertility problems and maximize the yield of okra in the study area. Okra cultivated with NPS rate of (75-90-16.5) kg $ha^{-1}$ in the Abobo area, provides the best growth, yield and quality. To offer firm recommendations for the study region, comparable field and economic feasibility studies must be carried out across several seasons in a range of soil types.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Benchasri S. Okra (*Abelmoschus esculentus (L.)* Moench) as a valuable vegetable of the world. Ratarstvoi Povrtarstvo. 2012;49(1):105-112.
2. Shivaramegowda KD, Krishnan A, Jayaramu YK, Kumar V, Koh HJ. Genotypic variation among okra (*Abelmoschus esculentus (L*.) Moench) germplasms in South India. Plant Breeding and Biotechnology. 2016;4(2): 234-241.
3. Olana G. Food source diversification: Potential to ameliorate the chronic food insecurity in Ethiopia. In The Potential of Indigenous Wild Foods Workshop Procedings. USAID/OFDA; 2001.
4. Aladele SE, Ariyo OJ, De Lapena R. Genetic relationship among West Africa Okra (Abelmoschus caillei) and Asian genotypes (Abelmoschus esculentus) using RAPD, Afr. J. Biotechnological. 2008;7:1426-1431.
5. Oyelade O, Ade-Omowaye B, Adeomi V. Influence of variety on protein, fat contents and some physical characteristics of okra seeds. Journal of Food Engineering. 2003;57(2):111-114.
6. Kumar K, Parida M, Katiyar V. Short term traffic flow prediction for a Non Urban highway using artificial neural network. Procedia-Social and Behavioral Sciences. 2013;104:755-764.
7. Mihretu Yonas, Weyessa Garedew, Adugna Debela. Multivariate analysis among okra (*Abelmoschus esculentus* (l.) moench) collection in South Western Ethiopia. Journal of Plant Sciences. 2014;9(2):43.
8. Van Rensburg WJ, Venter S, Netshiluvhi T, Van Den Heever E, Vorster H, De Ronde J, Bornman C. Role of indigenous leafy vegetables in combating hunger and malnutrition. South African Journal of Botany. 2004;70(1):52-59.
9. FAO. The state of food and agriculture (Food and Agriculture Organization of the United Nations; 2006.
10. Abbas Z, Mubashir M, Riaz U, Javid Z, Ashraf M, Qamar MJ, Mehdi SM. Combined Impacts of Compost, Poultry Manure and NPK Fertilizers on Yield of Okra Plant (*Abelmoschus esculentus* (L).). Pakistan Journal of Agricultural Research. 2019;32(3).
11. Habtamu Fekadu, Negussie Ratta, Gulelat Desse, Ashagrie Woldegiorgis, Fekadu Beyene. Nutritional quality and health benefits of okra (Abelmoschus esculentus): A review. J Food Process Technol. 2015;6(458):2.
12. El-Kader A, Shaaban S, El-Fattah M. Effect of irrigation levels and organic compost on okra plants (*Abelmoschus esculentus L.*) grown in sandy calcareous soil. Agric Biol JN Am. 2010;1(3):225-231.
13. Ardis, Grown in South Carolina: Okra; 2015. Available:https://www.thestate.com/living/food-drink/article32312634.html.
14. Tiamiyu R, Ahmed H, Muhammad A. Effect of sources of organic manure on growth and yields of okra (*Abelmoschus esculentus* L.) in Sokoto, Nigeria. Nigerian Journal of Basic and Applied Sciences. 2012;20(3):213-216.
15. Faostat D. Food and agriculture organization of the United Nations. Statistical database; 2019.
16. FAO. Discover global production data of Okra. Get production volume, price data, trends, and more. The information below is based on the FAO code 0430 (Okra); 2019.
17. Amanga Okelo. *Effects of plant population and nitrogenrates on growth and yield of okra [Abelmoschus esculentus (L.) Moench] in Gambella region, western Ethiopia.* MSc. Thesis at Haramaya University; 2014.
18. Mahmoud A, Javid S, Ahmad Z, Majeed A, Rafique R. Integrated use of bioslurry and chemical fertilizers for vegetable production. Pakistan Journal of Agricultural Sciences. 2010;51(3).
19. Bruce RC, Rayment GE. Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys. Queensland Department of Primary Industries; 1982.
20. Hazelton P, Murphy B. Interpreting soil test results: What do all the numbers mean? CSIRO Publishing; 2007.
21. Moro BM, Nuhu IR, Ato E, Naathanial B. Effect of nitrogen rates on the growth and

yield of three rice (*Oryza sativa* L.) varieties in rain-fed lowland in the forest agro-ecological zone of Ghana. International Journal of Agricultural Sciences. 2015;5(7):878- 885.
22. Uka UN, Chukwuka KS, Iwuagwu M. Relative effect of organic and inorganic fertilizers on the growth of okra [*Abelmoschus esculentus* (L.) Moench]. Journal of Agricultural Sciences, Belgrade. 2013;58(3):159-166.
23. Agbede T, Adekiya A. Effect of wood ash, poultry manure and Npk Fertilizer on Soil and Leafnutrient Composition, Growth and Yield of Okra (*Abelmoschus Esculentus*). .*Emirates* Journal of Food and Agriculture. 2012;314-321.
24. Firoz Z. Impact of nitrogen and phosphorus on the growth and yield of Okra [*Abelmoschus esculentus* (L.) *Moench*] in hill slope condition. Bangladesh Journal of Agricultural Research. 2009;34(4):713-722.
25. Baw A, Gedamuand F, Dechassa N. Effect of plant population and nitrogen rates on growth and yield of okra [*Abelmoscus esculentus* (L). Moench] in Gambella region, Western Ethiopia. 2017;12(16):1395-1403
26. Zibelo H, Tsadik K, Sharma JJ. Effect of inter-and intra-row spacing on growth and yield of Okra (*Abelmoschus esculentus (L.) Moench*) at Humera, Northern Ethiopia. Journal of Biology, Agriculture and Healthcare. 2016;6(3).
27. Aikins S, Afuakwa J, Owusu-Akuoko O. Effect of four different tillage practices on maize performance under rainfed conditions. Carbon. 2012;1:1-51.
28. CIMMYT. From agronomic data to farmer recommendations: An economics training manual: CIMMYT; 1988.
29. Tanner D, Amanuel Gorfu, Mwangi W, Taa A. On-farm research to derive fertilizer recommendations for small-scale bread wheat production methodological issues and technical results. Influence The Phenology Of Okra. 1991;45(2):479–482.
30. Bashour I. Fertility and fertilizer requirements in rural integrated development of the mountains of Northern Lebanon. FAO report to Ministry of Agriculture, Beirut, Lebanon. 2001;116.
31. Nardos Mulugeta Walle. Effect of NPS fertilizer rates on yield and yield components of tomato (*Lycopersicon esculentum* mill) varieties at Ginchi, central high land of west shoa zone of Oromia, Ethiopia (Doctoral dissertation, Ambo University); 2021.
32. Sayed MA, Said MT. Estimation of heterosis and combining ability effects on grain yield and some agronomic traits of sorghum under three NPK fertilizers levels. Journal of Agronomy. 2016;38:257-280.
33. Geremew Taye. Effects of nitrogen and phosphorus fertilizers on the growth, yield and yield components of maize (*Zea mays* L.) at Nedjo, west Wollega, Ethiopia. Haramaya University, Dire Dawa, Ethiopia, M.Sc. thesis; 2009.
34. Yitbarek Abrham, Geletaw Kebede. Effect of Blended NPS Fertilizer Rates on Growth. Performance of Tomato (*Solanum lycopersicum L*) at Wolaita Sodo University, Ethiopia; 2019.
35. Khandaker MM, Nor MF, Dalorima T, Sajili MH, Mat N. Effect of different rates of inorganic fertilizer on physiology, growth and yield of Okra (*'Abelmoschus esculentus'*) cultivated on Bris soil of Terengganu, Malaysia. Australian Journal of Crop Science. 2017;11(7):880-887.
36. Shambel Aseffa. Effects of Nitrogen and Phosphorus Fertilizer Rates on Growth, Yield and Yield Components of Okra (*Abelmoschus esculentus* (L.) Monech) Under Rain Fed Condition in Pawe District, Northwestern Ethiopia (Doctoral dissertation, Bahir Dar University); 2019.
37. Yebirzaf Yeshiwas. Effect of different rate of nitrogen fertilizer on the growth and yield of cabbage (Brassica oleraceae) at Debre Markos, North West Ethiopia. African Journal of Plant Science. 2017;11(7):276-281.
38. Sajid M, Khan M, Rab A, Shah S, Arif M, Jan I, Mukhtiar M. Impact of nitrogen and phosphorus on seed yield and yield components of okra cultivars. J. Anim. Plant Sci. 2012;22(3):704-707.
39. Addisu Ebbisa, Tadele Amdemariam. Effects of NPS and bio-organic fertilizers on yield and yield components of Faba bean (*Vicia faba* L.) in Gozamin District, East Gojjam, Ethiopia; 2021.
40. Zainab MA, Vincent EC, Ayodele OS, Lakwannum GY, Kehinde OS. Effects of organic and inorganic fertilizers on the growth of NH-Ae 47-4 variety of okra. Journal of Applied Sciences and Environmental Management. 2016;20(1): 201-206.

41. Endris Solomon, Masresha Fetene, Tilahun Amede. CO2 exchange, dry matter accumulation and growth response of sorghum (*Sorghum bicolor* L. Moench) to terminal drought as affected by potassium and blended-NPSBZn fertilization. Journal of Agronomy and Crop Science. 2021;207(3):450-464.
42. Ahmad M, Alam S, Ahmad W, Jan I, Zia A. Application of the 4R nutrient stewardship concept for growing off-season tomatoes in high tunnels. Journal of Soil Science and Plant Nutrition. 2018;18(4):989-1001.
43. Mal B, Mahapatra P, Mohanty S. Effect of diazotrophs and chemical fertilizers on production and economics of okra (*Abelmoschus esculentus*, L.) cultivars. American Journal of Plant Sciences; 2014.
44. Ngbede SO, Onyegbule UN, Ibekwe HN, Uwalaka OA, Okpara SC. Economic Anaylsis of Okra (*Abelmoschus esculentus* l. Moench) Production under Different Rates of Organic Manure in Okigwe, Southern Nigeria. Asian Journal of Agriculture and Food Sciences. 2014;2(2).
45. Belay Mekuannet, Kiya Adare. Response of growth, yield components, and yield of hybrid maize (*Zea mays* L.) varieties to newly introduced blended NPS and N fertilizer rates at Haramaya, Eastern Ethiopia. Cogent Food and Agriculture. 2020;6(1):1771115.

# APPENDIXES

## 1. Appendix tables

**Appendix Table 1. Meteorological information of Abobo, Ethiopia (January - December) 2021**

| Months | Monthly Rainfall (mm) | Average Temperature ($^0$c) | | Average Relative |
|---|---|---|---|---|
| | | Minimum | Maximum | Humidity (%) |
| **January** | 33.01 | 21.0 | 34.0 | 54 |
| **February** | 31.94 | 21.0 | 35.0 | 47 |
| **March** | 77.94 | 19.0 | 32.0 | 55 |
| **April** | 130.02 | 18.0 | 31.0 | 64 |
| **May** | 419.25 | 16.0 | 28.0 | 83 |
| **June** | 366.22 | 15.0 | 25.0 | 89 |
| **July** | 425.11 | 16.0 | 24.0 | 92 |
| **August** | 461.11 | 15.0 | 24.0 | 92 |
| **September** | 454.66 | 15.0 | 26.0 | 91 |
| **October** | 287.57 | 15.0 | 27.0 | 86 |
| **November** | 162.87 | 16.0 | 29.0 | 79 |
| **December** | 67.61 | 18.0 | 31.0 | 68 |

*Source: Ethiopian Institute of Agricultural Research Agro-meteorological Service*

**Appendix Table 2. Simple correlation analysis among okra parameters**

| | DTF | NLPP | Ph | LPBZ | NBPP | LA | DTPS | NPPP | PL | PD | IPW | NSPP | FBY | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DTF | 1 | | | | | | | | | | | | | | | | |
| NLPP | 0.22$^{ns}$ | 1 | | | | | | | | | | | | | | | |
| Ph | 0.240$^{ns}$ | 0.41$^{*}$ | 1 | | | | | | | | | | | | | | |
| LPBZ | 0.10$^{ns}$ | 0.48$^{*}$ | 0.55$^{**}$ | 1 | | | | | | | | | | | | | |
| NBPP | -0.08$^{ns}$ | 0.49$^{*}$ | 0.12$^{ns}$ | 0.23$^{ns}$ | 1 | | | | | | | | | | | | |
| LA | 0.15$^{ns}$ | 0.59$^{**}$ | 0.12$^{ns}$ | 0.38$^{ns}$ | 0.57$^{**}$ | 1 | | | | | | | | | | | |
| DTPS | 1.00$^{***}$ | 0.22$^{ns}$ | 0.23$^{ns}$ | 0.10$^{ns}$ | -0.08$^{ns}$ | 0.15$^{ns}$ | 1 | | | | | | | | | | |
| NPPP | -0.15$^{ns}$ | 0.48$^{*}$ | 0.31$^{ns}$ | 0.36$^{ns}$ | 0.66$^{**}$ | 0.49$^{*}$ | -0.14$^{ns}$ | 1 | | | | | | | | | |
| PL PD | -0.24$^{ns}$ | 0.47$^{*}$ | 0.20$^{ns}$ | 0.42$^{*}$ | 0.55$^{*}$ | 0.63$^{**}$ | -0.24$^{ns}$ | 0.64$^{**}$ | 1 | | | | | | | | |
| | 0ns | 0.41$^{*}$ | 0.17$^{ns}$ | 0.46$^{*}$ | 0.50$^{*}$ | 0.42$^{ns}$ | 0$^{ns}$ | 0.52$^{*}$ | 0.67$^{**}$ | 1 | | | | | | | |
| IPW | -0.27$^{ns}$ | 0.35$^{ns}$ | 0.26$^{ns}$ | 0.34$^{ns}$ | 0.64$^{**}$ | 0.50$^{*}$ | -0.27$^{ns}$ | 0.61$^{**}$ | 0.87$^{***}$ | 064$^{**}$ | 1 | | | | | | |
| NSPP | -0.09$^{ns}$ | 0.59$^{*}$ | 0.61$^{**}$ | 0.65$^{**}$ | 0.54$^{*}$ | 0.46$^{*}$ | -0.08$^{ns}$ | 0.52$^{*}$ | 0.64$^{**}$ | 0.52$^{*}$ | 0.65$^{**}$ | 1 | | | | | |
| FBY | 0.41$^{*}$ | 0.65$^{**}$ | 0.51$^{*}$ | 0.51$^{*}$ | 0.58$^{**}$ | 0.64$^{**}$ | 0.41$^{*}$ | 0.54$^{*}$ | 0.48$^{*}$ | 0.58$^{**}$ | 0.53$^{*}$ | 0.68$^{**}$ | 1 | | | | |
| DBY | 0.12$^{ns}$ | 0.72$^{***}$ | 0.46$^{*}$ | 0.50$^{*}$ | 0.71$^{***}$ | 0.63$^{**}$ | 0.12$^{ns}$ | 0.72$^{***}$ | 0.63$^{**}$ | 0.72$^{**}$ | 0.64$^{**}$ | 0.72$^{***}$ | 0.91$^{**}$ | 1 | | | |
| TY | -0.09$^{ns}$ | 0.53$^{**}$ | 0.40$^{ns}$ | 0.44$^{*}$ | 0.64$^{***}$ | 0.58$^{**}$ | -0.09$^{ns}$ | 0.59$^{***}$ | 0.52$^{***}$ | 0.51$^{**}$ | 0.58$^{***}$ | 0.76$^{***}$ | 0.81$^{***}$ | 0.86$^{***}$ | 1 | | |
| TSS | -0.02$^{ns}$ | 0.59$^{**}$ | 0.30$^{ns}$ | 0.31$^{ns}$ | 0.79$^{***}$ | 0.67$^{**}$ - | 0.02$^{ns}$ | 0.75$^{***}$ | 0.72$^{***}$ | 0.63$^{**}$ | 0.69$^{**}$ | 0.63$^{**}$ | 0.62$^{**}$ | 0.76$^{***}$ | 0.69$^{**}$ | 1 | |
| DMC | -0.09$^{ns}$ | 0.31$^{ns}$ | 0.56$^{**}$ | 0.41$^{*}$ | 0.04$^{ns}$ | 0.34$^{ns}$ | -0.09$^{ns}$ | 0.29$^{ns}$ | 0.47$^{*}$ | 0.25$^{ns}$ | 0.57$^{**}$ | 0.60$^{**}$ | 0.40$^{ns}$ | 0.49$^{*}$ | 0.50$^{*}$ | 0.29 | 1 |

*Note: DTF=days to 50% flowering; NLPP=number leaf per plant PH = plant height; LPBZ= length pod bearing zone ; LA = leaf area; DTPS= days to pod setting; NBPP= number of branch per plant; PL= pod length; PD= pod diameter; IPW= individual pod weight; NSPP= number of seed per pod FBY= fresh biomass yield; DBY= dry biomass yield; TY= total yield; TSS= total soluble solute; PDMC= pod dry matter content; ns= not significant; * = significant; **= highly significant; ***= very highly significant*

**Appendix Table 3. Mean square values of ANOVA for phonological parameters**

| SV | DF | Mean Square | |
|---|---|---|---|
| | | DTF | DTPS |
| **Replication** | 3 | 0.29 | 0.29 |
| **NPS** | 7 | 6.14$^{***}$ | 6.14$^{***}$ |
| **Error** | 14 | 0.24 | 0.24 |
| **Total** | 23 | | |
| **CV%** | | 1.1 | 1.0 |

*Note: DFT=Days to 50% Flowering; DTPS= Days to Pos setting; DF= degree of freedom; ns= not significant; * = significant; **= highly significant; ***= very highly significant*

**Appendix Table 4. Mean square values of ANOVA for growth parameters of okra**

| SV | DF | Mean Square | | | | |
|---|---|---|---|---|---|---|
| | | PH (cm) | LPBZ (cm) | NBPP | LA (cm) | NLPP |
| **Replication** | 3 | 162.12 | 118.79 | 0.01 | 2.32 | 1.40 |
| **NPS** | 7 | 990.4^ns | 39.40^ns | 0.13** | 1.11* | 5.44^ns |
| **Error** | 14 | 86.53 | 88.24 | 88.24 | 0.85 | 5.45 |
| **Total** | 23 | | | | | |
| **CV%** | | 14.1 | 18.1 | 25.4 | 19.3 | 14.5 |

*Note: PH = plant height; LPBZ= length pod bearing zone; LA = leaf area; NBPP= number of branch per plant; NLPP= number of leaf per plant. DF= degree of freedom; ns= not significant; * = significant; **= highly significant; ***= very highly significant*

**Appendix Table 5. Mean square values of ANOVA for yield and yield component parameters of okra**

| SV | DF | Means square | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NPPP | PL(cm) | PD(cm) | APW (g) | NSPP | FBY (g) | DBY(g) | FPY(tah$^{-1}$) |
| **Replication** | 2 | 0.7 | 7.92 | 0.14 | 2.94 | 159.88 | 1704.7 | 250.88 | 1.58 |
| **NPS** | 7 | 3.20** | 35.08** | 0.29** | 5.29*** | 464.07** | 1775139** | 3948.71** | 23.84** |
| **Error** | 14 | 0.63 | 3.03 | 0.03 | 0.29 | 107.30 | 139.52 | 46.03 | 0.81 |
| **Total** | 23 | | | | | | | | |
| **CV%** | | **14.1** | **7.3** | **8.5** | **3.3** | **13.5** | **1.7** | **3.5** | **8.3** |

*Note: NPPP = number of pods per plant PL= pod length; PD= pod diameter; IPW= individual pod weight; NSPP= number of seed per pod FBY= fresh biomass yield; DBY= dry biomass yield; ; DF= degree of freedom; ns= not significant; * = significant; **= highly significant; ***= very highly significant*

**Appendix Table 6. Mean square values of ANOVA for quality parameters of okra**

| SV | DF | Mean Square | |
|---|---|---|---|
| | | DTF | DTPS |
| **Replication** | 3 | 0.04 | 107.62 |
| **NPS** | 7 | 0.16*** | 19.13*** |
| **Error** | 14 | 0.10 | 2.31 |
| **Total** | 23 | | |
| **CV%** | | 1.1 | 1.0 |

*Note: TY= total yield; TSS= total soluble solute; PDMC= pod dry matter content; DF= degree of freedo m; ns= not significant; * = significant; **= highly significant; *** = very highly significant.*

## 2. Appendix Figures

**Appendix Fig. 1. Pictures taken during sowing**

**Appendix Fig. 2. Pictures showing treatment effects at early growth of okra crop**

**Appendix Fig. 3. Pictures taken during growth of okra crop**

**Appendix Fig. 4. Pictures taken during 50% flowering and pod setting**

**Appendix Fig. 5. Pictures taken during the time of harvesting okra (January - December) 2021**



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*https://prh.globalpresshub.com/review-history/1658*