

Effects of NPS Fertilizer Application and Tillage Practices on Yield and Yield Components of Sesame (*Sesamum Indicum L.*) in Kebribeyah District of Somali Region

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ABSTRACT

Drought and low soil fertility are the main production factors affecting sesame yield. Therefore, this study aimed to examine the effects of NPS fertilization and tillage practices on yield components and yield of sesame. Treatments comprise the combination of three tillage practices (i.e., tied-ridge, flatbed, and no-tillage) and three fertilizations [i.e. fertilizing, 0 kg NPS ha^{-1} (control), 150 kg NPS ha^{-1} , and 300 kg NPS ha^{-1}] which overall gave nine treatments. Treatments were tested in a randomized complete block in a factorial arrangement and were replicated three times. The results showed that the main effects of tillage and fertilizer on the leaf area index (LAI) were significant and the tied ridge and the 150 kg NPS ha^{-1} applications recorded the highest LAI while the lowest LAI came from the control and zero-tillage, respectively. The main effects of tillage and fertilizer on plant height, number of branches per plant (NBPP), number of capsules per branch (NCPB), number of seeds per capsule (NSPC), 1000 seed weight, and seed yield (SYD) were significant, while the interactive effect of tillage and fertilizer was significant only for plant height, NBPP and SYD. Fertilizing 150 kg NPS ha^{-1} with tied ridge tillage recorded the tallest height and number of branches per plant. The application of 150 kg NPS ha^{-1} recorded the highest number of capsules per branch, the number of seeds per capsule, and the weight of a thousand seeds. The lowest values of these parameters were obtained from the control treatment. Similarly, the main effect of tillage is significant for all recorded parameters. The highest values of these parameters were recorded during tillage on the tied ridge, followed by flatbed, while the lowest values came from the zero tillage method. The highest yield of sesame seeds was observed in the combined application of tied ridge with 150 kg NPS ha^{-1} while the lowest seed yield was from zero-tillage without fertilization. The partial budget analysis result showed that the highest net benefit (38304.79 ETB) was recorded in tied ridge combined with 150 kg NPS ha^{-1} (T8) followed by flatbed + 150 kg NPS ha^{-1} (T5) (37422.36). Whereas, the highest marginal rate of return (575.1%) was recorded in the combination of flatbed with 150 kg NPS ha^{-1} (T5). Therefore, based on these results we recommend the use of tied ridge tillage with 150 kg NPS ha^{-1} to increase sesame yield in the Kebribeyah area. However, for broader applications, the study should be repeated across different locations and seasons.

Key Words: Flatbed, seed yield, tied ridges, zero-tillage

1. Introduction

Sesame (*Sesamum indicum L.*) is an important traditional oilseed crop in Ethiopia. Its seed contains about 50% edible oil of high quality. The sesame oil does not turn rancid, unlike other edible oils because of the presence of the antioxidant 'Sesamol' (Hatam and Abbasi, 1994). Its oil has high oleic and linoleic oil contents. The oil is used

for cooking, baking, candy making, soaps, lubricant, body massage, hair treatment, food manufacture, industrial uses, and alternative medicine for blood pressure, ageing, stress, and tension (Ahmed et al., 2009).

Sesame is grown on an area of 370 thousand hectares in Ethiopia with a total production of 2.5 million quintals giving an average yield of 691 kg ha^{-1} (CSA, 2018) which is much lower than the yield obtained in many other countries of the world like Honduras (1200 kg ha^{-1}), Egypt (1172 kg ha^{-1}), Central African Republic (780 kg ha^{-1}) and Saudi Arabia (769 kg ha^{-1}).

Sesame research in Ethiopia has been carried out in the lowland research station at Melka Werer in the Central Eastern parts of the Rift Valley. Haramaya University has also carried out research work on sesame and other oil crops in the Babile area and released some sesame varieties for similar agroecological conditions. The Ethiopian Statistical Authority report of 2017/18 indicates that the national average yield of sesame is 691 kg ha^{-1} countrywide (of Ethiopia), (2018). It is understood that the current productivity level of sesame in Ethiopia is far below the expected average,

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and therefore there is room for improvement using a better farming system and the implementation of improved inputs such as varieties, fertilizer application, and tillage practices.

Tillage has been developed in farming to improve soil conditions concerning the water balance and crop growth, to incorporate crop residues, and for weed control and preparation of the seedbed. The effects of tillage depend greatly on the water content and the characteristics of the soil (Gómez et al., 2016). Tillage practices have been reported to have a significant impact on sesame production, especially through the improvement of soil properties with the provision of a suitable seedbed for good seed germination, easy emergence, and good establishment of seedlings through enhanced root growth through a reduction in soil strength (Okeleye and Oyekanmi, 2003).

Soil water deficit in Sub-Sahara Africa is attributed to low infiltration rates (due to surface sealing and crusting and low organic matter content) and subsequent high runoff rates (Rockström et al., 2003). Soil water conservation in semi-arid areas needs proper tillage practices that not only improve rain infiltration but also conserve adequate soil moisture for plant growth. Conservation tillage practices such as ridging and subsoiling have the potential for soil moisture retention and mitigation of intra-seasonal dry spells that would otherwise result in low productivity and crop failure (Manyatsi et al., 2011). The success of any tillage practices is directly related to the improvement of soil's physical properties. Research has shown that soil bulk density, porosity, soil surface sealing and crusting, surface roughness, hydraulic conductivity, and infiltration rates are very important soil properties affecting soil moisture (Gicheru et al., 2004).

Among the various factors known to augment crop production per unit area, fertilizer aided with suitable agronomic practices can play a pivotal role in boosting crop yield. Based on the nutrient requirement of plants, nitrogen, phosphorus, and potash are considered major nutrients used in large quantities by plants. Thus, the importance of fertilizer as agricultural input cannot be over-emphasized, particularly in Ethiopia where the nutrient levels of the soils are low (EthioSIS, 2016). Fertilizer has been used to improve the yield of sesame for many years, especially in the Somali Regional State of Ethiopia, where it is paramount for fertility management because of the inherently low organic matter content of the soils in the region.

Unluckily, fertilizers in Ethiopia are expensive and often inaccessible to resource-poor farmers. This results in a reduction in the rates of chemical fertilization by these farmers (Ojeniyi et al., 2016). To achieve the desired goal of the sesame producers, it, therefore, becomes imperative to study the effect of tillage practices as well as fertilizer rates on the yield of sesame. To increase the production of this crop, there is a need for the adoption of appropriate tillage practices as well as sound fertilizer recommendations that would ensure the optimum yield of sesame varieties. In Ethiopia, optimum sowing dates, seed rates, and weeding regimes have been studied in different locations. However, there is no adequate information on the optimum fertilizer

rates and appropriate tillage practices for this crop in the Somali region. The recent increase in awareness, production, and cultivation of sesame in Ethiopia has, therefore, necessitated the need to determine its yield response to tillage, soil properties, and fertilizer rates in the region. The objective of the study was to examine the influence of fertilizer application and tillage practice on the productivity of sesame and soil properties of the study area.

2. Materials and Methods

2.1. The Study Site

The study was conducted at Kahoo Kebele in the Kebri Beyah district. Kebri Beyah is found at a Latitude of 9° 04' 60" N and longitude of 43° 04' 60" E. Agroclimatologically the area is categorized under the semi-arid agro-ecological zone. The historic average annual temperature is 19 °C, the mean maximum temperature is 27 °C, and the mean minimum temperature is 13 °C while December is the coolest month at 9 °C. There are two rainy seasons: the main meher rains occur from July to September and the short belg rains in April and June. Average annual rainfall in the study area ranged from 500-700 mm.

2.2. Experimental Materials

The sesame variety Kelafo was used for the study and the seed for this variety was obtained from EIAR. The variety was released in 1990 for eastern Ethiopia and other areas with similar agro-ecologies. Since then the variety has been under cultivation in the region and its adaptability was already checked. Kelafo is white-seeded, which is preferred by users with high protein (27.1%) and crude oil (56%) content. This variety is found to be moderately tolerant to bacterial leaf blight. NPS fertilizer containing nitrogen (19%), phosphorous (7%), and sulfur (7%) nutrients were used for the experiment.

2.3. Experimental Design and Treatment

The experiment consisted of two factors (i.e., NPS and Tillage) at different levels. Tillage practices were at three levels (zero tillage, conventional tillage, and tied-ridge) while fertilizer rates were at three levels (0 kg/ha, 150 kg/ha, and 300 kg/ha of NPS). The treatments were arranged in a factorial experiment in a Randomized Complete Block Design (RCBD) with the sesame variety Kelafo as a test crop. A total of 9 treatments were replicated thrice resulting in a total of 27 treatment plots. The plot size was 3.6 m wide and 3 m long having a gross area of 10.8 m². A 1.5 cm and a 1m spacing were left between blocks and between plots, respectively.

2.4. Experimental Procedure and Field Management

The land was ploughed using a tractor twice and levelled manually on June 25, 2022. Planting was done on June 27, 2022. Sesame seeds were sown at an inter and intra-row spacing of 60 x 10 cm. The gross plot size was 3 x 3 m² = 9 m² with five rows per plot. the outer rows on both sides

of the plot are considered as borders and excluded from data collection. The net plot size was $1.8 \times 3 \text{ m} = 5.4 \text{ m}^2$. Sesame seeds were drilled along the ridges (or straight lines on flat land and zero tillage) and thinned at two weeks after planting (WAP) to the recommended plant population of 166,666 plants ha^{-1} (Jakusko and Usman, 2013). NPS fertilizer application was done at planting. Crop harvested from the net plots was used for grain yield determination. Sesame crops were harvested when about 50% of the capsules turned yellow from green.

2.5. Soil Samples Analysis

The soil sample was taken from the experimental field in a zig-zag manner and samples were composited, dried, ground to pass a 2 mm sieve, and then analyzed for some physicochemical properties of soil such as particle size distribution, pH, Organic Carbon, Total Nitrogen, Available phosphorus, and exchangeable cations [Mg^{2+} , Ca^{2+} , Na^{+} , and K^{+}] as well as Cation Exchange Capacity (CEC). The samples were analyzed for CEC by ammonium acetate and distillation (Jackson, 1973). Soil pH (H_2O) was analyzed by potentiometric method (Estefan et al., 2013). Organic carbon (OC) using the wet digestion method (Walkly and Black, 1934), total N using the micro-Kjeldahl digestion (of Official Analytical Chemists), 1994), available P using sodium bicarbonate solution (Olsen and Sommers, 1982), extractable K, Ca, Mg and Na using 1M ammonium acetate solution (Miller and Keeney, 2003) and recorded by atomic absorption spectrophotometer (Black et al., 1965). The soil texture was analyzed by hydrometer and bulk density by gravimetric methods following Sahlemedhin and Bekele's (2000) soil analysis procedures.

2.6. Data Collection

2.6.1. Crop phenological parameters

Days to 50% flowering: Days to 50% flowering were recorded by counting the number of days from emergence to when 50% of plants in a net plot start to flower. Days to 90% physiological maturity: Number of days from emergence to when 90% of the plant population turned their leaves yellow and the lowermost capsules started to open. All phenological stages were determined by visual observations.

2.6.2. Growth parameters

Plant height (cm): It was recorded from five randomly pre-tagged plants in each net plot area by measuring their height from the base to the tip of the stem at harvest. The number of primary branches per plant: It was recorded from the above five randomly pre-tagged plants as above at harvest.

2.6.3. Yield-related traits and yield

The number of capsules per plant: The total number of capsules in the pre-tagged plants was counted to find the number of capsules per plant. The number of seeds per capsule: At physiological maturity, seeds of three capsules from three positions (lower, middle, and upper) from five plants per treatment were counted and their mean number was

calculated as the seed number per capsule. Thousand seed weight (g): After harvest, 1000 seeds were taken randomly from the seed lots of each plot and then it was weighed. Seed yield (kg/ha): The sun-dried seed from the net plot area was cleaned, weighed, and converted into yield in kilogram per hectare. Biological yield (kg/ha): Crop from each net plot was harvested close to the ground level and kept separately, sun-dried for two weeks and weighed. Harvest Index (%): It was calculated as the ratio of seed yield to total biological yields times one hundred.

2.7. Data Analysis

Data were subjected to the analysis of variance based on RCBD design using SAS software version 9.2 (SAS/STAT 9.1 Users Guide. Cary NC., USA: SAS Institute Inc.). The mean separation was done at a 5 per cent probability level.

2.8. Economic Analysis

A partial budget analysis was conducted with the assumption that fertilizer costs, transport of fertilizer, fertilizer application, labour costs for tillage practices (zero tillage, conventional tillage, tied-ridge), harvesting and threshing costs were the costs that vary. Costs like seed cost, planting, weeding, and crop protection practices were similar across treatments and did not affect farmers' choice of treatments hence they were excluded from the economic analysis. Net benefit, dominance and marginal rates of return (MRR) analysis were done following the CIMMIYT guideline (Program, 1988)(CIMMIYT, 1988).

3. Results and Discussion

3.1. Soil Physicochemical properties

Analysis of soil samples before planting was done for the major soil physical and chemical properties and the results are indicated in Table 1. Accordingly, the soil had a total N of 0.22%, rated as moderate according to where the authors classified soil total N availability of $< 0.05\%$ as very low, 0.05 - 0.12% as poor, 0.12 - 0.25% as moderate and $> 0.25\%$ as high. This could be that the area was used to cultivate cereal crops without using any organic or inorganic fertilizers. The organic carbon content of the experimental site was 0.57% and this was rated as low according to (Landon, 2014) while the organic matter content of the soil computed as a function of organic carbon multiplied by 1.724 was 0.98% and was also rated as low according to the classification of (Debele, 1982). The author rated soils with organic matter content of $> 5.20\%$ (high), 2.6 - 5.2% (medium), 0.8 - 2.6% (low), and $< 0.8\%$ (very low). The soil analysis result also showed that the available P content was rated low (5.87 ppm) according to who described soils with available P < 10 , 11-31, 32-56, > 56 ppm as low, medium, high and very high, respectively. The cation exchange capacity (CEC) of the soil was medium (16.95 cmol (+)/kg) according to Landon (1991) who described top soils having CEC greater than 40 cmol (+)/kg of soil are rated as very high and 25-40 cmol (+)/kg as high, 15-25 cmol (+)/kg as medium, 5-15 cmol (+)/kg as low and < 5 cmol (+)/kg as very low.

Table 1: Physicochemical soil properties of the experimental site at Kahoo Kebele, Kebridahar district

Parameters tested	Result	Rating	References
Total N (%)	0.22	Moderate	Tekalign et al. (1991)
OC (%)	0.57	low	Landon (1991)
OM (%)	0.98	low	Berhanu (1980)
Av. P (ppm)	5.87	Low	Tekalign et al. (1991)
CEC (cmol/100g)	16.95	Moderate	London (1991)
pH (CaCl ₂)	8.0	Alkaline	Tekalign (1991)
EC (Ms/m)	0.53	Moderate	London (1991)
Ext. K (cmol (+)/kg)	0.86	Low	Barker and Pil-bean (2007)
Ext. Ca (cmol (+)/kg)	39.5	Low	Barker and Pil-bean (2007)
Ext. Mg (cmol (+)/kg)	21.4	Low	Barker and Pil-bean (2007)
Clay (%)	10		
Silt (%)	30		
Sand (%)	60		
Textural class	Sandy loam		Landon (1991)

Further, the pH value was 8.5, which is considered alkaline soil according to Tekalign (1991). EC of soil is 0.53 which is considered moderate according to London (1991). Furthermore, the experimental site soil contains exchangeable K (0.86 cmol (+)/kg), exchangeable Ca (39.5 cmol (+)/kg), exchangeable Mg (21.4 cmol (+)/kg) which are rated as low by.

The soil of the experimental site was sandy loam in texture with 60% sand, 30% silt, and 10% clay (Table 1). This texture is perfect for sesame production as sesame requires soils that are well-drained for optimum growth and yield. The higher sand content of the soils (60%) was characteristic of the low clay content which may be due to the soil separates sorting activities by soil organism, clay eluviation, surface soil disintegration, parent materials or a combination of these variables (NA, 2010).

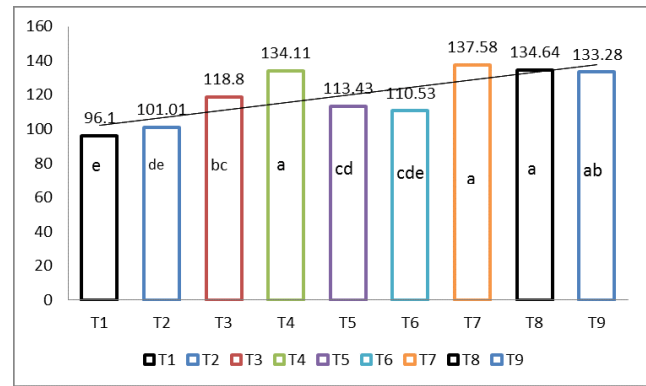
The alkaline pH of the soils (pH 8) also shows that the soils are suitable for sesame production as the crops prefer slightly acidic to alkaline soil (pH 5-8) with moderate fertility (Langham et al., 2008; Bennet, 2011).

The soils were low in essential plant nutrients and organic carbon except nitrogen which was moderate when compared with soil fertility ratings by Tekalign et al. (1991). The poor nutrient status of this soil is characteristic of many tropical soils where the production of crops year after year without fertilization and nutrient cycling as the residue is used for livestock feed low rainfall prevents the build-up of organic matter which is the storehouse of most nutrients.

3.2. Growth

3.2.1. Plant height

The result showed that the main effect of NPS fertilizer and its interaction with tillage were significant ($P < 0.05$) on plant height while the main effect of tillage on plant height was not significant (Table 2). The highest plant height was recorded with tied-ridges with no fertilizer application (T7) (137.58 cm) although the mean difference among T7, T8,

**Figure 1:** Interaction effect of NPS and tillage on the number of branches per plant

Where, T1 = zero-till + 0 kg NPS ha^{-1} ; T2 = zero-till + 150 kg NPS ha^{-1} ; T3 = zero-till + 300 kg NPS ha^{-1} ; T4 = flatbed + 0 kg NPS ha^{-1} ; T5 = flatbed + 150 kg NPS ha^{-1} ; T6 = flatbed + 300 kg NPS ha^{-1} ; T7 = tied ridge + 0 kg NPS ha^{-1} ; T8 = tied ridge + 150 kg NPS ha^{-1} ; and T9 = tied ridge + 300 kg NPS ha^{-1} .

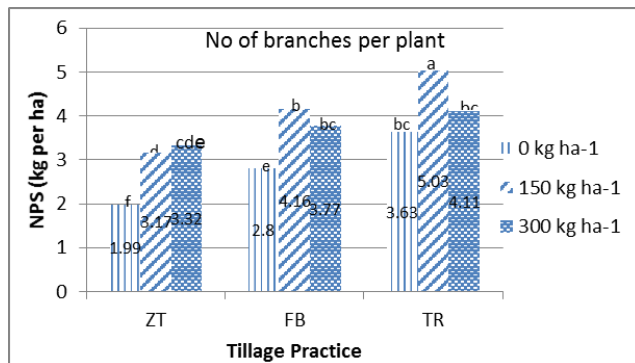
T4 and T9 were non-significant, while the lowest (96.1 cm) was obtained from the control (T1) (Fig.1). Plant height was increased by 43.2% with the combined application of flatbed (conventional tillage) with 150 kg NPS ha^{-1} as compared to the control.

Figure 1. The interaction effect of NPS fertilizer and tillage practices on plant height of sesame at Kahoo kebele. The highest plant height was recorded in the combination of the tied ridge with 150 kg NPS ha^{-1} (Fig 1). The plant height was increased by 43.2% with the combined application of the tied ridge and 150 kg NPS ha^{-1} as compared to the control (zero tillage + 0 kg NPS ha^{-1}). The second higher plant height was observed in treatment T8 and T4 despite the mean difference between them was not significant (Figure 1). The increase in plant height may be owing to nitrogen which enhances amino acid production and growth hormones, which in turn facilitates cell division and enlargement. Phosphorus might also have a role in the development of an extensive root system that enables plants to absorb more water and nutrients from deeper layers of the soil. A tied ridge is used to reduce water runoff and increase the infiltration of rainwater into the soil. It has been effective in reducing surface runoff and increasing soil water storage in the dryland regions (Gebreyesus Brhane et al., 2006). When moisture conservation combined with nutrient management like the application of NPS improves plant growth and development by a great deal. The highest plant height with the combined tied ridge and 150 kg NPS ha^{-1} could be due to the role of the tied ridge in moisture conservation and concentrating it in the effective root zone of the crop and the NPS fertilizer supplied N, P and S as these nutrients are very essential for plant growth and development. Combining nutrient management with moisture conservation in the dryland area increases the use efficiency of applied fertilizers since nutrients should

Table 2: ANOVA table for the effect of NPS and tillage practice on sesame productivity at Kahoo kebele

Source of variation	PH	NBPP	LAI	NCPP	NSPC	SWTPP	TSWT	SYD
Replication	234.59	0.1399	0.485	148.00	197.44	0.73	0.50	5684.5
NPS Fertilize	2009.1***	2.351**	5.28***	1381.3***	500.33***	2.28***	1.43***	50659.6***
Tillage	93.21NS	0.752NS	0.54*	240.11***	111.00***	0.74**	0.31**	7183.5**
NPS*Tillage	423.66**	1.205*	0.25NS	11.11NS	4.83NS	0.08NS	0.148NS	1421.9*
Error	69.93	0.302	0.116	8.54	3.36	0.091	0.0424	510.4
CV (%)	6.97	15.58	10.58	5.31	6.65	6.96	5.36	4.77

Where, DF = degree of freedom, PH = plant height, NBPP = number of branches per plant, NCPP = number of capsules per plant, NSPC = number of seeds per capsule, LAI = leaf area index, SWTPP = seed weight per plant, TSWT = thousand seeds weight, SYD = seed yield, LSD = least significance difference at 5% probability level, and CV (%) = coefficient of variation.

**Figure 2:** Interaction effect of NPS and tillage on the number of branches per plant

be dissolved in water to be absorbed and utilized by the crop. The current result was in agreement with (Gebreyesus Brhane et al., 2006; Teame et al., 2021) who reported that the tied ridge conserves high moisture and makes it available for plant extraction.

3.2.2. Number of branches per plant

The result indicated that the main effects of NPS and tillage practices and their interaction were significant on the number of branches per plant (Table 2). The highest number of branches per plant (5.03) was obtained from tide ridge with 150 kg NPS ha^{-1} application followed by flatbed tillage with 150 kg NPS ha^{-1} fertilization (Figure 2). The number of branches per plant obtained with tide-ridge and flatbed with 150 kg NPS ha^{-1} was at par with that obtained in tide-ridge without NPS application. The least number of branches per plant (1.99) was obtained from zero tillage without fertilization followed by flatbed without fertilizer application (Figure 2). The increment of the number of branches per plant with tide ridge and 150 kg NPS ha^{-1} was 52.76% as compared to zero tillage without fertilization. This result was in partial agreement with Motaka et al. (2016) who reported a maximum number of branches per plant in sesame with the application of 75 kg N ha^{-1} in India.

3.2.3. Leaf area index

The leaf area index was significantly ($p < 0.05$) affected by NPS and tillage practices, whereas, the interaction effect of NPS and tillage practices on the leaf area index was non-significant (Table 2). The leaf area index recorded with 150

kg ha^{-1} and 300 kg ha^{-1} was higher than that recorded in no fertilizer application. The increment in leaf area index obtained with a 150 kg ha^{-1} NPS application was 33.8% as compared to no fertilizer application. The increase in LAI may be because N hastens the action of meristem and photosynthesis rate, which creates more leaves per plant. It may be due to the auspicious effects of phosphorus on hormonal balance that aided proper growth and development of the sesame plant (Zebene and Geleta, 2022). Similar findings were reported by applying N up to 120 kg ha^{-1} (Ashfaq Ahmad et al., 2001). (Imayavaramban et al., 2002) also reported similar findings.

Similarly, the highest leaf area index value was obtained from tide-ridge practice, followed by flatbed and the least from zero tillage (Table 3). This might be due to the higher rain-water storage capacity of the tide ridge which in turn promoted cell division, photosynthesis and growth of leaves and produced a higher leaf area index. Similar results were reported by (Teame et al., 2021; Bekele and Chemed, 2022).

3.3. Yield Components

3.3.1. Number of capsules per plant

The main effect of NPS and tillage practices on the number of capsules per plant was significant ($P < 0.05$), however, the interaction effects of NPS and tillage practices were not (Table 2). The maximum number of capsules per plant was observed at 150 kg NPS ha^{-1} ; however, there was no appreciable difference between this and the number of capsules per plant at 300 kg NPS ha^{-1} . The control had the fewest capsules per plant. With 150 kg NPS ha^{-1} , there was a 49% increase in the number of capsules produced per plant compared to the control. Similarly, tide ridges yielded the most capsules per plant, followed by flatbed tillage, while zero tillage yielded the fewest capsules per plant (Table 3). In comparison to no-tillage, the tide ridge caused a 20% increase in the number of capsules. The increase in the number of capsules per plant in the tide ridge tillage treatment could be due to the higher water storage capacity of tide ridges and nutrient concentration in the bottom of the furrow and available for plant extraction.

This result was in agreement with (Teame et al., 2021) who showed that the largest number of capsules (33.9) was recorded at the ridge and furrow land design approach, even though it did not significantly differ from bed furrow land configuration, while the lowest (29.3) was observed at flat.

(Malik et al., 2003) also discovered that ridge structure produced the most capsules (94) while flat planting produced the fewest (92). (Abrha, 2018) reported that the tide ridge tillage produced the highest number of capsules per plant compared with the flatbed planting.

3.3.2. Number of seeds per capsule

The main effect of NPS and tillage practice on the number of seeds per capsule was significant ($p < 0.05$), while the interaction effect of NPS and tillage practices on the number of seeds per capsule was not (Table 2). The number of seeds per capsule was higher in fertilizer treatments and lowest in control, although the difference between fertilizer treatments was not significant. The increase attributable to 300 kg NPS ha^{-1} was 71.94% greater than the control. The current result was corroborates the finding of (Haruna, 2011) who reported the application of 50 kg N ha^{-1} produced a significantly higher number of capsules per plant (83.8) and seed yield (888 kg) compared with the control in Nigeria.

Similarly, the maximum number of seeds per capsule was achieved in tide-ridge, followed by flatbed, and the lowest was obtained in zero tillage. The increase in the number of seeds per capsule due to tide-ridging was 28.9% more than that of zero tillage. This could be due to the efficiency of tide ridge tillage in moisture conservation and making it available for plant extraction. This improved plant growth, flower setting and producing more seed numbers per capsule. The number of seeds per capsule is a critical factor in determining the final yield of a sesame plant and is influenced by various stressors. According to the research conducted by (Teame et al., 2021), the highest seed numbers per capsule were observed at the ridge and furrow method and the lowest seed numbers were observed at the flatland configuration method. This observation is consistent with the findings of (Malik et al., 2003) who found a higher number of seeds per capsule with a tied ridge than flatbed tillage.

3.3.3. Seed weight per plant

The main effect of NPS and tillage practice on seed weight per plant was significant ($p < 0.05$). However, the interaction effect of NPS and tillage practice on seed weight per plant was not (Table 2). The maximum seed weight per plant was reported in fertilizer treatments regardless of the amount, while the lowest seed weight per plant was observed in the control (Table 3). With a 150 kg ha^{-1} application, the increase in seed weight per plant was 46.8% higher than the control. Increased nitrogen supply within certain limits is associated with increases in leaf area, carboxylase, and chlorophyll content, all of which increase leaf photosynthetic activity and ultimately dry matter production and assimilates distribution to different organs (Maqsood et al., 2016; Babajide and Oyeleke, 2014). Similarly, adequate phosphorus supply is usually associated with increased root density and proliferation, which supports large-scale plant exploration and the provision of nutrients and water to growing plants (Shehu et al., 2010). The result was in

agreement with (Amare et al., 2019) reported that N and P applications regardless of their rates increased seed weight which in turn increased the seed yield of sesame

Likewise, the highest seed weight per plant was reported in tide ridges, followed by flatbed and zero tillage in that order (Table 3). The increase in seed weight per plant obtained as a result of the tide ridge was 26.6% higher than zero tillage. This might be due higher capacity of tied ridges in storing more water in the effective root zone of sesame plants which in turn facilitated the growth and development of the crops which implication on seed weight. The result was in line with (Malik et al., 2003), who reported the highest thousand seed weight of sesame (3.3 g) under the ridge. A similar observation was also made by (Abrha, 2018).

3.3.4. Thousand Seeds weight

The effect of NPS and tillage practice was significant ($p < 0.05$) for thousand-grain weight, while the interaction effect of NPS and tillage on thousand-grain weight was insignificant (Table 1). The weight of the thousand seeds obtained from the treated fertilizer was higher than that of the control (Table 2). The observed increase in the 150 kg NPS ha^{-1} treatment was 45.7% compared to the control. The beneficial effects of nitrogen fertilizer on thousand seed weight may be because nitrogen stimulates plant growth, such as plant height and number of branches per plant, and increases the amount of light energy received by leaves (Imayavaramban et al., 2002).

Similarly, tide ridge practice recorded the highest thousand-grain weight, followed by flatbed, while the lowest was from no-till. The weight of thousands of seeds obtained at the tide ridge increased by 30.5% compared to the no-till. This finding was in line with (Teame et al., 2021), who found that the maximum thousand seed weight from the tide ridge and furrow configuration, while the minimum weight was obtained in the flatbed configuration. The results of this study concur with those of Malik et al. (2003) who found the maximum sesame seed weight under the ridge configuration and the minimum weight under the flatbed planting. (Abrha, 2018) Abrha et al., (2018), also found a similar result.

3.4. Yield

The results showed that the main effects of NPS and tillage practices and their interactions on grain yield were significant ($p < 0.05$) (Table 2). The highest grain yield was recorded with 150 kg NPS ha^{-1} and tide ridge, followed by 300 kg NPS ha^{-1} with tide ridge, while the lowest grain yield was recorded with tillage without fertilization. The next high grain yield was obtained from 150 kg NPS ha^{-1} and 300 kg NPS ha^{-1} with flatbed tillage practice (Figure 2). The increase in grain yield with 150 kg NPS ha^{-1} with tide ridge tillage practice compared with no fertilization and no-tillage was 88.4%. The improved seed yield was due to superior growth parameters (plant height and number of branches per plant) and yield-determining traits (pod/plant, thousand seed weight and seed yield/plant).

Several studies have found that nitrogen fertilization has a positive effect on sesame growth, yield attributes, seed

Table 3: Effects of NPS and tillage practices on the performance of sesame at Kahoo

Treatments	PH (cm)	NCPP	NSPC	LAI	SWTPP	TSWT
NPS						
0 kg ha ⁻¹	103.08b	40.78b	19.0b	2.72b	3.17b	3.44b
150 kg ha ⁻¹	122.58a	60.78a	31.0a	3.64a	4.65a	4.37a
300 kg ha ⁻¹	122.94a	63.44a	32.67a	3.55a	4.63a	4.27a
Tillage						
Zero tillage	106.69c	50.56c	24.22c	2.86c	3.72b	3.54c
Conventional tillage	115.25b	53.78b	27.22b	3.29b	4.04b	3.92b
Tide-ridge	126.66a	60.67a	31.22a	3.76a	4.71a	4.62a
LSD (0.05)	6.8017	2.9207	1.8321	0.2541	0.4240	0.3149

Where, PH = plant height, NCPP = number of capsules per plant, NSPC = number of seeds per capsule, LAI = leaf area index, SWTPP = seed weight per plant, TSWT = thousand seeds weight, LSD = least significance difference at 5% probability level.

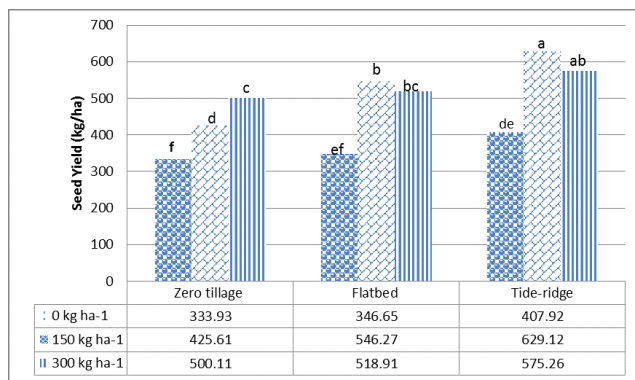


Figure 3: Interaction effects of NPS and tillage practice on seed yield (kg/ha)

yield, and quality. According to Osman (1993), applying 40 kg N ha⁻¹ significantly increased sesame grain yield and other yield parameters. With the application of 60 kg N ha⁻¹, Hossein et al. (2007) recorded the highest sesame seed yield.

The ridge and furrow configuration approach produced the maximum sesame seed yield (558 kg ha⁻¹) whereas the flat land configuration method produced the lowest (400 kg ha⁻¹) in Humera, Ethiopia (Teame et al., 2021). The ridge and furrow approaches retained the most soil moisture, resulting in the best plant and seed production performance. Cultivation plays an important role in increasing the yield and yield factor of various crops. For example, according to The ridge and furrow configuration approach produced the maximum sesame seed yield (558 kg ha⁻¹) whereas the flat land configuration method produced the lowest (400 kg ha⁻¹) in Humera, Ethiopia (Teame et al., 2021). The ridge and furrow approaches retained the most soil moisture, resulting in the best plant and seed production performance. Cultivation plays an important role in increasing the yield

and yield factor of various crops. For example, according to (Teame et al., 2021), higher seed yields were observed in the ridge and furrow land composition method, whereas the lowest yields were observed in the flatland method. The highest yields were obtained using the furrow construction method, which could be due to moisture conservation. The number of branches per plant, plant height, number of capsules per plant, and number of seeds per capsule all contribute to the highest yield. This finding is consistent with the results of (Malik et al., 2003) reported the highest yield with the tied ridge configuration method for sunflowers, and the results of (Reddy et al., 2009), higher seed yields were observed in the ridge and furrow land composition method, whereas the lowest yields were observed in the flatland method. The highest yields were obtained using the furrow construction method, which could be due to moisture conservation. The number of branches per plant, plant height, number of capsules per plant, and number of seeds per capsule all contribute to the highest yield. This finding is consistent with the results of (Malik et al., 2003) reported the highest yield with the tied ridge configuration method for sunflowers, and the results of (Reddy et al., 2009).

3.5. Partial Budget Analysis

Among the three fertilizer treatments, the costs of NPS fertilizer), fertilizer application, and harvesting were the costs that vary from treatment to treatment. Likewise, the cost of tillage practices was the labour cost. All the other costs like the cost of planting material, labour for planting, weeding and other management practices were similar for all treatments. The price for NPS fertilizer at the local market was 55 birr/kg. The labour cost for fertilizer application and transport was 1000 birr per 100 kg NPS per hectare while the harvesting and threshing costs were 0.2 birr per kg sesame seed. The labour cost for Tide-Tide Ridge was 3000 birr per ha while the labour cost for flatbed/conventional tillage was 1500 birr ha⁻¹. Whereas, zero tillage costs nothing. At the local market at the time of harvesting a selling price of 1 kg sesame was 100 ETB. The highest net benefit (38304.79 ETB) was obtained in the tide ridges with the 150 kg NPS ha⁻¹, followed by T5 (37422.36 ETB) while the lowest net benefit was from the control (Table 4). The dominance analysis result showed that treatments T2, T3 and T4 were dominated and they were excluded from the marginal rate of return analysis (Table 5), The highest marginal rate of return (575.1%) was recorded in the flatbeds with the 150 kg NPS ha⁻¹ (T5) followed by the MRR (254.57%) obtained from the tied-ridge tillage with the 0 kg NPS ha⁻¹ (T7). The MRR from the flatbeds with the 150 kg NPS ha⁻¹ treatments was higher than the acceptable minimum marginal rate of return (100%) (Table 5), Therefore, based on the net benefit and MRR value the flatbeds with the 150 kg NPS ha⁻¹ application or tied-ridge tillage with no NPS application was recommended.

Table 4: Total variable cost and net benefit analysis for the effect of tillage and NPS fertilizer application on yield of sesame at Kahoo

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9
Av. SYD (kg/ha)	333.93	425.61	500.11	346.65	546.27	518.91	407.92	629.12	575.26
Adj. SYD (kg/ha)	300.54	383.05	450.1	311.99	491.64	467.02	367.13	566.21	517.73
GFB (ETB/ha)	30054	38305	45010	31199	49164	46702	36713	56621	51773
TVC (ETB/ha)	300.54	10133.35	19950.1	1811.99	11741.64	24467.02	3367.13	18316.21	23017.73
NB (ETB/ha)	29753.46	28171.65	25059.9	29387.01	37422.36	22234.98	33345.87	38304.79	28755.27

Where, Av. SYD = average seed yield; adj. SYD = adjusted seed yield; GFB = gross field benefit; NB = net benefit; TVC= total variable cost, ETB = Ethiopian birr; T1 = zero-till + 0 kg NPS ha^{-1} ; T2 = zero-till + 150 kg NPS ha^{-1} ; T3 = zero-till + 300 kg NPS ha^{-1} ; T4 = flatbed + 0 kg NPS ha^{-1} ; T5 = flatbed + 150 kg NPS ha^{-1} ; T6 = flatbed + 300 kg NPS ha^{-1} ; T7 = tide ridge + 0 kg NPS ha^{-1} ; T8 = tide ridge + 150 kg NPS ha^{-1} ; and T9 = tide ridge + 300 kg NPS ha^{-1} .

Table 5: Dominance and MRR analysis for the effect of tillage and NPS fertilizer application on yield of sesame at Kahoo

Treatment	TVC	NB	TVC	NB	MRR (%)
T1	300.54	29753.46	-	-	-
T4	1811.99	29387.01	1511.45	-407.59	D
T7	3367.13	33345.87	1555.14	3958.86	254.57
T2	101333.05	28171.95	6765.92	-	D
				5174.52	
T5	11741.64	37422.36	1608.59	9251.01	575.1
T8	13316.21	38304.79	1574.57	882.43	56.04
T3	19950.10	25059.90	6633.83	-	D
				18244.89	
T6	21467.02	25234.98	1516.92	179.08	11.81
T9	23017.73	28753.27	1550.71	3518.29	226.9

Where, TVC = total variable cost; NB= net benefit; TVC = change in consecutive total variable cost; NB = change in consecutive net benefit; MRR (%) = marginal rate of return; D = treatments that were dominated as the dominance analysis shows; ETB = Ethiopian birr; T1 = zero-till + 0 kg NPS ha^{-1} ; T2 = zero-till + 150 kg NPS ha^{-1} ; T3 = zero-till + 300 kg NPS ha^{-1} ; T4 = flatbed + 0 kg NPS ha^{-1} ; T5 = flatbed + 150 kg NPS ha^{-1} ; T6 = flatbed + 300 kg NPS ha^{-1} ; T7 = tide ridge + 0 kg NPS ha^{-1} ; T8 = tide ridge + 150 kg NPS ha^{-1} ; and T9 = tide ridge + 300 kg NPS ha^{-1} .

4. Conclusion and Recommendations

Based on the results, it can be concluded that tillage practice and fertilizer application significantly affected plant growth, yield components, and yield of sesame. Among the tillage practices, tide ridge performed better than flatbed while zero tillage was the least performer. Likewise, fertilizer treatments increased growth, yield components, and yield of sesame compared to the control. Among the fertilizer treatments application of 150 kg NPS ha^{-1} produced the highest number of branches per plant, number of capsules per branch, number of seeds per capsule, and 1000-seeds weight of sesame followed by the application of 300 kg NPS ha^{-1} . On the other hand, the interaction effect of tillage and fertilizer application was significant for seed yield and the leaf area index where tide ridges combined with 150 kg NPS ha^{-1} application recorded the highest leaf area index. Whereas, the interaction effect of tillage and fertilizer on other parameters was not significant. The partial budget analysis result showed that the highest net benefit (38304.79 ETB) was obtained from T8 and the second higher net benefit (37422.36) was recorded in T5 whereas, the highest marginal rate of return (575.1%) was recorded in T5

followed by MRR recorded with T7 (254.57%). Therefore, based on the net benefit and MRR value the flatbeds with the 150 kg NPS ha^{-1} application or tied-ridge tillage with no NPS application was tentatively recommended. However, before making a wide area recommendation, the study should be repeated across seasons and different agroecologies.

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Conflict of Interest

Authors declare that there is no conflict of interests involve in publishing this research paper.

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