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Effect of NPS Fertilizer Rates on Yield and Yield Components of Sesame (*Sesamum indicum* L.) Varieties at Uke, Western Ethiopia

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Abstract: In Ethiopia, sesame is the leading oil crop followed by Niger seed and linseed; and oil seed is the third largest sector after cereal and pulse. Production and productivity of sesame is greatly affected by lack of optimum fertilizer rate, inappropriate sowing time, lack of optimum plant population, biotic and a biotic factor such as disease and pest infestation, low yielding variety, post-harvest lost, low fertilizer response, difference in capsule maturity, shattering etc. The study was carried out in 2018 main cropping season at Uke in Guto Gida District of East Wollega Zone of Oromia Regional State with the objectives of investigating the effects of NPS fertilizer rates on yield and yield components of sesame varieties. The treatment consisted of three sesame varieties (Chalsa, Dicho and Obsa) and five levels of NPS fertilizer (0, 50, 100, 150 and 200 kg/ha) and combined factorially and laid out in Randomized Complete Block Design with three replications. Data were taken for agronomic traits and subjected to analysis of variance using General Liner Model procedures of SAS (SAS, 2004) and means differences were tested for their significance using least significance difference method. The results of analysis of variance indicated that the effects of varieties were significant ($P<0.05$) for all parameters except for days to 50% emergency, length of capsule bearing zone and capsule length. Similarly, the effects of NPS fertilizer rates were significant ($P<0.05$) for all parameters. The interaction effect of varieties by NPS fertilizer rates were significant ($P<0.05$) for all parameters except for days to 50% emergency and capsule length. Obsa variety with application of 150kg NPS/ha fertilizer gave the highest grain yield (813.9kg/ha). Generally, sesame yield can be increased substantially by applying NPS fertilizer rate up to 150kg/ha to all the three varieties. The application of 150kg NPS/ha specifically to Obsa variety increased grain yield and yield components of sesame through improving soil nutrient availability resulting in better vegetative growth, yield components and, thereby, higher yield and net benefit, 20572.5 ETB/ha thus, can be recommended for the production of sesame in the study area. However, since the study was conducted only at one location for single cropping season and it should be repeated at diverse locations and years to give a conclusive recommendation.

Keywords: Sesame, Varieties, Grain Yield, NPS Fertilizer, Net Benefit

1. Introduction

Sesame (*Sesamum indicum* L.) is an annual plant that belongs to the *Pedaliaceae* family. It is one of the world's oldest oil seed crop grown mainly for its high oil content of the seeds that contain approximately 52 to 57% oil and 25% protein content [1]. Sesame has been grown in the Near East and Africa for over 5,000 years for cooking and medicinal needs. And it is recorded as a crop in Babylon and Assyria some 4,000 years ago [2].

Sesame is an erect herbaceous annual plant with either single stemmed or branched growth habits and two growth characteristics of indeterminate and determinate, reaching up to 2 m height and with a large tap root of up to 90cm [3]. Areas with annual rainfall of 625-1100 mm and temperature of $>27^0$c is most conducive for sesame production. The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams [4].

More than 9.42 million hectares of the total world crop area is under sesame cultivation with about 4 million metric tons of total production [5]. Although, the order of leading sesame producer countries is changing from time to time but Ethiopia is the sixth largest sesame producer in the world following Myanmar, India, China, Sudan and Tanzania, and third in Africa followed by Uganda and Nigeria. Of the world production of sesame, the top 5 countries account over 64.3% [6].

In Ethiopia during 2015/16 cropping season, the total land coverage, production and national productivity of sesame is 388,245.50 ha, 274,217.43 quintals and 0.71tons per hectare respectively [7]. While area of land covered by the crop in Oromia Region is about 58,202.10 ha with a total production of 45,485.11 tons. According to [8] from an area of 337,926.82 hectares produce 2,678,665.46 quintals with the yield of 7.93 quintals/ha.

The Ethiopian quality sesame varieties are usually known by their brand name. There are three sesame variety types commonly used for commercial production and these are Humera, Gondar and Wollega types. Humera type is appreciated worldwide for its aroma and sweet taste. It is said to be good uniform white seeds, which are quite larger. This makes it very suitable for bakery products. The Gondar type is also suitable for the bakery market. The major competitive advantage of the Wollega type is its high oil content [9].

The major constraints in sesame production worldwide are lack of wider adapting cultivars, shattering of capsules at maturity, nonsynchronous maturity, poor stand establishment, lack of fertilizer response, profuse branching, biotic and abiotic factors such as pest infestation, low yielding, post-harvest lost, poor storage facility and low harvest index [1].

Even though sesame is considered as a low nutrient feeder, organic and inorganic fertilizer application showed yield increment compared to untreated plots [10]. Recommend NPK fertilizer at a rate of 75 kg N, 45 kg P_2O_5 and 22.5 kg K_2O/ha for highest net return in sesame production [11]. Sesame is one of the most widely grown crop around the experimental site, and mainly produced for the purpose of both consumption as well as marketing. It is grown during the main cropping season (June to November). However, the yield reduction due to lack of optimum fertilizer rate and the yield response of sesame varieties is not well known by the farmers in the study area. They do not have enough information on the yield advantage of optimum fertilizer rates on sesame varieties. And also the use of sesame varieties is not well adaptable by the farmers. Fertilization needs to be optimumly used in order to avoid a negative ecological impact and undesirable effects on the sustainability of agricultural production system. Excessive application of fertilizers also affects the farmers' economy.

1.1. General Objective

The general objective of this trail is to determine the effect of NPS fertilizer rates on sesame varieties that improves their productivity and thereby increase the income of producers in the study area.

1.2. Specific Objectives

1) To determine the optimum rate of NPS fertilizer for yield and yield components of sesame varieties.
2) To determine the cost benefit analysis of NPS fertilizer application and identify economical rate of NPS fertilizer application for sesame production.

2. Materials and Methods

2.1. Study Area

The study was carried out at Uke Research and Technology Demonstration Site of Wollega University and the site is located in Guto Gida District of East Wollega Zone of Oromia Regional State. The center is located about 365km far away from Addis Ababa and around 40 km far away from Nekemte in the northern direction on the main road to Bahir Dar Town. The topography of the area is between 1500-1700 masl. The area is characterized by mixed farming type dominantly by cereal crops. The area receives rain once in a year which is suitable to produce crops in once in a year. The temperature of the area is characterized by warm which is suitable for different growing crops including field crops, vegetables and root crops. The pH of the soil is acidic with red color of Nitosol; a dominant soil type in the western Ethiopia (Guto Gida Agricultural Office, 2009, Unpublisded data).

2.2. Planting Materials

Three varieties of sesame Chalsa, Obsa and Dicho were taken from Bako Agricultural Research Center. Obsa (Acc. EW004) and Dicho (Acc. EW015) were selected and released for production originally from local landraces collected from western region of Ethiopia by IBC (Institute of Biodiversity Conservation) decades ago.

Table 1. *Description of planting materials.*

Varieties	Year of release	Yield qt/ha	Seed color	Thousand seeds weight (g)	Oil (%)	Maturity date	Adaptation Areas
Chalsa	2013	10.5-12	Light white	-	51	95-120	Bako, Deddesa, Gutin and similar agro-ecologies
Dicho	2010	10.63	White	2.72	53.8	131-142	Bako, Deddesa, Gutin and similar agro-ecologies
Obsa	2010	10.69	White –tan	2.56	51.55	120-137	Bako, Deddesa, Gutin and similar agro-ecologies

Source: MoARD, crop variety register book 2007- 2016.

2.3. Experimental Treatments and Design

The treatments consists of two factors, NPS fertilizer levels (0, 50, 100, 150 and 200 kg/ha) and three varieties (Chalasa, Dicho and Obsa) and combined factorially and laid out in Randomized Complete Block Design with three replications. The spacing between rows and plants were 40 and 10cm respectively and there were six (6) rows in each plot. The area of each plot was 2.4*3m=7.2m^2. The distance between two plots and blocks was 0.5m and 1.5m respectively. The total experimental area was 530m^2.

2.4. Experimental Procedures

According to the experimental design selected, a field layout was prepared and each treatment was assigned randomly to a plot within a block. The sesame varieties were sown on a well prepared fine seed bed with NPS fertilizer rates; and 50 kg/ha Urea (half at planting and half before flowering) was applied uniformly to all experimental units. The sesame varieties were planted using the recommended seed rate (4g/plot). Then, all other necessary cultural practices were applied uniformly.

2.5. Data Collection and Analysis

Data such as Days to 50% emergence, Days to 50% flowering, Days to 90% maturity, Plant height, Length of capsules bearing zone, Capsule length, Number of primary branches per plant, Number of capsules per plant, Number of seeds per capsule, Biomass yield, Thousand seed weight, Grain yield, Harvest index were collected from the central four rows. All parameters were recorded from six randomly selected plants in the middle rows on the net plot bases.

Prior to sowing, soil samples were taken from five representative points within the experimental area at 0-30 cm depth using zigzag line in the experimental field to make a composite sample for analysis of physical and chemical properties of soil. Similarly, soil samples were taken from each plot after harvesting and plots those received equal fertilizer levels were composited together in to 5 samples. Soil analysis for specific parameters (texture, pH, organic carbon, organic matter, phosphorus availability, total nitrogen and potassium availability) was carried out at Nekemte Soil Research Center.

The data collected were subjected to analysis of variance by SAS software. Means that showed a significant difference were separated by least significant difference at 0.05 probability level by SAS (SAS, 2004). Correlations analysis among growth, yield and yield components were done.

2.6. Partial Budget Analysis

Partial budget analysis procedure was employed for economic analysis of fertilizer application for sesame yield. The potential response of crop towards the added fertilizers and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application [12] (CIMMYT, 1988). To estimate the total costs, mean current prices of Urea (13.00 ETB/kg) and NPS (15.00 ETB/kg) were collected at the time of planting. Application cost 6 persons for 50kg NPS/ha with 50kg/ha Urea = 300 ETB/ha, 10 persons for 100 kg NPS/ha with 50kg/ha Urea =500 ETB/ha, 14 persons for 150kg NPS/ha with 50kg/ha Urea = 700 ETB/ha and 18 persons for 200kg NPS/ha with 50kg/ha Urea =900 ETB/ha. The wage rate per worker was 50 ETB per day. Sale price of sesame varieties- Chalsa, Dicho and Obsa was 33 ETB/kg. Cost of land preparation, field management, harvest, transportation, guarding, storage, planting material, post-harvest handling, and other similar costs were not included in the calculation, since everything was done uniformly for all treatments.

Gross average yield (GAY) (kg/ha): is an average yield of each treatment.

Adjusted yield (AJY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

$$AJY = GAY - (GAY * 0.1)$$

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield.

$$GFB = AJY * \text{field/farm gate price of a crop}$$

Total cost (TC): mean current prices of Urea (13.00 ETB/kg), NPS (15.00 ETB/kg), and the wages for fertilizer application were considered per hectare.

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

3. Results and Discussion

3.1. Physico-Chemical Properties of Soil

The soil before sowing was clay loam in texture and was not affected by application of NPS fertilizer. Soil texture is the inherent property of the soil, which is sufficiently permanent and is often used to characterize the soil physical make up [13]. Chemical properties of the soil after harvest showed increase in contents of total nitrogen, available phosphorus, organic matter and organic carbon; but decreased in pH as the rates of NPS fertilizer applied increased (Table 2).

Table 2. *Soil Physical and Chemical properties before sowing and after harvest.*

Sample from plots with NPS (kg/ha)	Soil texture			Soil texture Class	PH (H_2O)	OC %	OM %	TN (%)	AP (ppm)	AK (ppm)
	% Sand	% Silt	% Clay							
Before sowing	44	18	38	Clay loam	5.72	1.37	2.35	0.12	7.29	64
0	43	18	39	Clay loam	5.77	1.07	1.84	0.1	7.68	59
50	42	18	38	Clay loam	5.75	2.01	3.41	0.17	8.32	66
100	43	16	37	Clay loam	5.73	2.13	3.67	0.18	8.13	69
150	43	18	39	Clay loam	5.73	2.6	4.48	0.22	10.2	71.5
200	41	20	39	Clay loam	5.60	3.15	5.43	0.27	11.5	72.5

OC-organic carbon; OM- organic matter; TN- total nitrogen; AP- available phosphorous; AK- available potassium.

3.2. Analysis of Variance

The results of Analysis of Variance for different parameters are presented in Table 3. The results indicated that the effects of varieties were significant (P<0.05) for all parameters except for days to 50 % emergency, length of capsule bearing zone and capsule length. Similarly, the effects of NPS fertilizer rates were significant (P<0.05) for all parameters. The interaction effect of varieties by NPS fertilizer rates were significant (P<0.05) for all parameters except for days to 50% emergency, capsule length and number of nodes per main stem. Therefore, for those parameters with non-significant interaction effects, the main effects (variety and NPS rates) are more important and the results were presented accordingly.

Table 3. *Mean square values for different agronomic traits in sesame as affected by variety, fertilizer rates and the interaction of variety by fertilizer rates.*

Traits	Rep (df=2)	V (df=2)	NPS (df=4)	V x NPS (df=8)	Error (df=28)	Mean	CV (%)
DE	0.088^{ns}	0.42^{ns}	2.25^{*}	0.088^{ns}	0.39	6.96	9.07
DF	7.35^{**}	180.82^{**}	415.42^{**}	1.57^{*}	0.45	59.48	1.13
DM	31.48^{**}	372.8^{**}	133.4^{**}	1.988^{*}	0.79	107.18	0.83
PH	109.11^{**}	128.75^{**}	3619.78^{**}	8.93^{**}	2.68	101.08	1.62
LCBZ	28.67^{*}	10.38^{ns}	1327.75^{**}	16.88^{*}	5.81	55.008	4.38
CL	0.19^{**}	0.038^{ns}	0.34^{**}	0.0089^{ns}	0.018	2.25	5.98
NPB	0.64^{**}	1.54^{**}	9.05^{**}	0.14^{**}	0.033	4.83	3.79
NCPP	123.12^{**}	101.70^{**}	1494.97^{**}	6.86^{*}	2.48	2.48	2.95
NSPC	19.29^{**}	30.49^{**}	1247.3^{**}	3.02^{*}	1.31	59.78	1.92
TSW	0.061^{**}	0.133^{**}	0.092^{**}	0.004^{*}	0.002	2.42	1.66
GY	2213.47^{**}	5061.52^{**}	190909.32^{**}	466.5^{*}	146.7	681.43	1.77
BY	8652.47^{*}	4998.13^{*}	1701352.49^{**}	2781.332^{*}	1117.65	3060.60	1.09
HI	0.00076^{**}	0.00078^{**}	0.0035^{**}	0.00004^{*}	0.00001	0.22	1.62

**=significant at 1%, *= significant at 5% level of probability, ns=non-significant, DE= Days to 50% emergency, DF= Days to 50% flowering, DM= Days to 90% maturity, PH=Plant height (cm), LCBZ= Length of capsule bearing zone (cm), CL= Capsule length (cm), NPB=Number of primary branches per plant, NCPP= Number of capsules per plant, NSPC=Number of seeds per capsule, TSW= Thousand seeds weight (g), GY= Grain yield (kg/ha), BY= Biomass yield (kg/ha) and HI= Harvest index.

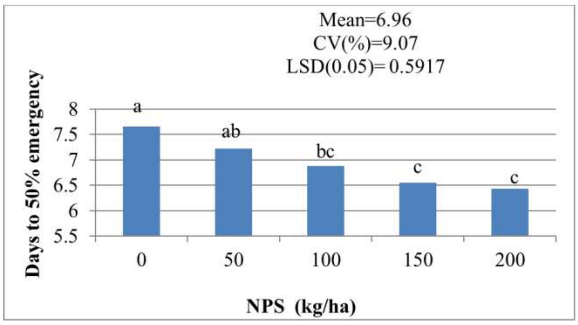

Figure 1. *Main effect of NPS fertilizer rate on days to 50% emergency of sesame at Uke.*

3.3. The Effect of NPS Fertilizer Rates on Phenology of Sesame Varieties

3.3.1. Days to 50% Emergency

On the ANOVA (Table 3) varieties and interaction effect of variety by NPS fertilizer rates did not show significance difference on 50% days to emergency of sesame. However, NPS fertilizer levels showed significance difference at (P <0.05). The maximum number of days to 50% emergency (7.66) was obtained from the control but not significantly different from 50kg NPS/ha with 7.22 days. The minimum DE was 6.22 obtained from 200 kg NPS/ha but it was not significantly different from 150 and 100 kg NPS/ha with 6.55 and 6.44 days respectively (Figure 1). Phosphorus is a key component of Phytin, which is a seed component that is essential to inducing germination [14]. Application of inorganic N fertilizer at the time of planting stimulates better crop emergence especially in N deficient soil [15]. This result contradicts with finding of [16] who reported that plants depend mostly on stored food than on external nutrients for germination.

Table 4. *Interaction effect of varieties by fertilizer rates on days to 50 % flowering.*

Varieties	Days to 50 % flowering (DF)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	66.67^{b}	58.67^{e}	56.33^{f}	54.67^{g}	49.00^{h}
Dicho	73.00^{a}	67.00^{b}	62.67^{c}	60.67	54.00^{g}
Obsa	67.00^{b}	61.00^{d}	58.00^{e}	55.33^{gf}	48.33^{h}
Mean	59.49				
LSD (0.05)	1.59				
CV (%)	1.13				
SEM (±)	0.24				

*means followed by the same letters in the columns and rows of each trait are not significantly different at P<0.05.

3.3.2. Days to 50% Flowering

The mean value for the effect of variety with NPS rates are presented in Table 4. Days to 50% flowering was significantly affected by the interaction effect of variety by NPS fertilizer rates. The longest time to 50% flowering was 73.0 days for Dicho variety with control, 0kg NPS/ha. The fewest number of days to flowering (48.33 days) was obtained from Obsa with application of 200 kg NPS/ha and it was statistically in par with the treatment Chalsa x 200 kg NPS/ha (49.00 days). In general, the lower fertilizer rates resulted in longer days to flowering, while higher fertilizer levels respond shorter days to flowering for all the three varieties. The deficiency of major nutrients stunted the plant growth, resulting in maximum days taken to flowering. Gradual increase in NPS levels reduced the days taken to flowering. Nitrogen plays a major role in the synthesis of proteins, nucleic acid, nucleotides, enzymes, alkaloids, vitamins and chlorophyll and it also affect flowering and fruit setting in sesame [17].

3.3.3. Days to 90% Maturity

Table 3 shows a significant effect of varieties, NPS and their interaction on days to maturity of sesame. The results of the effects of variety by NPS fertilizer rates for mean values of days to maturity (DM) are presented in Table 5. The results showed that the treatment combination of Dicho with 200kg NPS/ha and Chalsa with 0kg NPS/ha produced the highest (117.7 days) and the lowest (97.33 days) values respectively. Numbers of days to 90% maturity were significantly increased as NPS fertilizer rate increased. This might be because of vigorous and enhanced vegetative growth of plants at the expense of reproductive growth which brought about a delay in maturity. Senescence and maturation are accelerated by N deficiency. This could be attributed to the fact that nitrogen have been reported to increase leaf size and chlorophyll content, delayed maturity time and increased vegetative growth period [18]. Phosphorus deficit is the most important restrictive factor in plant growth and development [19].

Table 5. *Interaction effect of variety by fertilizer rate on days to 90 % maturity.*

Variety	Days to 90 % maturity (DM)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	97.33^{j}	100.0^{ij}	101.7^{hi}	103.3^{gh}	105.7^{fg}
Dicho	106.3^{ef}	109.0^{de}	110.0^{d}	113.0^{bc}	117.7^{a}
Obsa	103.3^{gh}	106.3^{ef}	109.0^{de}	111.0^{cd}	114.0^{b}
Mean	107.18				
LSD (0.05)	2.81				
CV (%)	0.83				
SEM (±)	0.41				

*means followed by the same letters in the columns and rows under each trait are not significantly different at P<0.05.

3.4. Effect of NPS Fertilizer Rates on Growth Characters of Sesame Varieties

3.4.1. Plant Height

The results of the mean values for interaction of variety x NPS rates on plant height are presented in Table 6. The results indicated that Dicho variety with application of 200kg NPS/ha gave the maximum plant height (122.5 cm) and it was statistically in par with the treatments Chalsa x 200 kg NPS/ha and Obsa x 200 kg NPS/ha with mean values of 120.4 and 118.9 cm respectively. While the shortest plant with mean value of 64.3 cm was obtained from Dicho x 0kg NPS/ha combination. The increment of plant height may be due to the role of nitrogen in stimulating amino acid building and growth hormones, which in turn acts positively on cell division and enlargement. And also it may be attributable to the role of phosphorus in the development of more extensive root system which enables plants to absorb more water and nutrients from depth of the soil. Iorlamen T. et al. [20] Reported that application of nitrogen fertilizer to soils that are below nitrogen critical range of 10 to 15 kg/ha causes optimum growth of crops but this is only possible when other nutrients are available in the soil in sufficient and balanced quantities. Previous studies revealed that application of 60 to 150 kg N/ha significantly increased plant height, number of branch per plant and leaf area index of sesame and it was attributed to the role of nitrogen in promoting physiological processes in sesame plant [21]. In contrast, [22] reported that application of 22.5 kg P/ha increased total dry matter yield of sesame, but increases beyond this rate did not significantly affect dry matter yield of sesame.

Table 6. *Interaction effect of variety by fertilizer rate on days to 90 % maturity.*

Variety	Plant height (PH, cm)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	64.3^{j}	91.3^{g}	104.6^{e}	112.4^{cd}	118.9^{ab}
Dicho	75.5^{h}	97.6^{f}	107.8^{de}	117.3^{bc}	122.5^{a}
Obsa	70.1^{i}	94.3^{fg}	104.03^{e}	115.3^{bc}	120.4^{ab}
Mean	101.1				
LSD (0.05)	5.21				
CV (%)	1.62				
SEM (±)	0.78				

*means followed by the same letters in the columns and rows under each trait are not significantly different at P<0.05.

3.4.2. Capsule Length

NPS fertilizer rates had a significant effect on capsule length of sesame. However, varieties and their interaction with fertilizer rates did not show significant effect (Table 3). The longest capsule (2.4 cm) was recorded from 200 kg NPS/ha but it was statistically at par with 150 and 100kg NPS/ha with the mean value of 2.39 and 2.33 cm, respectively. The shortest capsule (1.94 cm) was recorded from the control (Figure 2). These increase in capsule length as NPS fertilizer increase might be attributed to increase of cell division and elongation activities of sesame fruits bud. These results agree with [12] reported that significant differences in capsule length were recorded among phosphorus levels. According to the same source, minimum (2.20 cm) capsule length was recorded in control plots when phosphorus levels were enhanced from 0 to 120 kg/ha, and capsule length increased from 2.20 cm to 2.81 cm.

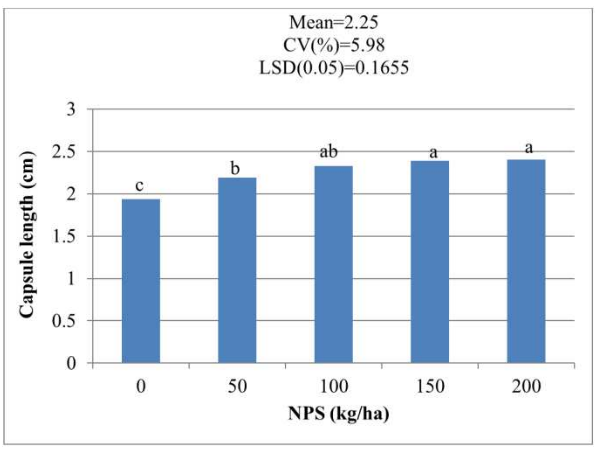

Figure 2. *Main effect of NPS fertilizer rate on capsule length of sesame at Uke.*

3.4.3. Length of Capsule Bearing Zone

Except varieties, NPS fertilizer rates and interaction of varieties by fertilizer rates had a significant effect on length of capsule bearing zone of sesame (Table 3). The results of mean values for length of capsule bearing zone (LCBZ) as affected by varieties and NPS fertilizer rates are presented in (Table 7). The maximum value for LCBZ (65.53 cm) was recorded from Obsa variety treated with 200kg NPS/ha and it was statistically at par with treatment combinations of Chalsa x 200, Dicho x 200, Obsa x 150, Chalsa x 150 and Dicho x 150kg NPS/ha with mean values of 65.13cm, 64.96 cm, 63.4 cm, 62.3 cm and 61.8cm respectively. The minimum capsule bearing zone mean length was resulted by Chalsa with 0 kg NPS/ha and statistically similar with Dicho with 0kg NPS/ha with mean of 34.2 cm. Abdel-Rahman, K. et al. [23] reported that the height of the first branch and first capsule as well as the length of the fruiting zone were highest at 60 kg N/fed for sesame in Egypt.

Table 7. *Interaction effect of varieties by fertilizer rates on length of capsule bearing zone of sesame.*

Variety	Length of capsule bearing zone (LCBZ)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	32.00^{h}	54.2^{ef}	56.7^{def}	62.3^{abc}	65.13^{ab}
Dicho	34.20^{gh}	55.1^{ef}	60.9^{bcd}	61.8^{abc}	64.96^{ab}
Obsa	37.03^{g}	58.4^{cde}	53.5^{f}	63.4^{ab}	65.53^{a}
Mean	55.01				
LSD (0.05)	4.52				
CV (%)	4.38				
SEM (±)	0.67				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.4.4. Number of Primary Branches Per Plant

The results of mean values for number of primary branches per plant (NPB) as affected by varieties and NPS fertilizer rates are presented in Table 8. The results indicated that the highest mean number of primary branches per plant were produced from Obsa variety treated with 150 and 200 kg/ha NPS with 6.42 and 5.95, respectively, while the lowest mean number of primary branches, 3.18, was obtained from Chalsa x 0kg NPS/ha and it was statistically in par with Dicho and Obsa under 0kg NPS/ha with 3.2 and 3.32 respectively. Number of primary branches were increased up to 150 kg/ha and decreased at 200 kg/ha for all the three varieties because, as NPS rate increases the plant were elongated rather than branching. The increase in primary branches per plant may be due to the fact that N encourages the meristematic activity and photosynthesis rate, which produced more number of branches per plant. And also it may be due to favorable effects of phosphorus on hormonal balance that helped proper growth and development of the sesame plant. In this respect, [24] noted similar finding by applying N up to 120 Kg/ha. Imayavaramban et al. [25] observed that the application of 52 kg N, 23 kg P_2O_5 and 23kg K_2O/ha significantly increased the plant height, primary, secondary and tertiary branches per plant compared to the relatively low level of the three nutrients.

Table 8. *Interaction effect of varieties by fertilizer rates on number of primary branches per plant of sesame.*

Variety	Number of primary branches per plant (NPB)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	3.18^{h}	4.45^{g}	4.8^{efg}	5.27^{cd}	5.05^{cdef}
Dicho	3.20^{h}	4.60^{fg}	4.9^{defg}	5.92^{b}	5.2^{cde}
Obsa	3.32^{h}	4.9^{defg}	5.33^{c}	6.42^{a}	5.95^{b}
Mean	4.8				
LSD (0.05)	0.45				
CV (%)	3.79				
SEM (±)	0.06				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5. Effect of NPS Fertilizer Rates on Yield and Yield Components of Sesame Varieties

3.5.1. Number of Capsules Per Plant

Varieties, NPS fertilizer rates and their interaction has shown significant (P < 0.05) difference on number of capsules per plant of sesame (Table 3). The results of mean number of capsules per plant as affected by the interaction of variety and NPS fertilizer rates are presented in Table 9. The results indicated that the fewest number of capsules per plant (34.25) was produced from Dicho variety under control and the maximum number of capsules (68.82) was produced from Obsa with application of 150kg NPS/ha. The positive increase in number of capsules per plant might be due to presence of adequate amount of nitrogen and role of phosphorus in seed formation supplied from the soil as added during the experiment. It is evident that the role of N as an essential element in formation of sesame number of capsules per plant due to its effect on number of lateral branches per plant, which produced greatly bud fruit and to its positive effect on plant growth. These results are in line with [12] who reported that capsules per plant increased with increasing N levels. Similarly, [26] reported significant response of Barsan variety to number of capsules obtained up to 46 kg N/ha. Abera Habte [27] reported that highest (32.16) and lowest (26.92) number of capsules per plant were obtained from plants treated with 46 kg N/ha and no N application respectively. Moreover, [28] found that application of 60 kg N/ha and 13.2 kg P/ha produced significantly the highest number of capsules per plant.

Table 9. *Interaction effect of varieties by NPS fertilizer rates on number of capsules per plant of sesame.*

Variety	Number of capsules per plant (NCPP)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	34.44^{h}	43.50^{g}	52.83^{e}	64.17^{abc}	60.80^{cd}
Dicho	34.25^{h}	46.00^{fg}	58.50^{d}	65.10^{abc}	61.42^{bcd}
Obsa	35.75^{h}	49.12^{ef}	61.17^{cd}	68.82^{a}	66.63^{ab}
Mean	53.50				
LSD (0.05)	5.41				
CV (%)	2.95				
SEM (±)	0.81				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5.2. Number of Seeds Per Capsule

Varieties, NPS fertilizer rates and their interaction showed a significant effect on number of seeds per capsule of sesame (Table 3). The results of mean number of seeds per capsule as affected by the interaction of variety and NPS fertilizer rates are presented in Table 10. Seeds per capsule were increased with increase in NPS levels up to 150 kg/ha further increase in NPS slightly reduce in number of seeds per capsule. The maximum number of seeds per capsule, 71.7 was obtained from Obsa with application of 150 kg but not significantly different from Dicho x 150, Obsa x 200, Dicho x 200 and Chalsa x 150 kg NPS/ha with mean values of 70.7, 70.7 and 70.0 capsules per plant respectively. The minimum number of seeds per capsule, 39.3, was produced by Chalsa variety under control and it was statistically in par with Dicho x 0kg NPS/ha with mean value of 41.0 seeds per capsule. The present study showed that, Seeds per capsule were increased with increase in NPS levels up to 150 kg/ha further increase in NPS slightly reduce in number of seeds per capsule. Similar results were reported by [15] who indicated that seeds per capsule increased with an increase in nitrogen level up to 80 kg/ha. Similar results were also reported by [15] that, when phosphorus levels were enhanced from 0 to 100 kg/ha, number of seeds increased from 37 to 64 per capsule. This results are in agreement with [29] who conducted a pot culture experiment and found that application of recommended NPK (35:22.5:22.5) kg/ha+ $ZnSO_4$ at 25 kg/ha+$MnSO_4$ at 25 kg/ha significantly superior in enhancing the number of seed per capsule.

Table 10. *Interaction effect of varieties by NPS fertilizer rates on number of seeds per capsule of sesame.*

Variety	Number of seeds per capsule (NSPC)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	39.3^{h}	55.7^{f}	58.7^{de}	70.0^{ab}	69.0^{b}
Dicho	41.0^{h}	56.3^{ef}	59.3^{cd}	70.7^{ab}	70.0^{ab}
Obsa	45.3^{g}	57.3^{def}	61.7^{c}	71.7^{a}	70.7^{ab}
Mean	59.80				
LSD (0.05)	2.64				
CV (%)	1.92				
SEM (±)	0.35				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5.3. Thousand Seeds Weight

The results for interaction effect of variety x fertilizer rate on mean of thousand seed weight are presented in Table 11. The results showed that the highest weight of thousand seeds (2.7g) was obtained from Obsa with application of 150 kg NPS/ha. While, the lowest weight (2.23g) was recorded from Chalsa with control which is statistically similar with Dicho and Obsa under 0kg NPS/ha. This may be due to large amount of phosphorus found in the seed and capsules, which is considered essential for seed formation and size of seeds. These results agree with those of [30] who reported that increasing phosphorus application significantly increased the seed weight. These results are in line with those of [11] who reported that increasing rate of nitrogen application significantly increased the mean seed weight. The favorable effect of nitrogen fertilizer on thousand seeds weight may be due to the reason that nitrogen stimulated plant growth such as plant height and number of branches per plant, which increased the amount of light energy intercepted by leaves [31]. The difference between cultivars in thousand seeds weight was observed by [25]. The supply of essential nutrients *i.e.* nitrogen and phosphorus to plants in adequate amounts produced great thousand seed weight as compared to plants grown in control where nutrients supply was poor [32]. Mian, M. et al. [33] conducted a field experiment to observe the crop performance under variable phosphorus levels and reported the highest thousand seeds weight at (90 kg P/ha).

Table 11. *Interaction effect of variety by fertilizer rate on thousand seed weight of sesame.*

Variety	Thousand seed weight (TSW, g)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	2.23^{g}	2.3^{fg}	2.33^{efg}	2.43^{cde}	2.37^{def}
Dicho	2.27^{fg}	2.37^{def}	2.43^{cde}	2.5^{bc}	2.47^{cd}
Obsa	2.33^{efg}	2.47^{cd}	2.5^{bc}	2.7^{a}	2.6^{ab}
Mean	2.42				
LSD (0.05)	0.12				
CV (%)	1.66				
SEM (±)	0.10				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5.4. Grain Yield (kg/ha)

The results for interaction effect of variety x fertilizer rate on mean of grain yield are presented in Table 12. The results indicated that Obsa variety with application of 150 kg NPS/ha resulted the highest grain yield, (813.9 kg/ha) and it was statistically in par with Dicho x 150, Obsa x 200 and Dicho x 200 kg NPS/ha with mean value of 801.00 kg/ha, 789.97 kg/ha and 789.6 kg/ha, respectively. While the minimum grain yields were 435.93 kg/ha, 438.90 kg/ha and 439.22 kg/ha were produced by Chalsa, Dicho and Obsa varieties with control (0kg NPS/ha) respectively and they were statistically in par. Fertilizer rates increased grain yields of the three sesame varieties up to 150kg NPS/ha. That means, application of excess amount of fertilizer did not significantly increase the grain yield of sesame. Excess N promotes over-luxuriant growth of shoots with lower numbers of seeds and fruits resulting in lower yield. This could be attributed to the fact that excessive nitrogen and manure application was reported to reduce fruit number and yield but enhances plant growth [18]. Similar findings were earlier reported by [30] who reported that yield increased with the increase in P level up to 95 kg/ha. Higher level than that did not increased seed yield. Incremental application of NPK fertilizer up to 150 kg/ha [34] significantly increased the average sesame seed yield and this seems to be the optimum level as further additions reduced yield, perhaps due to an increase in vegetative growth. However, [28] reported a non-significant response in sesame grain yield at nitrogen above 60kgN/ha.

Table 12. *Interaction effect of variety by fertilizer rate on and grain yield of sesame.*

Variety	Grain yield (GY, kg/ha)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	435.93^{i}	625.87^{h}	706.73^{fg}	773.67^{bc}	762.56^{cd}
Dicho	438.90^{i}	683.77^{g}	721.17^{ef}	801.00^{ab}	789.60^{abc}
Obsa	439.22^{i}	688.86^{g}	741.30^{de}	813.90^{a}	$798.97^{a\ b}$
Mean	681.43				
LSD (0.05)	28.13				
CV (%)	1.77				
SEM (±)	3.98				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5.5. Biomass Yield

The results for interaction effect of variety x fertilizer rate on mean of biomass yield are presented in Table 13. The results indicated that Dicho containing higher dose of applied fertilizer (200 kg NPS/ha) gave significantly maximum total biomass 3442.0 kg/ha, as compared to other treatments but had no significant difference from Chalsa x 200kg NPS/ha with a yield of 3404.3kg/ha. While, Chalsa with control (0kg NPS/ha) produced the minimum biomass yield, 2298.3 kg/ha but, it was not significantly different from Obsa and Dicho with biomass yield of 2298.9 and 2330.8 kg/ha respectively at 0kg/ha. The minimum fertilizer rates resulted lower biomass yields, while higher doses of fertilizer gave maximum biomass yields for the three varieties. The increase in biomass yield with the application of NPS fertilizer might be due to the increase in vegetative growth of the plant. Higher biomass yield might be due to better root growth and increased uptake of nutrients favoring better growth of the crop. These results agree with the findings of [30] who reported that increasing rate of phosphorus application significantly increased biological yield over control plots. Shehu, H. et al. [11] also obtained significant increase in aerial dry biomass yield of sesame with increasing N application rates.

Table 13. *Interaction effect of variety by fertilizer rate on biological yield of sesame.*

Variety	Biological yield (BY, kg/ha)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	2298.3^{f}	3081.3^{e}	3134.8^{e}	3307.2^{c}	3404.3^{ab}
Dicho	2330.8^{f}	3101.5^{e}	3202.7^{d}	3326.7^{c}	3442^{a}
Obsa	2298.9^{f}	3132.6^{e}	3210.9^{d}	3289.3^{c}	3347.6^{bc}
Mean	3060.55				
LSD (0.05)	67.11				
CV (%)	1.09				
SEM (±)	8.36				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.5.6. Harvest Index

The results for interaction effect of variety x fertilizer rate on mean of biomass yield are presented in Table 14. The results indicated that the maximum harvest index (0.25) was recorded from Obsa with application of 150 kg NPS/ha. The lowest harvest index, 0.18 resulted from Chalsa under control, but it was statistically similar with Dicho and Obsa under control, 0kg NPS/ha with 0.19 harvest index. Harvest index showed a significant increase up to 150 kg NPS/ha and decreased at the higher dose, 200 kg/ha for the varieties. The effect of NPS on harvest index is the outcome of its effect on number of capsules per plant, number of seed per capsule as well as thousand seeds weight and grain yield per hectare. The highest result of harvest index was the indicator of high yield than the dry biomass. These results agree with the findings of [11] who conducted an experiment and reported that on nitrogen, phosphorus and potassium nutrition of sesame and reported that application of 75 kg/ha, 45 kg/ha and 22.5 kg/ha, respectively produced the highest harvest index. Ashfaq, A. et al. [24] reported that harvest index increased with increasing rates of nitrogen application and 120 kg/ha treatment gave the maximum harvest index, but found variation in harvest index among the varieties.

Table 14. *Interaction effect of variety by fertilizer rate on harvest index of sesame.*

Variety	Harvest index (HI)				
	NPS (kg/ha)				
	0	50	100	150	200
Chalsa	0.18^{g}	0.20^{f}	0.22^{de}	0.23^{bc}	0.22^{cde}
Dicho	0.19^{fg}	0.21^{e}	0.22^{cde}	0.24^{b}	0.23^{bc}
Obsa	0.19^{fg}	0.22^{cde}	0.23^{bcd}	0.25^{a}	0.24^{b}
Mean	0.22				
LSD (0.05)	0.01				
CV (%)	1.62				
SEM (±)	0.002				

*means followed by the same letters in the columns and rows in each trait are not significantly different at P<0.05.

3.6. Partial Budget Analysis of NPS Applications on Yield of Sesame Varieties

Obsa variety with application of 150 kg NPS/ha gave the maximum value of gross field benefit, 24172.5 ETB/ha and followed by Dicho under 150 kg NPS/ha with 23789.7 ETB/ha gross field benefit. The minimum gross field benefit, 12947.22 ETB/ha was recorded from Chalsa under control. The partial budget analysis indicated that the highest net benefit of 20572.5 ETB/ha was recorded for Obsa with 150 kg NPS/ha followed by Dicho under 150 kg NPS/ha (20189.7 ETB/ha). The lowest net benefit (12947.22 ETB/ha) was obtained from the Chalsa under control which did not receive any fertilizers (Table 11). The high net benefit from treatments mentioned above could be mainly attributed to high grain yield resulted from the interaction of NPS and varieties, while the lowest net benefit was attributed to low. grain yield due to the absence of adequate plant nutrients. Abera Habte [27] reported the highest net benefit (12361 ETB/ha) from variety Tate with the combined application of 46 kg N/ha with 20 kg P/ha.

Table 15. *Partial budget analysis for NPS on yield of sesame varieties.*

Variety	NPS (kg/ha)	GAY (kg/ha	AJY (kg/ha)	GFB ETB/ha	TC ETB/ha	NB ETB/ha
Chalsa	0	435.93	392.34	12947.22	0	12947.22
	50	625.87	563.28	18588.24	1700	16888.24
	100	706.73	636.06	20989.98	2650	18339.98
	150	773.67	696.3	22977.9	3600	19377.9
	200	762.56	686.3	22647.9	4550	18097.9
Dicho	0	438.9	395.01	13035.33	0	13035.33
	50	683.77	615.39	20307.87	1700	18607.87
	100	721.17	649.05	21418.65	2650	18768.65
	150	801.00	720.9	23789.7	3600	20189.7
	200	789.6	710.64	23451.12	4550	18901.12
Obsa	0	439.22	395.3	13044.9	0	13044.9
	50	688.86	619.97	20459.01	1700	18759.01
	100	741.3	667.17	22016.61	2650	19366.61
	150	813.9	732.5	24172.5	3600	20572.5
	200	798.97	719.07	23729.31	4550	19179.31

GAY=gross average yield; AJY= adjusted yield; GFB= gross field benefit; TC=total cost; NB= net benefit.

4. Summary and Conclusion

The results of soil analyses for physico-chemical properties before sowing showed clay loam texture with acidic soil and the soil had low organic carbon, organic matter, total nitrogen, available phosphorus and available potassium. As NPS fertilizer rates increased, the value of these soil parameters increased while, pH of the soil decreased.

The result of the study indicated that all parameters including days to 50% emergency, days to 50% flowering, days to 95% maturity, plant height, capsule length, length of capsule bearing zone, number of primary branches, number of capsule per plant, number of seeds per capsule, thousand seed weight, grain yield, biomass yield and harvest index were significantly affected ($p<0.05$) by main factor NPS fertilizer. But days to 50% emergency, capsule length and length of capsule bearing zone were not significantly affected by the main factor variety. Similarly, days to 50% emergency, and capsule length were not significantly affected by the interaction of variety and NPS fertilizer. From the interaction effect of variety by fertilizer rate, the maximum and minimum mean values of grain yield (813.9 and 435.93 kg/ha) and harvest index (0.25 and 0.18) were recorded for Obsa treated with 150 kg NPS/ha and Chalsa with control respectively. The highest net benefit for grain yield of sesame (20572.5 ETB/ha) was recorded for Obsa variety with application of 150 kg NPS/ha and the lowest (12947.22 ETB/ha) was recorded for Chalsa with 0kg NPS/ha.

On the basis of results of one year field experiment during summer 2018, it may be concluded that, under the agro-climatic conditions of the experimental site, application of 150 kg NPS/ha especially for Obsa variety improved grain yield and yield components of sesame through improving soil nutrient availability resulting in better vegetative growth, yield components and, thereby, higher yield and net benefit of the sesame. Therefore, it can be recommended that farmers in the study area can cultivate the Obsa variety by applying NPS at the rate of 150kg NPS/ha. However, to give a conclusive recommendation, similar experiments should be conducted over seasons and locations using more number of varieties of the crop in the study area.

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