Impact of Inorganic Fertilizers on Yield and Yield Components of Linseed (Linumusitatissimum L.) at Western Ethiopia

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Abstract
The study was conducted west showa zone, Chaliya district Chobi Tulu Chori kebele and Horo Guduru Zone, Horo District Gitilo Dole Kebele during 2018 and 2019 main cropping season to identify optimum agronomic and economic threshold of NPS and Nitrogen inorganic 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 and yield of linseed were significantly influenced by the effects of NPS and nitrogen fertilizers. The highest grain yields (1400kg and 1382 kg ha^{-1}) were obtained from the application of 25 kg ha^{-1} NPS + 69 N kg ha^{-1} and 25 kg ha^{-1} NPS + 46 kg ha^{-1} N fertilizers respectively. The lowest grain yield (520 kg ha^{-1}) was recorded from the control treatment (0 kg ha^{-1}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 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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INTRODUCTION

Linseed, (*Linum usitatissimum L.*) (n = 15), also called flax, is an important oilseed crop which belongs to the family linaceae having 14 genera and over 200 species. Linseed is one of the oldest crops known to man and it has been cultivated for both fiber and seed oil. Originated from Europe and Southern Asia (Casa *et al.*, 1999). Linseed is thought to have been an early introduction to Ethiopia (Belayneh & Alemayehu, 1988). The oil, which is approximately found in the rate of 35-46% in the linseed (Zuk M. *et al.,* 2015).

Nitrogen is often the most important plant nutrients, which influences the amount of protein, protoplasm and chlorophyll formed, consequently increases cell size, leaf area and photosynthetic activity. The response of linseed to nitrogen has been well established, as has the sensitivity of crop emergence and seed yield to seed-placed nitrogen (Lafond *et al.,* 2003). Soethe *et al.* (2013) also reported that nitrogen levels influenced plant height, number of capsules/plant, 1000-seed weight and seed yield ha^{-1}. Phosphorus fertilizer is also critical for plant growth and yield of linseed. In this respect, Khan *et al.* (2000) reported that mean performances of linseed differed for seed and straw yields with the application of phosphorus fertilizer. Lafond *et al.* (2003) 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. Kadar *et al.* (204) reported that P did not significantly increase the yield. You *et al.* (2007) 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 and the first producers in Africa, which is mainly produced in central highland of the nation (Delesa *et al.,* 2010). It 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 traditional agriculture of Ethiopia (Delesa *et al.,* 2010). About 25% of the total land allocated for oil crop production in Oromia region was covered by linseed (CSA, 2019). 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.

Optimum agronomic practice can considerably enhance the productivity of the crop. Despite its diverse use and wide production, linseed production in Ethiopia in general and in central highlands of Western Oromia is characterized by low yield and poor product quality mainly due to environmental and genetic factors as well as poor management practices such as lack of proper weed management system, poor seed and field hygiene, poor seed bed preparation, inappropriate seeding rates and methods, improper threshing ground and improper cleaning. Also little attention has been given to the fertilizer requirements of the linseed crop production in the country. Farmer use of fertilizers with linseed has been minimal to date. Even though fertilizer types applied in Ethiopia agriculture system are only urea and di-ammonium phosphate which contain only nitrogen and phosphorous. However, they may not probably satisfy the nutritional requirements of crop plants. To solve this situation the

Ministry of Agriculture of the country has recently introduced a new fertilizer containing nitrogen, phosphorous and sulfur with the ratio of 19% N, 38% P2O5 and 7% S (NPS fertilizer) that substituted DAP in Ethiopian agriculture. Thus, this research was aimed;

- To determinate the optimum agronomic and economic threshold of NPS and Nitrogen inorganic fertilizers.

MATERIAL AND METHODES

Description of the Study Area

The study was conducted West showa zone, Chaliya district Chobi Tulu Chori kebele and Horo Guduru Zone, Horo District Gitilo Dole Kebele during 2018 and 2019 main cropping season. Chobi Tullu Chori kebel is located between 9o0'00''N to 9o3'30''N, 37o32'00''E to 37o8'00''E and its altitude 2450m and Gitilo Dole kebele is located between 9o30'30''N to 9o34'30''N, 37o0'30''E to 37o8'00''E and its altitude 2800m (Fig.1). Both locations receive a mono modal pattern of rainfall distribution that receives from May to September, which is the main rain season 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

Figure 1. Map of the study area

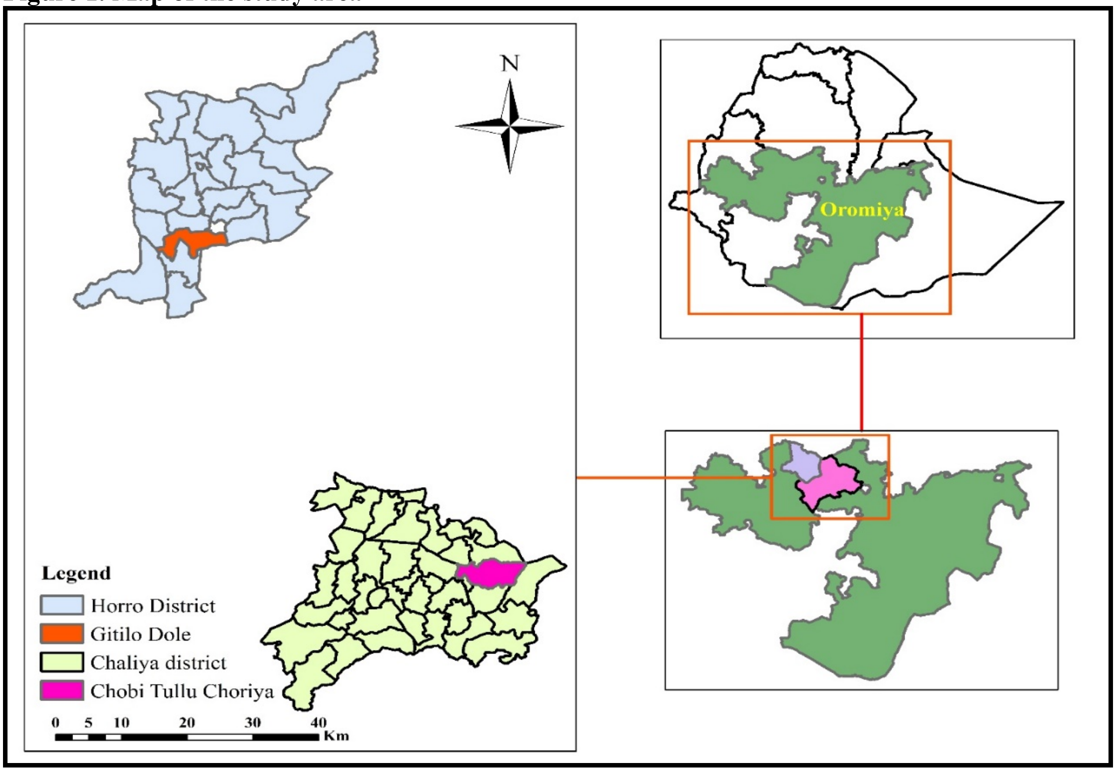

Table 1: Physico-chemical properties of experimental soil before planting

Soil characteristic	Value		Description
	Chobi Tulu Chori	**Gitilo Dole**	
Textural class	Clay loam	Clay loam	
pH (1:2.5 H2O)	5.02	5.07	acidic
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)

Treatments and Experimental Design

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. Recently adapted linseed variety to the study areas (Kulumsa-1) was used as a test crop. Each treatment was planted in a plot consisting of six rows of 4 m long with spacing of 20 cm between rows at a seed rate of 25kg/ha

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% during planting and the remaining 50% at vegetative stage of the crop.

Soil Sampling and Analysis
Soil samples were taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field before planting from both locations. Composite samples were prepared separately for both locations to determine the physico-chemical properties of the soil of the experimental locations. The composite soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen was determined following the kjeldahl procedure as described by (Cottenie, 1980); the soil pH was determined by using a digital pH meter (Page, 1982). Organic carbon was determined following wet digestion method as described by (Walkley and Black, 1934); and the available phosphorus was measured using Olson II methods (Olsen *et al.,* 1954)

Data Collection and Measurements
Crop Phenology and growth: Days to flowering, Days to maturity, Plant height (cm) and Number of primary branches per plant.
Yield and Yield Components: Number of capsule per plant Biomass yield (kg ha^{-1}) and yield (kg ha^{-1})
Quality parameters: Oil content (%)
Statistical Data Analysis:
Analysis of variance was carried using General Linear Model of ANOVA using SAS software. Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION
Crop Phenology and Growth
The analysis of variance over locations and years showed that 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 (senescence) which reduces the ability of the crop to efficiently fill the grain. Similarly, Thomas George *et al.* (1990) reported 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.

Table 2. Main effects of NPS and N fertilizers on days to flowering and days to physiological maturity

Treatment	Chobi Tulu Chori		Gitilo Dole	
	DF	DM	DF	DM
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 flower initiation; DM= Days to physiological maturity; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation; NS =Non Significant

Plant height (cm)

Plant height was significantly (P<0.05) affected by the main effect of N fertilizer rates but not affected by the main effects of NPS fertilizer rates and the interaction effects. The highest plant height (86.01cm and 85.99 cm) were recorded from 69 kg ha^{-1} and 46 kg N ha^{-1} respectively (Table 3). As the amount of nitrogen increased from 0 kg to 69kg the plant height also increased. The increase in plant height with increasing mineral N fertilizer rate up to 69 kg N ha^{-1} could be explained by the stimulation effect for cell elongation directly after division (Dixit and Sharma, 1993) and the increase in plant height in response to application of N fertilizers is p attributed due to availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulted in more dry matter accumulation. In agreement with this result, Geovan Soethe *et al.* (2013) reported that plant height was increased as the amount of urea fertilizer increased from 0 kg to 200 kg. Similar to the present findings, plant height exhibited positive response to applications of high rates of N fertilizer (Genene *et al.,* 2006) also Pande *et al.,* 1970) reported that increasing levels of N from 0 to 22.4 and 44.8 kg ha^{-1} significantly influenced the plant height. El-Nagdy *et al.* (2010) also found that plant height was 66.8, 83.7 and 105. 9cm by adding 25, 50 and 100% of the recommended mineral N fertilizer rate of linseed, respectively.

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	NSPP	PH (cm)
Nitrogen		
0	8.37	82.74b
23	8.49	84.66ab
46	8.32	85.99a
69	8.40	86.01a
LSD	NS	2.48
NPS		
0	8.37	84.25
25	8.50	84.97
50	8.21	85.20
75	8.48	84.43
100	8.40	85.38
LSD (0.05)	NS	NS
CV (%)	12.86	8.13

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation; NS =Non Significant;; NSPP= Number of seed per capsule; PH= plant height

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} + 69 kg N ha^{-1} and 25 kg NPS ha^{-1} + 69 kg N ha^{-1} respectively. These results are also in agreement with researchers (Nayital and Singh 1984b) stated that the number of primary and secondary branches per plant increased significantly when N level increased up to 90 kg $ha^{-1.}$ Also Sharma and Rajput (1984) stated that the growth attributes like plant height and number of primary branches per plant were significantly superior with the application of 20 kg N and 20 kg P_2O_5 ha^{-1} as compared to no fertilizer application**.**

Table 4. Linseed primary branch as affected by the interaction of NPS and Nitrogen fertilizer rates 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	3.66fg	3.54g	3.63fg	3.85e-g
23	4.25c-e	4.15d-f	4.23c-e	4.26c-e	4.23c-e
46	4.59cd	4.75bc	4.77a-c	4.67b-d	4.13d-f
69	4.78a-c	5.15ab	5.33a	4.58cd	4.28c-e
LSD (0.05)			0.56		
CV (%)			16.22		

Means within the column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference; CV = Coefficient of Variation

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 responses of linseed to NPS fertilizer rates were very low when compared to its responses to N fertilizer rates but when nitrogen fertilizer was increased from 0 kg to 69 kg ha^{-1} yield and yield components were significantly increased.

Capsule per plant and seeds per capsule

The combined analysis of variance over locations and years revealed that 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). In contrast, number of seeds per capsule were not affected by NPS and N fertilizer rates (Table 3). The highest capsule per plant at higher N fertilizer could 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 Singh (1968) increased levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}) increased the number of capsules per plant. Pawar *et al*. (1990) reported that with increased levels of nitrogen (0, 15, 30, 45 or 60 kg N ha^{-1}) there was an increase in the number of capsules per plant (77.81 to 98.03).

Table 5. Capsule per plant of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen	NPS fertilizer				
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 within the column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference; CV = Coefficient of Variation

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 zero to 69 kg ha^{-1} the amount of above ground dry biomass also increased from 39.56 to 55.47 quintal ha^{-1}. 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}. The increase in biomass with increased Nitrogen rates could be attributed to the fact that the enhanced availability of N significantly increased plant height, number of capsules per plant and to the overall vegetative growth of the plants that contributed to higher aboveground biomass. This result was in line with that of Veeresh (2003) who reported that total dry matter production per plant increased significantly from 12.0 to 16.03 g due to increased nitrogen application from 40 to 120 kg N ha^{-1} on French bean.

Table 6. Aboveground dry biomass of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen	NPS fertilizer				
fertilizer	0	25	50	75	100
0	39.56jk	36.60k	43.50g-j	44.09g-j	41.26i-k
23	42.46h-j	41.98h-j	46.96e-h	44.98f-i	44.27g-j
46	50.62b-e	53.82b-c	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 within the same column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of variation

Grain yield (kg ha^{-1})

The combined analysis of variance over locations and years revealed that the main effects of NPS and nitrogen fertilizers and their interaction highly significantly (P≤0.01) affected grain yield. The highest grain yield (1400 kg ha^{-1} and 1382 kg ha^{-1}) were obtained from 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}) (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. The response of grain yield to NPS fertilizer was smaller in magnitude than N fertilizer. In other words when nitrogen fertilizer was 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} kg to 100 kg ha^{-1} the observed difference was low on yield. The lower yield difference due to NPS may be due to the Mycorrhizae soil fungi that live in a symbiotic relationship with plants receive carbohydrates from the plants, and in return, the plant receives mineral nutrients from the mycorrhizae, particularly phosphate. When linseed is not fertilized with P, yield is maintained and mycorrhizae infection is high. When linseed receives fertilizer P, mycorrhizae infection is reduced (Grant *et al.,* 2004). According to Thingstrup I. *et al* (1998) the effect of the mycorrhizal fungi increased with decreasing soil P levels. The increase of grain yield due to increasing mineral nitrogen fertilizer levels 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. These results are also in agreement with those of several researchers (Fataneh P. K. *et al.* 2012) the highest grain yield (2290.79 kg ha$^{-1)}$ was obtained with 90 kg N ha^{-1} ; Soethe *et al.* (2013), and Ibrahim M.H. *et al* (2016) the highest grain yield was obtained from the highest N fertilizer.

Table 7. Grain yield (kg ha^{-1}) of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen	NPS fertilizer				
fertilizer	0	25	50	75	100
0	520j	645ij	874.17fgh	771.67hi	775.83ghi
23	922.50ef	930ef	995c-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 within the same column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of variation

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% (Zuk M. et al., 2015).

Economic evaluation

The economic assessments were made using partial budget analysis as described by CIMMYT (1988). Economic analysis is based on the average yield of each treatment. Therefore, the net benefit estimate for 20 treatments is presented in Table 8. The highest net benefit (35389 ETB) was obtained from the application of 25 kg NPS ha^{-1} + 46 kg N ha^{-1}. The lowest net benefit (14040 ETB) was obtained from control treatment (0 kg NPS ha^{-1} + 0 kg N ha^{-1}). The highest net benefit obtained from the application of 25 kg NPS ha^{-1} + 46 kg N ha^{-1} indicated that the optimum level of fertilizer rate and net benefit increased until this fertilizer rate.

Dominance analysis

The dominant analysis showed that the net benefit of all treatments were dominated except unfertilized plot and application of 25 kg NPS ha^{-1} + 0 kg N ha^{-1}, 0 kg NPS ha^{-1} + 23 kg N ha^{-1}, 50 kg NPS ha^{-1} + 23 kg N ha^{-1}, 0 kg NPS ha^{-1} + 46 kg N ha^{-1} and 25kg NPS ha^{-1} + 46 kg N ha^{-1} (Table 8). This result indicated that the net benefit decreased as the total cost that varies increased beyond undominated treatment (application of 25kg NPS ha^{-1} + 46 N kg ha^{-1}

Marginal rate of return

As shown in (Table 9) the result of analysis of dominant treatments indicated that for each one birr invested, it was to recover one birr plus an extra 6.50, 22.01, 1.91, 23.79 and 20.38 birr ha^{-1} as the fertilizer application changed from unfertilized plot until optimum level of 25 kg NPS ha^{-1} and 46 kg N ha^{-1}. From the control treatment that had the lowest costs to the end of the treatment which had the highest cost, that varies, the marginal rate of return obtained was above the minimum acceptable marginal rate of return. According to CIMMYT (1998) the minimum rate of return acceptable to farmers will be between 50% and 100%. The best recommendation for treatments subjected to marginal rate of return is not based on the highest marginal rate of return, rather, based on the minimum acceptable marginal rate of return, and the treatment with the highest net benefit together with an acceptable rate. Therefore in this study, 50 % was considered as the minimum acceptable rate of return for farmer's recommendation. In line with this study the application of 25 kg NPS ha^{-1} and 46 kg N ha^{-1} was the best for linseed production in the study area and similar agroecology.

Table 8. Net benefit estimation and Dominance analysis of the combined application of NPS and N 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}	Total variable cost	linseed Price (ETB kg $^{-1}$)	Gross return (ETB kg $^{-1}$)	Net benefit (ETB kg $^{-1}$)
0kg + 0kg	5.2	4.68	0	0	0	0	30.00	14040	14040
25kg + 0kg	6.45	5.805	375	0	75	450	30.00	17415	16965
0kg + 23kg	9.22	8.298	0	700	75	775	30.00	24894	24119
50kg + 0kg	8.74	7.866	750	0	75	825	30.00	23598	22773 D
25kg + 23kg	9.3	8.37	375	700	75	1150	30.00	25110	23960 D
75kg + 0kg	7.72	6.948	1125	0	75	1200	30.00	20844	19644 D
50kg + 23kg	9.95	8.955	750	700	2	1452	30.00	26865	25413
0kg + 46kg	10.85	9.765	0	1400	150	1550	30.00	29295	27745
100kg + 0kg	7.76	6.984	1500	0	150	1650	30.00	20952	19302 D
25kg + 46kg	13.82	12.438	375	1400	150	1925	30.00	37314	35389
75kg + 23kg	9.57	8.613	1125	700	150	1975	30.00	25839	23864 D
0kg + 69kg	10.98	9.882	0	2100	225	2325	30.00	29646	27321 D
100kg + 23kg	10.39	9.351	1500	700	150	2350	30.00	28053	25703 D
50kg + 46kg	11.27	10.143	750	1400	225	2375	30.00	30429	28054 D
25kg + 69kg	14	12.6	375	2100	225	2700	30.00	37800	35100 D
75kg + 46kg	9.08	8.172	1125	1400	225	2750	30.00	24516	21766 D
50kg + 69kg	11.11	9.999	750	2100	300	3150	30.00	29997	26847 D
100kg + 46kg	10.12	9.108	1500	1400	300	3200	30.00	27324	24124 D
75kg + 69kg	11.8	10.62	1125	2100	300	3525	30.00	31860	28335 D
100kg + 69kg	9.5	8.55	1500	2100	300	3900	30.00	25650	21750 D

ETB= Ethiopian birr, D= Dominated

Table 9. Marginal rate of return of NPS and N fertilizers application 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 (%)**
0kg + 0kg	0.00		14040		
25kg + 0kg	450	450	16965	2925	650
0kg + 23kg	775	325	24119	7154	2201
50kg + 23kg	1452	677	25413	1294	191
0kg + 46kg	1550	98	27745	2332	2379
25kg + 46kg	1925	375	35389	7644	2038

TVC = Total variable cost; MC= marginal cost, NB=net benefit MB= marginal benefit, MRR= marginal ret of return, ETB= Ethiopian birr,

CONCLUSION AND RECOMONDATION

Linseed production in Ethiopia in general and in central highlands of Western Oromia is characterized by low yield and poor product quality mainly due to environmental and genetic factors as well as management. Also little attention has been given to the fertilizer requirements of linseed production in the country. These situations should be diverted in order to improve income, livelihood and health of farmers.

The results revealed that the response of capsule per plant and grain yield to NPS fertilizer was smaller in magnitude than 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 but, as fertilizer rates of NPS vary from 0 ha^{-1} kg to 100 kg ha-1 the observed difference was low

The highest grin 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 N kg 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 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} kg 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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