**Optimization of Sesame (*Sesamum indicum* L.) production by Nitrogen and Phosphorous fertilizer application in West Gondar of the Amhara Region, Ethiopia**

Baye Ayalew1 ,Fentahun Biset1, Tamrat Worku1, Ayalew Addis1,, Melaku Azanaw1, Anteneh. Adebabay1, Habtamu Getnet2, Firnuse Haile1,Zerfu Bazie1,Melkamu Adane1 Tesfaye Feyisa3 Mogose Marie1, Simachew Kasahun1, Gizat Adugna1 and Sitotaw Zemene 1,

1. Gondar agricultural Research Center, P.O.Box 1337 Gondar, Ethiopia.

2. Adet agricultural Research Center, PO.Box 08 Bahir Dar, Ethiopia.

3. Amhara agricultural Research Institute, P.O.Box 527 Bahir Dar, Ethiopia.

Corresponding Author e-mail: ayalew.baye@yahoo.com

Abstract

This study investigated the impact of nitrogen (N) and phosphorus (P₂O₅) fertilizer application on sesame yield in Metema, West Armachiho, and Tegedie districts of the Amhara Region in 2023 using a Randomized Complete Block Design (RCBD) with three replications. Five N levels (0, 46, 69, 92, and 115 kg ha⁻¹) and three P₂O₅ levels (0, 23, and 46 kg ha⁻¹) were applied, with phosphorus fully incorporated at sowing and nitrogen split-applied at sowing and the branching stage. The results showed that location significantly influenced most parameters, except for thousand-seed weight. Both N and P₂O₅ had highly significant effects on growth and yield parameters, while their interaction significantly impacted branches per plant, thousand-seed weight, and grain yield. Location and N interactions also significantly influenced branches, thousand-seed weight, and grain yield but had no effect on plant height, seeds per pod, or pods per plant. Similarly, location and P₂O₅ interactions significantly affected branches and seed weight but no other parameters. The three-way interaction (location, N, and P₂O₅) had no significant effect on recorded parameters. The highest sesame yield (1305.2 kg/ha in Metema, and 923.4 kg/ha in West Armachiho, and 786.7 kg/ha in Tegedie) was achieved with 46 kg N and 23 kg P₂O₅/ha, resulting in yield improvements of 315.9%, 168.5%, and 260%, respectively, over the control. Partial budget and marginal rate of return analyses confirmed that this treatment provided the highest net benefits (169603 ETB in Metema, 159868 ETB in West Armachiho, and 97013 ETB in Tegedie) and acceptable returns on investment. The study recommends applying 46 kg N and 23 kg P₂O₅/ha for optimal sesame production in the West and Central Gondar zones.

### **Keywords:** Ethiopia,Nitrogen, Phosphorus, Sesame, Yield.

### Introduction

Sesame (Sesamum indicum L.) thrives in regions with annual rainfall of 625-1100 mm and temperatures above 27°C. The crop is drought-tolerant but sensitive to waterlogging and excessive rainfall (MARD, 2008). Global sesame seed production increased from 5.2 million tons per year in the early 2010s to 6.1 million tons per year by 2014. According to FAO (2016), the global area reserved for sesame planting reached 11.06 million hectares, with a production rate of 6.08 million tons per year and an average yield of 1.11 t ha⁻¹. In Africa, Ethiopia ranks fifth in sesame cultivation area after Sudan, Tanzania, Nigeria, and Burkina Faso, but ranks eighth in productivity after Central African Republic, Egypt, Somalia, Benin, Nigeria, Cameroon, and Morocco (FAO, 2016).

Agriculture is the main driver for other sectors and a critical component of Ethiopia's economy. Agriculture is also the largest source of foreign exchange earnings and employment. Among oilseeds, sesame (locally known as Selit) is the second-largest foreign exchange earner after coffee. It is widely cultivated in tropical and subtropical regions globally (Gebremariam, 2015) and in Ethiopia the major production areas include northwestern and southwestern Ethiopia, particularly Humera, West Gondar, and Wollega (CSA, 2013).

Nitrogen (N), and Phosphorus (P), are the major plant nutrients that limit crop productivity in Ethiopia. Nitrogen is a vital component of biomolecules such as amino acids, proteins, nucleic acids, phytohormones, enzymes, and coenzymes. It strongly stimulates growth, canopy expansion, and solar radiation interception (Eckert, 2010). Phosphorus, on the other hand, is crucial for plant structural compounds and plays a role in flower formation, seed production, crop maturity, quality improvement, and disease resistance (Bill, 2010). N fertilizers are crucial for increasing crop yields per unit area, as demonstrated by their positive effects on plant height, capsule number per plant, seed index, and seed yield in sesame (Jouyban & Moosavi, 2012; Blal *et al*., 2013). Nitrogen is beneficial for both carbohydrate and protein metabolism, particularly in seed development, where it supports fat synthesis and protein structure formation (Ali *et al*., 2016).

Studies have shown positive effects of nitrogen and phosphorus fertilization on the growth, yield attributes, seed yield, and quality of sesame. Abera (2010) reported that N and P applications significantly improved these parameters, while Haruna (2011) found that applying 60 kg N ha⁻¹ significantly increased grain yield compared to other levels of N application, although yield decreased when N rates were increased from 60 to 120 kg N ha⁻¹. Additionally, 13.2 kg P ha⁻¹ resulted in the highest grain yield per hectare compared to other P levels. Significant and consistent increases in sesame seed yield were observed with increasing phosphorus fertilizer levels from 57 to 76 kg P₂O₅ ha⁻¹ (Hafiz and El-Bramawy, 2012).

Despite the potential, sesame yield in Northern Ethiopia remains low, averaging 525 kg ha⁻¹ compared to the national average of 787 kg ha⁻¹ in 2017. This is in contrast to yields in other countries, such as India (417 kg ha⁻¹), Cameroon (1300 kg ha⁻¹), Central African Republic (1150 kg ha⁻¹), and China (1400 kg ha⁻¹) (FAOSTAT, 2019). The low productivity in Ethiopia is attributed to various constraints, including the lack of improved varieties, moisture stress, poor crop management, low soil fertility, and continuous sesame cultivation without crop rotation (Sisay Berhanu *et al*., 2016).

### 1.1. Objective

The objective of this study was to determine the optimum rates of nitrogen (N) and phosphorus (P) fertilizers for sesame production in Metema, Tegedie, and West Armachiho districts of the Amhara Region.

### 2. Materials and Methods

#### 2.1. Study Area

The study was conducted on farmers' fields in Metema, Tegedie, and West Armachiho districts in the West and Centeral Gondar administrative zones of Amhara National Regional State, Ethiopia. The altitude of the study areas ranges from 550 to 1608 meters above sea level (masl), with minimum annual temperatures between 22°C and 28°C. Daily temperatures can rise significantly between March and May, reaching up to 43°C. The mean annual rainfall ranges from 850 to 1100 mm,. The rainy season extends from June to September, with most precipitation occurring in July and August.



**Figure 1:** Location of the study areas.

#### 2.2. Experimental Treatments, Design, and Procedures

The study evaluated fifteen treatment combinations of five nitrogen levels (0, 46, 69, 92, and 115 kg N ha⁻¹) and three phosphorus levels (0, 23, and 46 kg P₂O₅ ha⁻¹). The experiment was conducted using a factorial design with a randomized complete block design (RCBD) with three replications. Each experimental unit was a plot measuring 2.4 m by 3 m (7.2 m²). A composite soil sample from 0-20 cm depth was collected from each experimental site for laboratory analysis before sowing.

The blocks were separated by a 1.5 m wide open space, and plots within each block were separated by a 1 m space. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient and water movement. Sesame seeds were planted on June 25, 2023, using hand drilling in rows spaced 40 cm apart. Nitrogen was applied in two equal splits: 50% at planting (basal) and the remaining 50% at the maximum branching stage (35-45 days after germination) as urea (46% N). Phosphorus was applied as a total basal dose using triple superphosphate (20% P) during sowing. Weed control was conducted manually by hand-weeding.

2.3 Data collection

Soil sampling and analysis

Before the commencement of the experiment, a composite soil sample was taken from the upper 0-20cm of the experimental field and analyzed for selected physical and chemical properties. Soil pH was determined using a pH meter with combined glass electrode in water (H2 O) at 1:2.5 soil: water ratio as described by Carter (1993). Organic carbon, was determined by oxidizing carbon with potassium dichromate in sulfuric acid solution following the Walkley and Black method. The total nitrogen contents in soils were determined using the Kjeldahl procedure by oxidizing the organic matter with sulfuric acid and converting the nitrogen into NH4 + as ammonium sulfate (Sertsu & Bekele, 2000). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by McLean, E. O. (1965). Available phosphorus was determined in Olsen method. Finally exchangeable bases (Ca,Mg,K and Na) in the soil were estimated by the ammonium acetate (1M NH4 OAc at pH 7) extraction method. In this procedure, the soil samples were extracted with excess of NH4 OAc solution, and Ca and Mg in the extracts were determined by atomic absorption spectrophotometer, while flame photometer was used to determine the contents of exchangeable K and Na as described by (Rowell, 1994).

 Yield related parameters

Plant height (PH cm): It was recorded from ten randomly selected plants from the net plot area at harvest. The average result was reported as plant height in cm.

Number of branches per plant (NBPP): It was recorded from ten randomly selected plants from the net plot area at harvest. The average result was reported as number of branches per plant.

Number of pods per plant (NPPP): It was recorded from ten randomly selected plants from the net plot area at harvest. The average result was reported as number of pods per plant.

Number of seeds per pod (NSPP) : It was determined from randomly selected five pods from the plants used for pod number count from the non-boarder plots. The average number of grain per pod was calculated by dividing the total number of grains with the number of pods per plant

Thousand seed weight (TSW gm): It was determined by weighing 250 randomly selected grains and weighing with sensitive balance and multiplying by four. It was reported as 1000 grain-weight.

Grain yield (Kg ha-1): It was determined after threshing and adjusting the grain yield at the appropriate moisture level of 10.5%. Finally, yield per plot was converted to per hectare basis.

Data analysis methods and software

All measured parameters were subjected to analysis using R software. Treatment means were compared using the least significant difference (LSD) test at 5% significant level.

#### 2.4. Economic Analysis

The economic feasibility of the fertilizer treatments was evaluated using partial budget analysis of, dominance analysis, and marginal rate of return (MRR) calculations:

Partial Budget Analysis: Mean grain yield of selected treatments was used for the economic analysis, incorporating the average open market price of sesame and the official prices of urea, and TSP fertilizers.

Dominance Analysis: Conducted as detailed by (CIMMYT,1988) this analysis identified potentially profitable (undominated) treatments versus less favorable (dominated) treatments. Treatments were ranked from the lowest cost (farmer’s practice) to the highest cost treatment.

Marginal Rate of Return (MRR): Calculated between pairs of undominated treatments, MRR denotes the return per unit of investment in fertilizer as a percentage.

#### **Results and discussion**

**Soil Characteristics and Interpretation**

Based on the initial soil parameters from the Sesame NP trial sites and the ratings from Tekalign et al. (1991), it can be made the following interpretations and recommendations (Table 1). The pH across all sites is about Neutral (6.43 to 6.95), which is suitable for Sesame but may indicate potential deficiencies in major nutrients such as nitrogen and phosphorus. Soil organic matter is low, ranging from 1.043% to 1.756%. Total nitrogen content is also Medium (0.073% to 0.115%), providing a reasonable level for Sesame growth. Available phosphorus varies significantly, all sites exhibit low levels (1.267 to 5.489 ppm), indicating a need for phosphorus supplementation at all sites. Exchangeable potassium is rated very low in most sites. The cation exchange capacity (CEC) is very high across all sites (73.637 to 78.474 cmol(+)/kg) Hazelton, P. and B. Murphy (2007), which is advantageous for nutrient retention and availability. Soil textures are generally heavy clay, which provides good drainage but may also affect nutrient availability and soil management practices. Therefore, targeted fertilization strategies, particularly for nitrogen and phosphorus were implemented to optimize Sesame yield.

Table 1. Initial soil parameters from Sesame NP trial sites

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters  | Metema |  West-Armachiho |  Tegedie |
| pH | 6.43-6.83 | 6.70-6.95 | 6.97 |
| Organic matter (%) | 1.043-1.643 | 1.093-1.756 | 1.135 |
| Total N (%) | 0.073-0.095 | 0.081-0.115 | 0.082 |
| Available P (ppm) | 1.861-5.489 | 1.267-1.802 | 4.656 |
| Ex. K+ cmol(+)/kg | 0.1536-0.2176 | 0.064-0.1408 | 0.2048 |
| CEC cmol(+)/kg | 76.762-78.196 | 73.637-78.474 | 75.649 |
| Sand (%) | 10.72-14.72 | 14.72-16.72 | 10.72 |
| Clay (%) | 66.72-74.72 | 60.72-70.72 | 74.72 |
| Silt (%) | 10.56-22.56 | 14.56-22.56 | 14.56 |
| Textural class | heavy clay |  heavy clay |  heavy clay |

The results of the ANOVA on sesame N and P₂O₅ combined across five locations in 2023 for growth parameters, yield, and yield-related parameters are summarized in Table 2. The ANOVA results indicated that location had a highly significant effect (P<0.01) on all recorded parameters, except for thousand seed weight. The main effects of nitrogen (N) and phosphorus (P₂O₅) were a lso highly significant (P<0.01) on all recorded parameters listed in Table 2.

However, the interaction between nitrogen and phosphorus had a highly significant effect (P<0.01) on the number of branches per plant, thousand seed weight, and grain yield. The combined interaction effect of location and nitrogen had a highly significant impact (P<0.01) on the number of branches per plant, thousand seed weight, and grain yield, while it had no significant effect (P>0.05) on plant height, number of seeds per pod, and number of pods per plant. Similarly, the combined interaction effect of location and P₂O₅ fertilizer had a highly significant effect (P<0.01) on the number of branches per plant and thousand seed weight, but it had no significant effect (P>0.05) on plant height, number of pods per plant, number of seeds per pod, and grain yield. Finally, the combined interaction effect of location, nitrogen, and phosphorus did not significantly affect (P>0.05) any of the recorded parameters listed in Table 2.

Table 2. Mean squares of analysis of variance on the effects of N and P2O5 on growth and yield variables of sesame.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SOV | DoF | PH | NBPP | NPPP | NSPP  | THSW | YIELD |
| Loc |  4 | 2894\*\*\* | 85.27\*\*\* | 2734\*\*\* | 253.7\*\*\* | 0.019ns | 3375820\*\*\* |
| N | 4 | 4155\*\*\* |  41.11\*\* |  7051.3\*\*\* | 142.8\*\*\* | 1.23\*\*\* | 3079117\*\*\* |
| P | 2 | 678\*\*\* | 15.8\*\* | 3978.8\*\*\* | 198.6\*\*\* | 3.64\*\*\* | 1229514\*\*\* |
| N\*P | 8 | 169ns | 0.81\*\*\* | 200.7ns | 88.4ns | 0.041\*\* | 111063\*\*\* |
| Loc\*N  | 16 | 61ns | 0.65\*\*\* | 46.5ns | 20.7ns | 0.051\*\*\* | 43280\* |
| Loc\*P2O5  | 8 | 18ns | 0.86\*\*\* | 88.6ns | 11.78ns | 0.071\*\*\* | 17453ns |
| Loc\*N\* P2O5 | 32 |  31ns | 0.1ns | 70.5ns | 10.18ns | 0.012ns | 10432ns |

PH=Plant height, NPPP= Number of pods per plant, NSPP= Number of seed per pod, THSW= Thousand seed weight, NBPP= Number of branches per plant and Yield= yield per hectare

Plant Height

The application of nitrogenous and phosphorus fertilizers significantly enhanced the plant height of sesame. As nitrogen levels increased from 0 kg/ha to 115 kg/ha, plant height raises from 162.5 cm to 181.7 cm, with the highest growth recorded at the 115 kg/ha nitrogen rate. Nitrogen’s positive effect on growth is attributed to its essential role in chlorophyll formation and overall plant development. Similarly, increasing phosphorus application from 0 kg/ha to 46 kg/ha resulted in a height increase from 172.5 cm to 175.9 cm (Table 3). These findings align with previous research by Kashani *et al*. (2015), which also noted significant improvements in plant height and capsule production with higher nitrogen and phosphorus rates, highlighting the critical role of these nutrients in optimizing sesame growth.

**Number of seeds/pod**

The number of seeds per pod was significantly influenced by nitrogen and phosphorus levels, but their interaction had no notable effect. Nitrogen fertilization, particularly at 69 kg N/ha, led to the highest seed count per pod (70.9), highlighting its importance in promoting pod development. Similarly, phosphorus at 46 kg P/ha yielded the highest seed number per pod (71.3), suggesting that phosphorus supplementation enhances seed development. These findings align with Akhtar *et al*. (2015), who observed a similar trend with higher seed counts at increased nitrogen and phosphorus levels (60 kg N/ha and 80 kg P/ha). Overall, nitrogen and phosphorus both play crucial, independent roles in enhancing seed development, with moderate levels proving most effective.

Number of pods/plant

The number of pods per plant in sesame was significantly influenced by varying levels of nitrogen and phosphorus application. The highest pod count (97.4) was observed with 115 kg N/ha, while the lowest (64.3) occurred with no nitrogen. Similarly, phosphorus levels also showed a positive effect, with 46 kg P/ha resulting in (87.5) pods per plant, while the absence of phosphorus led to (75.4) pods (Table 3). These findings suggest that adequate nitrogen and phosphorus are crucial for pod formation, aligning with previous studies by Shehu *et al*. (2010) and Haggai (2004), which emphasized the importance of these nutrients in enhancing pod production.

Table 3. Main effect of N and P2O5 fertilizers of growth parameters of sesame over five locations

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | PH | NSPP | NPPP | NBPP | THSW | Grain yield |
| Nitrogen  |  |  |  |  |  |  |
| 0 | 162.5d | 65.5c | 64.3e | 3.6d | 2.6c | 660d |
| 46 | 171.5c | 68.4bc | 82.6c | 5.2c | 3b | 1130.8c |
| 69 | 176.6b | 70.9a | 76.4d | 5.6b | 3.04b | 1219.6b |
| 92 | 180.6a | 70.28ab | 90.5b | 5.7b | 3.1a | 1275.2a |
| 115 | 181.7a | 70.8a | 97.4a |  6.1a | 3.03b | 1287.8a |
| LSD (5%) | 3.68 | 2.13 | 6.8 | 0.2 | 0.05 | 55.3 |
| Phosphors |  |  |  |  |  |  |
| 0 | 172.2b | 68.3b | 75.4c | 4.7c | 2.7c | 968.6b |
| 23 | 175.6a | 68.9b | 80.4b | 5.3b | 3.07b | 1168.2a |
| 46 | 175.9a | 71.3a | 87.5a | 5.7a | 3.13a | 1207.2a |
| LSD (5%) | 2.85 | 1.6 | 5.6 | 0.15 | 0.037 | 43.5 |
| Mean | 174.6 | 69.3 | 81.5 | 5.3 | 2.9 | 1114.7 |
| CV (%) | 3.17 | 7.38 | 11.5 | 9.12 | 3.94 | 11.82 |

PH=Plant height, NSPP= Number of seed per pod and NPPP= Number of pods per plant, NBPP= Number of branch per plant, THSW= Thousands seed weight and Grain yield

Table. 4 The main effects of N and P2O5 on the grain yield of sesame(kg) at different locations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | West-Armachiho | Metema | Tsegede | Mean yield |
| Nitrogen  |  |  |  |  |
| 0 | 677.9c | 778.4c | 387.58c | 614.6 |
| 46 | 1165.4b | 1288.8b | 745.61b | 1066.6 |
| 69 | 1266.5a | 1392.5a | 780.01b | 1146.3 |
| 92 | 1282a | 1466.7a | 878.54a | 1209.1 |
| 115 | 1303.7a | 1473.1a | 885.43a | 1220.7 |
| LSD (5%) | 85.82 | 98.09 | 96 | 93.3 |
| Phosphors |  |  |  |  |
| 0 | 983.4b | 1122.2b | 631.65b | 912.4 |
| 23 | 1196.8a | 1333.8a | 779.98a | 1103.5 |
| 46 | 1237.1a | 1383.7a | 794.65a | 1138.48 |
| LSD (5%) | 66.47 | 75.97 | 74.36 | 72.3 |
| Mean | 1139.1 | 1279.9 | 735.43 | 1051.47 |
| CV(%) | 11.29 | 11.49 | 13.52 |  |

Number of branches per plant

The combined main and interaction effect of N and P₂O₅ were highly significant (P<0.01) effect on number of branches per plant (Table 5). The highest (6.64) number of branch per plant were recorded from the plant growth with the application 115 kg N/ha by 46 kg P₂O₅/ha. The lowest (3.1) number of branches per plant were recorded from the plant growth without N and P₂O₅ fertilizers (Table 5). This finding is in line with the work of Kashani, S *et al.,* (2015) who reported that In case of fertilizer, maximum branches plant−1 was recorded in nitrogen (N) and phosphorus (P₂O₅) at 70 - 70 kg∙ha−1, whereas minimum growth and yield parameters were noted in No fertilizer (Control).

Thousand seed weight

The combined main and interaction effects of nitrogen (N) and phosphorus (P₂O₅) were highly significant (P<0.01) on thousand seed weight (Table 5). The highest thousand seed weight (3.3 gm.) was recorded in plants grown with the application of 92 kg N/ha and 46 kg P₂O₅/ha. In contrast, the lowest thousand seed weight (2.43 gm.) was observed in plants grown without any nitrogen or phosphorus fertilizers (Table 5). The adequate supply of essential nutrients, such as nitrogen and phosphorus, significantly enhanced thousand seed weight compared to the control plants, which had poor nutrient availability. This finding is consistent with the work of Akhtar *et al*. (2015), who reported that the interaction between nitrogen and phosphorus resulted in the highest thousand seed weight (4.43 g) at a 100:60 kg N: P/ha application ratio, while the lowest thousand seed weight (3.80 g) was observed at a 40:60 kg N: P/ha ratio.

Grain yield

The combined analysis of variance indicated that the interaction effect of nitrogen (N) and phosphorus (P₂O₅) had a highly significant impact (P < 0.01) on the grain yield of sesame (Table 5). The highest grain yield (1358.6 kg ha⁻¹) was observed from a treatment of 115 kg/ha N and 46 kg/ha P₂O₅. In contrast, the lowest grain yield (592.4 kg ha⁻¹) occurred in the control treatment, where no nitrogen or phosphorus fertilizers were applied (Table 4). The increase in seed yield due to the application of nitrogen and phosphorus can be attributed to an increase in the number of capsules per plant, the number of seeds per capsule, and the 1000-seed weight. This finding is consistent with the study by Akhtar *et al*. (2015), which also demonstrated that the interaction between nitrogen and phosphorus fertilization resulted in higher seed yields, with the highest yield (891.26 kg/ha) observed in plots treated with 100 kg N and 80 kg P/ha.

Previously, the recommended fertilizer rate was 30 kg Nitrogen (N) per hectare. However, based on recent findings, the new recommendation has been adjusted to 46 kg Nitrogen (N) per hectare combined with 23 kg Phosphorus ( P2O5) per hectare.

Table 5. Interaction effect of N & P2O5 fertilizers of growth, yield related and yield combined over five locations

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | NBPP | THSW | YIELD |
| Phosphors rate |
| Nitrogen rates | 0 | 23 | 46 | 0 | 23 | 46 | 0 | 23 | 46 |
| 0 | 3.1h | 3.6g | 4.1f | 2.43h | 2.84e | 2.82ef | **592.4g** | 692.1f | 744.2ef |
| 46 | 4.4f | 5.58d | 5.78bcd | 2.71g | 3.13cd | 3.18bcd | 813.5e | 1281.4abc | 1297.5ab |
| 69 | 5.1e | 5.78bcd | 5.9bcd | 2.75fg | 3.2bc | 3.2ab | 1088d | 1278.3abc | 1292.5ab |
| 92 | 5.64cd | 5.62cd | 5.96bc | 2.9e | 3.16bcd | 3.3a | 1205.5bc | 1276.7abc | 1343.3a |
| 115 | 5.56d | 6.13b | 6.64a | 2.85e | 3.1d | 3.14cd | 1192cd | 1312.8a | **1358.6a** |
| MEAN | 5.27 | 2.98 | 1114.7 |
| LSD (5%) | 0.35 | 0.09 | 105.5 |
| CV (%) | 9.11 | 3.93 | 11.82 |

NBPP= Number of branches per plant, THSW= Thousand seed weight and Yield= yield per hectare

Nitrogen application positively influences grain yield, but excessive nitrogen beyond (92 kg/ha) may not provide substantial yield benefits. The response to nitrogen varies between locations , with "Metema" showing a greater initial increase. Optimal nitrogen application should consider economic and environmental aspects to avoid unnecessary fertilizer use.(figure2.)

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#### Figure 2. Effect of nitrogen rates on sesame grain yield in (a) West Armachihi and Metema, (b) Tegedie.

Applying phosphorus fertilizer improves grain yield across all locations. The response is stronger at lower phosphorus levels but diminishes at higher levels.Different locations respond differently, with W\_Armachiho performing the best and Tegedie the lowest.Optimal phosphorus application should be considered to maximize yield while avoiding excessive fertilizer use.(figure3.)



#### Figure 3. Effect of phosphorus rates on sesame grain yield in study areas

#### Regression Analysis of N and P Fertilizer on Sesame Yield

The regression analysis of the effects of nitrogen and phosphorus on sesame yield in the study areas (West Armachiho, Tegedie, and Metema) is summarized in Figure3.

 The regression models for each location are as follows:

* Metema: GY=7.32N+5.41P2O5+536.075 GY = 7.32N + 5.41P\_{2}O\_{5} + 536.075GY=7.32N+5.41P2​O5​+536.075 with R2=0.65R^2 = 0.65R2=0.65,

Adjusted R2=0.63R^2 = 0.63R2=0.63

* West Armachiho: GY=3.7N+3.6P2O5+827.1GY = 3.7N + 3.6P\_{2}O\_{5} + 827.1GY=3.7N+3.6P2​O5​+827.1 with R2=0.68R^2 = 0.68R2=0.68,

Adjusted R2=0.65R^2 = 0.65R2=0.65

* Tegedie: GY=4.4N+3.5P2O5+374.6GY = 4.4N + 3.5P\_{2}O\_{5} + 374.6GY=4.4N+3.5P2​O5​+374.6 with R2=0.77R^2 = 0.77R2=0.77,

Adjusted R2=0.74R^2 = 0.74R2=0.74



**Figure 4:** Scatter plots with regression planes for (a) West Armachiho, (b) Tegedie, and (c) Metema.

The regression analysis revealed that 65%,68%, and77 % of the total variation of sesame grain yield in Metema,West Armachiho and Tegedie was significantly explained by the regression equation. The intercept, nitrogen, and phosphorus levels all had highly significant effects (P<0.01) on grain yield across all sites. Sesame grain yield increased with increasing rates of N and P, with the highest yield (1571.1 kg/ha) achieved at 115 kg N/ha and 46 kg P₂O₅/ha, indicated by the purple color in Figure 4. The lowest yield (780.8 kg/ha) was observed without fertilizer application in Metema. These findings are consistent with previous studies (Jahan et al., 2019; Priyadarshini et al., 2021) that reported optimal yields with 112.5 kg N/ha and 45 kg P/ha. Conversely, Haruna et al. (2010) noted that further increasing P₂O₅ rates could decrease yields, and excessive P application did not enhance benefits.

#### Table 6. Partial budget analysis of Sesame predicted grain yield response to fertilizers in Metema

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N | P2O5 | Gy | Adj.Gy | GB | N | P2O5 | Labor | TVC | NB | D | MRR |
| 0 | 0 | 459.1 | 413.1 | 57834 | 0 | 0 | 0 | 0 | 57834 |   |   |
| 0 | 23 | 614.9 | 553.4 | 77476 | 0 | 2000 | 1375 | 3375 | 74101 |   | 482.0 |
| 0 | 46 | 695.7 | 626.1 | 87654 | 0 | 4000 | 500 | 4500 | 83154 |   | 804.7 |
| 30 | 0 | 595.6 | 536.1 | 75054 | 2935 | 0 | 3423 | 6358 | 68696 | D |  |
| 30 | 23 | 830.7 | 747.6 | 104664 | 2935 | 2000 | 4798 | 9733 | 94931 |   | 777.3 |
| 46 | 0 | 950.1 | 855.1 | 119714 | 4500 | 0 | 5250 | 9750 | 109964 |   | 88429.4 |
| 60 | 0 | 764.6 | 688.1 | 96334 | 5870 | 0 | 6846 | 12716 | 83618 | D |  |
| 30 | 46 | 904.3 | 813.9 | 113946 | 2935 | 4000 | 6173 | 13108 | 100838 |   | 4392.9 |
| 46 | 23 | 1450.2 | 1305.2 | 182728 | 4500 | 2000 | 6625 | 13125 | 169603 |   | 404500 |
| 69 | 0 | 1274.7 | 1147.2 | 160608 | 6750 | 0 | 7875 | 14625 | 145983 | D |  |
| 60 | 23 | 923.6 | 831.3 | 116382 | 5870 | 2000 | 8221 | 16091 | 100291 | D |  |
| 46 | 46 | 1466.2 | 1319.6 | 184744 | 4500 | 4000 | 8000 | 16500 | 168244 |   | 16614.4 |
| 69 | 23 | 1438.9 | 1295.1 | 181314 | 6750 | 2000 | 9250 | 18000 | 163314 | D |  |
| 90 | 0 | 1043.7 | 939.3 | 131502 | 8805 | 0 | 10269 | 19074 | 112428 | D |  |
| 60 | 46 | 1058.8 | 952.9 | 133406 | 5870 | 4000 | 9596 | 19466 | 113940 |   | 385.7 |
| 92 | 0 | 1386.1 | 1247.5 | 174650 | 9000 | 0 | 10500 | 19500 | 155150 |   | 121206 |
| 69 | 46 | 1463.8 | 1317.4 | 184436 | 6750 | 4000 | 10625 | 21375 | 163061 |   | 421.9 |
| 90 | 23 | 1008.9 | 908.1 | 127134 | 8805 | 2000 | 11644 | 22449 | 104685 | D |  |
| 92 | 23 | 1458.2 | 1312.4 | 183736 | 9000 | 2000 | 11875 | 22875 | 160861 |   | 13186.9 |
| 115 | 0 | 1359.4 | 1223.4 | 171276 | 11250 | 0 | 13125 | 24375 | 146901 | D |  |
| 90 | 46 | 1108.4 | 997.5 | 139650 | 8805 | 4000 | 13019 | 25824 | 113826 | D |  |
| 92 | 46 | 1545.7 | 1391.1 | 194758.2 | 9000 | 4000 | 13250 | 26250 | 168508.2 |   | 12836.2 |
| 115 | 23 | 1488.9 | 1340.1 | 187614 | 11250 | 2000 | 14500 | 27750 | 159864 | D |  |
| 115 | 46 | 1571.1 | 1413.9 | 197951 | 11250 | 4000 | 15875 | 31125 | 166826 |   | 206.3 |

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Table 7. Partial budget analysis of sesame predicted grain yield response to fertilizers in West Armachiho

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N  | P2O5 | Gy | Adj.Gy | GB | N | P205 | Labor | TVC | NB | D | MRR |
| 0 | 0 | 780.8 | 702.7 | 98378 | 0 | 0 | 0 | 0 | 98378 |  |  |
| 0 | 23 | 870.8 | 783.8 | 109732 | 0 | 2000 | 125 | 2125 | 107607 |  | 434.3059 |
| 30 | 0 | 1023.7 | 921.3 | 128982 | 2935 | 0 | 163 | 3098 | 125884 |  | 1878.417 |
| 0 | 46 | 916.9 | 825.2 | 115528 | 0 | 4000 | 250 | 4250 | 111278 | D |  |
| 46 | 0 | 839.7 | 755.7 | 105798 | 4500 | 0 | 250 | 4750 | 101048 | D |  |
| 30 | 23 | 1051.2 | 946.1 | 132454 | 2935 | 2000 | 288 | 5223 | 127231 |  | 5535.518 |
| 60 | 0 | 1025.9 | 923.4 | 129276 | 5870 | 0 | 326 | 6196 | 123080 | D |  |
| 46 | 23 | 1340.2 | 1206.2 | 168868 | 4500 | 4000 | 500 | 9000 | 159868 |  | 6836.082 |
| 69 | 0 | 1146.6 | 1031.9 | 144466 | 6750 | 0 | 375 | 7125 | 137341 | D |  |
| 30 | 46 | 1018.9 | 916.9 | 128366 | 2935 | 4000 | 413 | 7348 | 121018 | D |  |
| 60 | 23 | 966.5 | 869.8 | 121772 | 5870 | 2000 | 451 | 8321 | 113451 | D |  |
| 46 | 46 | 1316.2 | 1184.6 | 165844 | 4500 | 2000 | 375 | 6875 | 158969 |  | 5285.567 |
| 69 | 23 | 1321.3 | 1189.2 | 166488 | 6750 | 2000 | 500 | 9250 | 157238 | D |  |
| 90 | 0 | 1169.45 | 1052.5 | 147350 | 8805 | 0 | 489 | 9294 | 138056 | D |  |
| 92 | 0 | 1192.9 | 1073.6 | 150304 | 9000 | 0 | 500 | 9500 | 140804 |  | 1333.981 |
| 60 | 46 | 1176.9 | 1059.2 | 148288 | 5870 | 4000 | 576 | 10446 | 137842 | D |  |
| 69 | 46 | 1331.6 | 1198.5 | 167790 | 6750 | 4000 | 625 | 11375 | 156415 |  | 1999.247 |
| 90 | 23 | 1187.8 | 1068.9 | 149646 | 8805 | 2000 | 614 | 11419 | 138227 | D |  |
| 92 | 23 | 1296.9 | 1167.2 | 163408 | 9000 | 2000 | 625 | 11625 | 151783 |  | 6580.583 |
| 115 | 0 | 1187.2 | 1068.5 | 149590 | 11250 | 0 | 625 | 11875 | 137715 | D |  |
| 90 | 46 | 1185.7 | 1067.1 | 149394 | 8805 | 4000 | 739 | 13544 | 135850 | D |  |
| 92 | 46 | 1356.2 | 1220.5 | 170870 | 9000 | 4000 | 750 | 13750 | 157120 |  | 10325.24 |
| 115 | 23 | 1349.5 | 1214.6 | 170044 | 11250 | 2000 | 750 | 14000 | 156044 | D |  |
| 115 | 46 | 1374.42 | 1236.9 | 173166 | 11250 | 4000 | 875 | 16125 | 157041 |  | 46.91765 |

Table 8. Partial budget analysis of Sesame predicted grain yield response to fertilizers in Tegedie.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N | P | Gy | Adj.Gy | GB | N | P2O5 | Labor | TVC | NB | D | MRR |  |
| 0 | 0 | 336 | 302.4 | 42336 | 0 | 0 | 0 | 0 | 42336 |  |  |  |
| 0 | 23 | 394.9 | 355.4 | 49756 | 0 | 2000 | 1375 | 3375 | 46381 |  | 119.9 |  |
| 0 | 46 | 431.9 | 388.7 | 54418 | 0 | 4000 | 500 | 4500 | 49918 |  | 314.4 |  |
| 46 | 0 | 488.1 | 439.3 | 61502 | 4500 | 0 | 5250 | 9750 | 51752 | D | 34.9 |  |
| 46 | 23 | 874.1 | 786.7 | 110138 | 4500 | 2000 | 6625 | 13125 | 97013 |  | 1341.1 |  |
| 69 | 0 | 597.6 | 537.8 | 75292 | 6750 | 0 | 7875 | 14625 | 60667 | D |  |  |
| 46 | 46 | 874.6 | 787.2 | 110208 | 4500 | 4000 | 8000 | 16500 | 93708 |  | 1762.2 |  |
| 69 | 23 | 870.8 | 783.8 | 109732 | 6750 | 2000 | 9250 | 18000 | 91732 | D |  |  |
| 92 | 0 | 869.7 | 782.7 | 109578 | 9000 | 0 | 10500 | 19500 | 90078 | D |  |  |
| 69 | 46 | 871.6 | 784.5 | 109830 | 6750 | 4000 | 10625 | 21375 | 88455 | D |  |  |
| 92 | 23 | 873.1 | 785.8 | 110012 | 9000 | 2000 | 11875 | 22875 | 87137 | D |  |  |
| 115 | 0 | 867 | 780.3 | 109242 | 11250 | 0 | 13125 | 24375 | 84867 | D |  |  |
| 92 | 46 | 892.8 | 803.5 | 112490 | 9000 | 4000 | 13250 | 26250 | 86240 |  | 73.2 |  |
| 115 | 23 | 887 | 798.3 | 111762 | 11250 | 2000 | 14500 | 27750 | 84012 | D |  |  |
| 115 | 46 | 902.3 | 812 | 113680 | 11250 | 4000 | 15875 | 31125 | 82555 | D |  |  |

Partial budget analysis was used to determine the net benefits of different fertilizer treatments. The treatment with 46 kg N and 23 kg P₂O₅/ha had the highest net benefit of 169603 ETB, 159868 ETB, 97013 ETB followed by 46 kg N and 46 kg P2o5/ha, with net benefits of 108861.5 ETB, 105589.5 ETB, and 93708 ETB, respectively in Metema, West Armachiho and Tegedie.. The lowest net benefit (5783439248.3 ETB),(98378 ETB),(42336 ETB) was observed in the control (no fertilizer).This analysis confirms that increased input application may or may not be profitable for farmers, necessitating careful economic evaluation.

### Conclusion and Recommendation

 The highest mean sesame yield (1305.2, 923.4,786.7kg/ha) were achieved with 46 kg N and 23 kg P₂O₅/ha, significantly improving yield by315.9%,168.5%,260% in Metema,West Armachiho and Tegedie respectively compared to the control. The partial budget analysis showed that this treatment also provided the highest net benefit (169603 ETB, 159868 ETB, 97013 ETB). Marginal rate of return analysis supported this finding, showing a high return on investment with acceptable MRR, low costs, and high net benefits. Therefore, the application of 46 kg N and 23 kg P₂O₅/ha is recommended for sesame production in the West and Centeral Gondar zones.

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