Effect of NPS and Nitrogen Fertilizers on Growth, Yield and Yield Components of Linseed (*Linum usitatissimum L.*) at Western Oromia, Ethiopia

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Abstract: The study was conducted at Chaliya district Chobi Tulu Chori kebele and Horo District Gitilo Dole Kebele during 2018 and 2019 main cropping season to identify optimum agronomic and economic threshold of NPS and Nitrogen fertilizers. The experiment consisted of two factors (0, 25, 50, 75 and 100 kg ha\(^{-1}\) NPS rates) and (0, 23, 46 and 69 kg ha\(^{-1}\) Nitrogen rates). A total of 20 treatments were laid out in Randomized Complete Block Design with three replications in 5x4 factorial arrangement. The results indicated that primary branch, capsule per plant, above ground dry biomass and yield were significantly affected by the main effect of NPS and nitrogen fertilizers. The highest grain yield (1400 kg and 1382 kg ha\(^{-1}\)) were obtained from the application of 25 kg NPS + 69 kg ha\(^{-1}\) and 25 kg NPS + 46 kg ha\(^{-1}\) N fertilizers respectively. The lowest grain yield (520 kg ha\(^{-1}\)) was recorded from the control treatment (0 kg NPS + 0 kg ha\(^{-1}\) N fertilizers). This indicates that 62.86% yield reduction was recorded as compared to the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\) fertilizer. The highest net benefit (35389ETB) and acceptable marginal rate of return (2038%) were obtained from the application of 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\). Therefore application of 25 kg NPS + 46 kg N ha\(^{-1}\) fertilizer rates was recommended for production of linseed in the study areas and similar agroecology.

Keywords: Fertilizer, Linseed, Marginal Rate of Return, Net Benefit

1. Introduction

Linseed, (*Linum usitatissimum L.*) (n=15), is an important oilseed crop which belongs to the family linaceae having 14 genera and over 200 species. It is one of the oldest crops known to man and it has been cultivated for fiber and seed oil. Originated from Europe and Southern Asia [1]. It is thought to have been an early introduction to Ethiopia [2]. The oil, which is approximately found in the rate of 35-46% in the linseed [3].

Nitrogen is often the most important plant nutrients, which affect the amount of protein, protoplasm and chlorophyll formed, consequently increases cell size, leaf area and photosynthetic activity. The reaction of linseed to nitrogen has been well established, as has the sensitivity of crop emergence and seed yield to seed-placed nitrogen [4, 5] also reported that nitrogen levels affect plant height, number of capsules/plant, 1000-seed weight and seed yield ha\(^{-1}\).

Phosphorus fertilizer is critical for plant growth and yield of linseed. [6] reported that mean performances of linseed differed for seed and straw yields with the application of phosphorus fertilizer [4] stated that linseed response to phosphorus fertilizer addition is highly variable, supporting the importance of maintaining medium to high soil P levels to optimize linseed yields. [7] reported that Phosphorus did not significantly increase the yield. [8] concluded that to optimize crop nutrition, phosphorus must be available to the crop in adequate amounts during the growing season.

Ethiopia is one the 5th major producer of linseed in the world after Canada, China, USA and India. In Africa Ethiopia is the first producers. Which is mainly produced in central highland of the nation [9]. Linseed has a long history of cultivation by smallholder farmers and the second most important oil crops next to Noug, exclusively for its oil in the...
The traditional agriculture of Ethiopia [9]. About 25% of the total land allocated for oil crop production in Oromia region was covered by linseed [10]). Even though the production area of linseed is the second largest next to Noug, its productivity is still low as compared to its potential productivity.

The reason why the productivity is low in Ethiopia is due to lack of high yielder variety, poor agronomic practice special application of inorganic fertilizer is very low. Because the perspective of farmers is low about the importance of inorganic fertilizer for linseed production and therefore, farmers produce linseed without or little application of fertilizer.

For the long period of time in Ethiopia agriculture system the farmer use only di-ammonium phosphate and Urea. But recently Ethiopian soil information system (EthioSIS) develop soil map based on soil fertility. Accordingly in the study areas soil was deficiency in sulfur in addition to nitrogen and phosphorus. To overcome this problem recently Ministry of Agriculture of the country introduced a new fertilizer (NPS) containing nitrogen, 19% phosphorous 38% and sulfur 7%. Therefore, this research was developed with the objective of;

to determinate the optimum agronomic and economic threshold of NPS and Nitrogen fertilizers.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Chaliya district, Chobi Tulu Chori kebele and Horo District, Gitilo Dole kebele for two consecutive years (2018 and 2019). Chobi Tulu Chori kebel is located between 9°0’00”N to 9°3’30”N, 37°32’00”E to 37°8’00”E and its altitude 2450m and Gitilo Dole kebele is located between 9°30’30”N to 9°34’30”N, 37°0’30”E to 37°8’00”E and its altitude 2800m (Figure 1). Both locations receive a mono modal pattern of rainfall distribution that receives from May to September and the soil of the areas is reddish. Wheat, Barley, Faba bean, Field bean, Linseed and Noug are the major crops that are commonly grown in the area.

![Map of the study area](image)

Figure 1. Map of the study area.

| Soil characteristic       | Value       | Chobi Tulu Chori | Gitilo Dole | Description                                      |
|---------------------------|------------|-----------------|-------------|-------------------------------------------------|
| Textural class            | Clay loam  | Clay loam       |             | acidic                                          |
| pH (1:2.5 H2O)            | 5.02       | 5.07            |             |                                                 |
| Organic matter (%)        | 2.74       | 1.83            |             | Low according to Berhanu (1980).                |
| Total nitrogen (%)        | 0.14       | 0.09            |             | Poor according to Tekalign et al. (1991).       |
| Available phosphorous (ppm)| 8.23       | 8.58            |             | low According to Tekalign et al. (1991).        |

Table 1. Physico-chemical properties of experimental soil before planting.
2.2. Treatments and Experimental Design

The experiment was laid down in randomized complete block design (RCBD) with factorial arrangement in three replications. There were a total of 20 treatments comprising five NPS rates (0, 25, 50, 75 and 100 kg ha\(^{-1}\)) and four nitrogen rates (0, 23, 46 and 69 kg ha\(^{-1}\)). Recently adapted linseed variety to the study areas (Kulumsa-1) was used as a test crop and planted at a seed rate of 25kg ha\(^{-1}\).

2.3. Experimental Procedures and Field Managements

The experimental plot were plowed by oxen three times and fine seed beds were prepared before planting. The seeds were sowed at spacing of 20 cm between rows on the experimental plot. NPS fertilizer was applied in the row as per the treatment and mixed with soil just at the time of planting while nitrogen fertilizer was applied in split, 50% at sowing and the rest 50% at vegetative stage of the crop.

2.4. Soil Sampling and Analysis

Soil samples were taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental area before planting from both locations to determine the physico-chemical properties of the soil of the experimental locations. Composite samples were prepared separately for both locations. The composite soil sample was dried, ground and sieved. Total nitrogen was determined following the kjeldahl procedure as described by [11]; the soil pH was determined by using a digital pH meter [12] Organic carbon was determined following wet digestion method as described by [13]; and the available phosphorus was measured using Olson II methods [14].

3. Data Collected

3.1. Crop Phenology and Growth

Days to flowering, days to maturity, plant height (cm) and number of primary branches per plant.

3.2. Yield and Yield Components

Number of capsule per plant, above ground dry biomass (quintal ha\(^{-1}\)) and grain yield (kg ha\(^{-1}\)).

3.3. Quality Parameters

Oil content (%).

4. Statistical Data Analysis

Data subjected to analyses of variance using SAS 9.1 computer software and treatment means were separated using fisher least significant difference (LSD) test at 0.05 probability level. The economic analysis was done using SIMMYT manual 1988.

5. Results and Discussion

5.1. Crop Phenology and Growth

5.1.1. Days to Flowering and Days to Physiological Maturity

Days to flowering and days to physiological maturity were not significantly affected by the main and interaction effects of NPS and N fertilizer rates; rather is a significantly affected due to location difference. The crop took 77 days to flower and 158 days to mature at Chobi Tulu Chori location. However, it reached flowering and maturity at 87 and 183 days, respectively at Gitilo Dole location. (Table 2). The difference could be due to altitude and temperature differences. Prolonged crop phenology at higher altitude and lower temperature. The effects of increased temperature exhibit a larger impact on grain yield than on vegetative growth because of the increased minimum temperatures. These effects are evident in an increased rate of maturity which reduces the ability of the crop to efficiently fill the grain. Similarly, [15] stated that days to flower initiation and physiological maturity between locations differed significantly and both phenological events were delayed considerably at the higher elevations compared to the lowest elevation.

| Treatment          | Chobi Tulu Chori | Gitilo Dole |     |
|--------------------|-----------------|-------------|-----|
|                    | DF   | DPM | DF  | DPM |    |     |
| Nitrogen fertilizer|      |     |     |     |    |     |
| 0                  | 77.26 | 159.03 | 87.27 | 183.60 |    |     |
| 23                 | 77.13 | 158.23 | 87.13 | 182.93 |    |     |
| 46                 | 77.00 | 158.10 | 86.93 | 182.87 |    |     |
| 69                 | 76.87 | 157.43 | 86.20 | 182.73 |    |     |
| LSD                | NS   | NS  | NS  | NS  |    |     |
| NPS fertilizer     |      |     |     |     |    |     |
| 0                  | 77.33 | 158.00 | 87.67 | 182.75 |    |     |
| 25                 | 77.17 | 157.83 | 86.25 | 182.50 |    |     |
| 50                 | 77.00 | 158.17 | 86.92 | 183.58 |    |     |
| 75                 | 77.00 | 158.50 | 86.93 | 183.25 |    |     |
| 100                | 76.83 | 158.50 | 86.67 | 183.08 |    |     |
| LSD (0.05)         | NS   | NS  | NS  | NS  |    |     |
| Mean               | 77.00 | 158.20 | 86.88 | 183.03 |    |     |
| CV (%)             | 0.38 | 1.02 | 1.50 | 0.67 |    |     |

DF= Days to flowering; DPM=Days to physiological maturity; LSD=least significant difference; CV=coefficient of variation; NS=non-significant

5.1.2. Plant Height

Plant height was significantly (P<0.05) affected by the main effect of N fertilizer rates but not affected by the main effect of NPS fertilizer rates and their interaction effect. The highest plant height (86.01 cm and 85.99 cm) were recorded from 69 kg ha\(^{-1}\) and 46 kg N ha\(^{-1}\) respectively (Table 3). When the amount of nitrogen increased from 0 kg to 69 kg the plant height also increased. The increase in plant height with increasing N fertilizer rate up to 69 kg N ha\(^{-1}\) could be explained by the stimulation effect for cell elongation.
directly after division [16]. In agreement with this result, [17] reported that plant height was increased as the rate of nitrogen fertilizer increased from 0 kg to 200 kg. Also [18] reported that increasing levels of N from 0 to 22.4 and 44.8 kg ha\(^{-1}\) significantly affect the plant height.

Table 3. Linseed plant height and seeds per capsule as affected by NPS and N fertilizers at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season.

| Treatment | NSPC | PH (cm) |
|-----------|------|---------|
| Nitrogen | 0    | 8.37    |
|           | 23   | 8.49    |
|           | 46   | 8.32    |
|           | 69   | 8.40    |
| LSD      |      | NS      |
| NPS      | 0    | 8.37    |
|           | 25   | 8.50    |
|           | 50   | 8.21    |
|           | 75   | 8.48    |
|           | 100  | 8.40    |
| LSD (0.05) | NS  | NS      |
| CV (%)   |      | 12.86   |
| LSD (0.05) |      | 8.13    |

Means within the same column followed by the same letter are not significantly different; LSD=Least Significant Difference (P < 0.05); CV=Coefficient of Variation; NS=Non Significant; NSPC=Number of seed per capsule; PH=plant height

### 5.1.3. Primary Branch per Plant

The analysis of variance over locations and year showed that primary branch was highly significantly (p<0.01) affected by main effect as well as their interaction effect of NPS and nitrogen fertilizer rates. The highest number of primary branches per plant (5.33.00 and 5.15) were recorded from application of 50 kg NPS ha\(^{-1}\) and 20 kg P\(^2\)O\(_5\) ha\(^{-1}\) respectively. In line with this finding [19] stated that the number of primary branches per plant increased significantly as N rate increased up to 90 kg ha\(^{-1}\). Also [20] stated that number of primary branches per plant was significantly increased with the application of 20 kg N and 20 kg P\(_2\)O\(_5\) ha\(^{-1}\) as compared to control treatment.

Table 4. Interaction effect of NPS and nitrogen fertilizer rates on primary branches at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season.

| Nitrogen fertilizer | NPS fertilizer | 0  | 25  | 50  | 75  | 100 |
|---------------------|----------------|----|-----|-----|-----|-----|
| 0                   | 2.97h          | 3.66d | 3.54g | 3.63f | 3.85e | 3.85-e |
| 23                  | 4.25c-e        | 4.15d-f | 4.23c-e | 4.26c-e | 4.23c-e | 4.23-c-e |
| 46                  | 4.59c-d        | 4.75b-c | 4.77a-c | 4.67b-d | 4.13d-f | 4.13-d-f |
| 69                  | 4.78a-c        | 5.15ab | 5.33a | 4.58cd | 4.28c-e | 4.28-c-e |
| LSD (0.05)          | 0.56           |      |      |      |      |      |
| CV (%)              | 16.22          |      |      |      |      |      |

Means with the same letter are not significantly different; LSD=Least Significant Difference; CV=Coefficient of Variation

### 5.2. Yield and Yield Components

The analysis of variance over locations and year showed that yield and yield components except seed per capsules were significantly ((P<0.01) affected by application of N and NPS fertilizer. The reaction of linseed to NPS fertilizer rates were low when examined with the reaction of linseed to N fertilizer rates.

#### 5.2.1. Capsule per Plant and Seeds per Capsule

Capsule per plant was highly significantly (p<0.01) affected by the main effect of NPS and N fertilizer rates and their interaction effect. The highest capsule per plant (45.16 and 42.10) was obtained from the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\) and 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\) respectively (Table 5). But number of seeds per capsule were not affected by main effect and interaction effect of NPS and N fertilizer rates (Table 3). The highest capsule per plant at higher N fertilizer may be due to the availability of nitrogen for plants is more when compared to the control treatment (0 kg NPS and 0 kg N). This indicates that Nitrogen is an important factor on distribution of photosynthetic assimilates between vegetative and reproductive organs. This result was in agreement with [21] the increased N application resulted in increasing number of capsules per plant and the highest number of capsules per plant obtained from the highest N application (92 kg ha\(^{-1}\)).

Table 5. Interaction effect of NPS and nitrogen fertilizer rates on Capsule per plant at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season.

| Nitrogen fertilizer | NPS fertilizer | 0  | 25  | 50  | 75  | 100 |
|---------------------|----------------|----|-----|-----|-----|-----|
| 0                   | 29.25i          | 31.15g-i | 39.16b-d | 30.28hi | 32.31g-i |
| 23                  | 32.20g-i        | 33.35f-h | 37.20d-f | 34.73e-g | 29.35i  |
| 46                  | 38.8c-e         | 42.10ab | 41.66a-c | 37.15e-f | 32.70g-i |
| 69                  | 39.16b-d        | 45.16a  | 40.33b-d | 34.78e-g | 3311g-i  |
| LSD (0.05)          | 3.91            |      |      |      |      |      |
| CV (%)              | 13.77           |      |      |      |      |      |

Means with the same letter are not significantly different; LSD=least significant difference; CV=coefficient of variation

#### 5.2.2. Above Ground dry Biomass (Quintal ha\(^{-1}\))

Above ground dry biomass was highly significantly (p<0.01) affected by the main effect of NPS and N fertilizer rates and their interaction effect. As the amount of nitrogen increased from 0 to 69 kg ha\(^{-1}\) the amount of above ground dry biomass also increased from 39.56 to 55.47 quintal ha\(^{-1}\). But the increment of above ground biomass with the increment of NPS fertilizer rates was very low when compared to N fertilizer. The highest above ground dry biomass (59.33 quintal) was obtained from the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\). This may be due to the availability of N to the plant increased and it causes increased plant height, number of capsules per plant and branches that contributed to the increase of aboveground biomass. This result was in agreement with [22] who stated that above ground biomass increased significantly when nitrogen fertilizer rates increased on French bean.
5.2.3. Grain Yield (kg ha\(^{-1}\))

Grain yield was highly significantly (P≤0.01) affected by the main effects of NPS and nitrogen fertilizers and their interaction effect. The highest grain yield (1400 kg ha\(^{-1}\)) was obtained from application of 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\) and 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\) respectively. The lowest grain yield (520 kg ha\(^{-1}\)) was recorded from the control treatment (0 kg NPS ha\(^{-1}\) + 0 kg N ha\(^{-1}\)) (Table 7). This indicates that 62.86% yield reduction was recorded as compared to the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\) fertilizer. Similar to others parameters of yield components; the reaction of grain yield to NPS fertilizer was low in amount than N fertilizer. This may be due to Mycorrhizae soil fungi that live in a symbiotic relationship with plants. According to [23] when linseed is not fertilized with P, yield is maintained and mycorrhizae infection is high but when linseed receives fertilizer P, mycorrhizae infection is reduced. The increase of grain yield due to increasing nitrogen fertilizer rates might be due to the role of nitrogen in protoplasm and chlorophyll formation, enhancement of meristematic activity and cell division, consequently increases cell size which improves vegetative growth, plant height and branch number and capsule number. Moreover, nitrogen encourages plants to uptake other elements activating, thereby growth of plants, consequently enhancing growth measurements and all seed yield components. Also Nitrogen is an important factor on distribution of photosynthetic assimilates between vegetative and reproductive organs. This result in agreement with [24] who stated that the highest grain yield (2290.79 kg ha\(^{-1}\)) was obtained from the application of 90 kg N ha\(^{-1}\).

5.3. Oil Content (%)

The oil content of linseed showed no significant response to NPS and Nitrogen fertilizers. Also the growing environments had no effect on oil content. However the result of laboratory tests indicated that the mean oil content was 38.56%. Which is found in the standard range of linseed oil 35-46% [3].

### Table 6. Interaction effect of NPS and nitrogen fertilizer rates on above ground dry biomass (quintal ha\(^{-1}\)) at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season.

| Nitrogen fertilizer NPS fertilizer | 0        | 25       | 50       | 75       | 100      |
|-----------------------------------|----------|----------|----------|----------|----------|
| 0                                 | 39.56kj  | 36.60k   | 43.50g-j | 44.09g-j | 41.26i-k |
| 23                                | 42.46h-i | 41.98f-h | 46.96e-h | 44.98f-i | 44.27g-j |
| 46                                | 50.62e-c | 53.82b-e | 47.87d-g | 45.75e-i | 45.86e-i |
| 69                                | 55.47ab  | 59.33a   | 53.15b-d | 52.51b-d | 49.93c-f |
| LSD (0.05)                        | 629      |          |          |          |          |
| CV (%)                            | 14.10    |          |          |          |          |

Means with the same letter are not significantly different; LSD=least significant difference; CV=coefficient of variation

### Table 7. Interaction effect of NPS and nitrogen fertilizer rates on grain yield (kg ha\(^{-1}\)) at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season.

| Nitrogen fertilizer NPS fertilizer | 0        | 25       | 50       | 75       | 100      |
|-----------------------------------|----------|----------|----------|----------|----------|
| 0                                 | 520j     | 645j     | 874.17fgh| 771.67hi | 775.83ghi|
| 23                                | 922.50ef | 930ef    | 999c-f   | 956.67def| 1039.17cde|
| 46                                | 1085bcd  | 1382a    | 1126.67bc| 908.33efg| 1011.67cde|
| 69                                | 1097.50bc| 1400a    | 1110.83bc| 1180b    | 950def   |
| LSD (0.05)                        | 135.76   |          |          |          |          |
| CV (%)                            | 17.14    |          |          |          |          |

Means with the same letter are not significantly different; LSD=least significant difference; CV=coefficient of variation

### Table 8. Partial budget analysis of NPS and nitrogen fertilizers on linseed in 2018 and 2019 for both locations.

| Treatment (NPS + N) | Average Yield kg ha\(^{-1}\) | Adjusted yield (10%) kg ha\(^{-1}\) | Cost of NPS ha\(^{-1}\) | Cost of N ha\(^{-1}\) | Cost of labor for fertilizer Application ha\(^{-1}\) |
|---------------------|-----------------------------|------------------------------------|------------------------|----------------------|----------------------------------------------------|
| 0kg + 0kg           | 5.2                         | 4.68                               | 0                      | 0                    | 0                                                  |
| 25kg + 0kg          | 6.45                        | 5.805                              | 375                    | 0                    | 75                                                 |
| 0kg + 23kg          | 9.22                        | 8.298                              | 0                      | 700                  | 75                                                 |
| 50kg + 0kg          | 8.74                        | 7.866                              | 750                    | 0                    | 75                                                 |
| 25kg + 23kg         | 9.3                         | 8.37                               | 375                    | 700                  | 75                                                 |
The results revealed that the response of capsule per plant and grain yield to NPS fertilizer was smaller when compared to N fertilizer. When nitrogen fertilizer was increased from 0 kg ha\(^{-1}\) to 69 kg ha\(^{-1}\), the capsule per plant and yield was increased significantly.

The highest grain yield (1400 kg ha\(^{-1}\) and 1382 kg ha\(^{-1}\)) was obtained from the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\) and 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\) respectively. The lowest grain yield (520 kg ha\(^{-1}\)) was recorded from the control treatment (0 kg NPS ha\(^{-1}\) + 0 kg N ha\(^{-1}\)). This indicates that 62.86% yield reduction was recorded as compared to the maximum grain yield.

6. Conclusion and Recommendation

Even though the production area of linseed is the second largest next to Noug, its productivity is still low as compared to its potential productivity.

The reason why the productivity is low in Ethiopia is due to lack of high-yielding variety, poor agronomic practice, special application of inorganic fertilizer is very low. Because the perspective of farmers is low about the importance of inorganic fertilizer without or little application of fertilizer, farmers produce linseed without or little application of fertilizer.

The results revealed that the response of capsule per plant and grain yield to NPS fertilizer was smaller when compared to N fertilizer. When nitrogen fertilizer was increased from 0 kg ha\(^{-1}\) to 69 kg ha\(^{-1}\), the capsule per plant and yield was increased significantly.

The highest grain yield (1400 kg ha\(^{-1}\) and 1382 kg ha\(^{-1}\)) was obtained from the application of 25 kg NPS ha\(^{-1}\) + 69 kg N ha\(^{-1}\) and 25 kg NPS ha\(^{-1}\) + 46 kg N ha\(^{-1}\) respectively. The lowest grain yield (520 kg ha\(^{-1}\)) was recorded from the control treatment (0 kg NPS ha\(^{-1}\) + 0 kg N ha\(^{-1}\)). This indicates that 62.86% yield reduction was recorded as compared to the

### Table 8. Continued.

| Treatment (NPS + N) | Total variable cost | linseed Price (ETB kg\(^{-1}\)) | Gross return (ETB kg\(^{-1}\)) | Net benefit (ETB kg\(^{-1}\)) |
|---------------------|---------------------|-------------------------------|-------------------------------|-----------------------------|
| 0 kg + 0 kg         | 0                   | 30.00                         | 14040                         | 14040                       |
| 25 kg + 0 kg        | 450                 | 30.00                         | 17415                         | 16965                       |
| 0 kg + 23 kg        | 775                 | 30.00                         | 24894                         | 24119                       |
| 50 kg + 0 kg        | 825                 | 30.00                         | 23598                         | 22773 D                     |
| 25 kg + 23 kg       | 1150                | 30.00                         | 25110                         | 23960 D                     |
| 75 kg + 0 kg        | 1200                | 30.00                         | 20844                         | 19644 D                     |
| 50 kg + 23 kg       | 1452                | 30.00                         | 26865                         | 25413                       |
| 0 kg + 46 kg        | 1550                | 30.00                         | 29295                         | 27745                       |
| 100 kg + 0 kg       | 1650                | 30.00                         | 20952                         | 19302 D                     |
| 25 kg + 46 kg       | 1925                | 30.00                         | 37314                         | 35389                       |
| 75 kg + 23 kg       | 1975                | 30.00                         | 25839                         | 23864 D                     |
| 0 kg + 69 kg        | 2325                | 30.00                         | 29646                         | 27321 D                     |
| 100 kg + 23 kg      | 2350                | 30.00                         | 28053                         | 25703 D                     |
| 50 kg + 46 kg       | 2375                | 30.00                         | 30429                         | 28054 D                     |
| 75 kg + 46 kg       | 2700                | 30.00                         | 37800                         | 35100 D                     |
| 50 kg + 69 kg       | 2750                | 30.00                         | 24516                         | 21766 D                     |
| 100 kg + 46 kg      | 3150                | 30.00                         | 29997                         | 26847 D                     |
| 75 kg + 69 kg       | 3200                | 30.00                         | 27324                         | 24124 D                     |
| 100 kg + 69 kg      | 3525                | 30.00                         | 31860                         | 28335 D                     |
| 10 kg + 69 kg       | 3900                | 30.00                         | 25650                         | 21750 D                     |

### Table 9. Marginal analyses of NPS and nitrogen fertilizers on linseed in 2018 and 2019 for both locations.

| Treatment (NPS + N) | TVC (ETB ha\(^{-1}\)) | MC (ETB ha\(^{-1}\)) | NB (ETB ha\(^{-1}\)) | MB (ETB ha\(^{-1}\)) | MRR (%) |
|---------------------|-----------------------|---------------------|---------------------|---------------------|---------|
| 0 kg + 0 kg         | 0.00                  | 14040               | 14040               | 650                 |
| 25 kg + 0 kg        | 450                   | 16965               | 2925                | 2201                |
| 0 kg + 23 kg        | 775                   | 24119               | 7154                | 191                 |
| 50 kg + 23 kg       | 1452                  | 25413               | 1294                | 191                 |
| 0 kg + 69 kg        | 1550                  | 27745               | 2332                | 2379                |
| 25 kg + 46 kg       | 1925                  | 35389               | 7644                | 2038                |

TVC=total variable cost; MC=marginal cost, NB=net benefit MB=marginal benefit, MRR=marginal ret of return, ETB=Ethiopian birr
application of 25 kg NPS ha$^{-1}$ + 69 kg N ha$^{-1}$ fertilizer. When fertilizer rates of nitrogen increased from 0 kg ha$^{-1}$ to 69 kg ha$^{-1}$ the yield was increased significantly but, as fertilizer rates of NPS vary from 0 ha$^{-1}$ to 100 kg ha$^{-1}$ the observed difference was low on yield. The partial budget analysis indicated that highest net benefit (35389ETB) and acceptable marginal rate of return (2038%) were obtained from the application of 25 kg NPS ha$^{-1}$ + 46 kg N ha$^{-1}$. Therefore application of 25 kg NPS + 46 kg N ha$^{-1}$ fertilizer rates was recommended for linseed production in the study area and similar agroecology.

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