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RESEARCH PAPER

Effect Of Nitrogen Fertilizer Rates on Seed Yield And Oil Quality of Linseed (*Linum Usitatissimum* L.) Varieties in Welmera District, Central Highland of Ethiopia

Alemu Dilenssie[1], Temesgen Deselagn[2] and Habtamu Ashagre[3]*

[1]*Oromia Agricultural Input Regulatory Authority;*

[2]*Institute of Agricultural Research, Addis Ababa;*

[3]*Ambo University, Department of Plant Science, Ambo*

***Corresponding Author:** Email: ashagrehabtamu@gmail.com*

Abstract

Linseed (Linum usitatissimum L.) is one of the most important oilseed crop in the central highlands of Ethiopia. However, poor soil fertility management and lack of improved varieties affect its seed yield and oil quality. Therefore, an experiment was conducted to evaluate the effects of nitrogen fertilizer rates on yield, and oil quality of linseed varieties in Welmera district. The experiment was laid out in a randomized completed block design with three replications. The treatments were factorial combinations of three linseed varieties (Bekoji-14, Jeldu, and Kulumsa-1) and five rates of Nitrogen (0, 11.5, 23.0, 34.5, and 46.0 kg N ha-1). The analysis of variance showed that the main effect nitrogen and varieties significantly (P<0.05) affected seed and oil yields, oil content, and fatty acid compositions of linseed. The maximum seed yield (1508 kg ha-1) and oil yield (604.4 Lt ha-1) were recorded from 46 kg N ha-1 with Jeldu variety; while the minimum seed yield (782 kg ha-1) and oil yield (445.8 lt ha-1) were obtained from the control treatment with Bokoji-14 variety. The highest polyunsaturated fatty acids content (linolenic 56.24, oleic 19.43, and linoleic 14.37%) and the optimal range of saturated fatty acids (palmitic 5.82 and stearic 4.89%) were recorded from 46 kg N ha-1 treatment. Moreover, the partial budget analysis also indicated that the maximum net benefit 36,865birr ha-1 with MRR 1738% was obtained from 46 kg N ha-1. Therefore, farmers in the study area can be advised to use Juldu variety with 46 kg N ha-1 for better seed and oil yields with optimal fatty acid composition.

Keywords: Fatty acid, oil content, oil yield and seed yield

Introduction

Ethiopia is considered to be the secondary center of diversity, and the 7th major producer of linseed in the world (FAOSTAT, 2014). It is the second most important oil crop in the highlands of Ethiopia (Adefris *et al.*, 1992). In Ethiopia, small-scale farmers have been producing linseed organically without applying any chemicals (fertilizers, herbicides, pesticides) with minimum inputs (Adugna, 2007). This crop is used in a crop rotation of five to seven years with cereals and maize as good precursor crops (Worku *et al.*, 2012), and cultivated in areas where nigerseed and safflower are not cultivated (Geleta and Ortiz, 2013).

Linseed is used for oil production and in the food industries because of its nutritional qualities, essential polyunsaturated fatty acids and rich supply of soluble dietary fiber (Mohammadi *et al.*, 2010). It is a food and cash crop that generate revenue both in local and export markets. The industrial oil is an important ingredient in the manufacture of paints, varnishes and linoleum (Morris, 2005)

The greatest challenges of linseed production in central highland of Ethiopia include poor usage and shortage of improved varieties, poor soil fertility management and unavailability of improved agronomic practices (Abebe and Adane, 2016). For instance the production of linseed in Ethiopia in 2016/17 was about 87,911.655 tons from 80,353.74 hectares with an average productivity of 1.094 tons ha^{-1} (CSA, 2017). On the other hand, using improved varieties along with good agronomic practices gave as high as 2.2 - 3 tons ha^{-1} on research fields and some model farmers managed to produce as high as 2.0- 2.5 tons ha^{-1} with an average of 38.6 percent oil content when supported with improved seed of linseed, intensive training and close supervision (Mulusew *et al.,* 2013; KARC, 2012; Adugna *et al.,* 2004). El-Beltagi *et al.*, (2011) also reported as the oil contents of linseed varieties varied with the ranging of 23- 45.7 % which are grown under diverse agro-ecological environments.

Linseed crop productivity and oil quality can be improved through the use of optimal fertilizer and identification of the most suitable variety. However, farmers usually do not apply fertilizers to linseed, rather grown on marginal lands, and priority is given to cereal and pulse crops. Absence of improved management practices, inadequate seedbed preparation and the use of half a century old nitrogen fertilizer recommendation (23 kg N ha^{-1}) are among the factors for low seed and oil yields of linseed crops. Linseed has also diverse and conflicting responses to nitrogen. Several reports indicated that it has a favorable response to nitrogen (Reta, 2015; Tanwar *et al*., 2011; Hocking, 1995) especially when soil nitrogen was low (Marchenkov *et al*., 2003). While other authors reported that linseed has a poor response to nitrogen and nitrogen had no effect on oil content (Leilah, 1993). These variable responses to nitrogen could be due to initial soil nitrogen level, soil moisture and seasons (Genene *et al.,* 2006).

According to Hiruy *et al.* (1992), 23 kg N ha^{-1} is the blanket recommendation for linseed production in the country. However, the amount of fertilizer recommended for crops should be depend on the soil fertility status, and nutrient utilization efficiency of the crops. Moreover, the dynamic nature of the soil environmental, complete removal of crop residues at harvest, and the poor soil management practices affect the efficiency of nitrogen utilization of linseed to enhance its productivity and oil quality.

Improved linseed varieties have better productivity and standard oil content compared to the local genotypes (Worku *et al*., 2012). However, their genetic potential is affected due to variation in agro-ecology, poor soil fertility and poor crop management practices. Hence, this study was undertaken to determine the optimal nitrogen fertilizer level to improve the seed and oil yields, and fatty acid compositions of linseed varieties in the study area.

Materials and methods

Description of Study Areas

The experiment was conducted in Welmera district in the central highland of Ethiopia during the main cropping season of 2017. The experiment was conducted 20 km far away from Holetta agricultural research center at $9^0$07’39’’ N latitude, $38^0$26'09" E longitude and at an altitude of about 2585 m.a.s.l. The area is characterized by a bimodal rainfall pattern and receives 100.2 mm rainfall during the short rainy season (February to April), and 963.2 mm during the long rainy season (mid-June to December) with an average monthly rainfall of 89.3 mm (HARC, 2017). The mean annual maximum and minimum temperatures were 24.1 and 6.6^{0}C, respectively. The preceding crop grown in the experimental field was barley.

Soil Sampling and Analysis

A composite soil samples were collected from the experimental plots in a diagonal pattern from a depth of 0-20cm before planting, and after harvest on individual plot basis. The selected physico-chemical properties like organic carbon, total nitrogen, soil pH, available phosphorus, cation exchange capacity, and soil textural analysis were undertaken using the standard procedures in Holeta Agricultural Research Center Soil Laboratory. Organic carbon (OC) content was determined by volumetric method (Walkley and Black, 1934). Total nitrogen was analyzed by Kjeldhal digestion method using sulfuric acid (Jackson, 1967). The pH of the soil was determined according to the procedure of FAO (2008), while cation exchange capacity (CEC) was measured as per Chapman, (1965). Available phosphorus was determined by the Bray II method (FAO, 2008). Particle size distribution was done by hydrometer method (FAO, 2008).

Treatments and Experimental Design

Factorial combination of three linseed varieties (Bekoji-14, Jeldu and Kulumsa-1) and five levels of nitrogen fertilizer (0, 11.5, 23, 34.5 and 46 kg ha^{-1}) were evaluated in this study. Urea (46% N kg ha^{-1}) was used as source of nitrogen. The experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement with three replications. Each plot consisted of 3m x 2m ($6m^2$) and has 15 rows with inter-row space of 20 cm. Adjacent blocks and plots were separated by 1.5 and 0.4 meter distances, respectively.

Management Practices

The land was prepared with tractor using mounted mould board plough and disc harrowed to break big soil clods into small sizes. The recommended seed rate (25 kg ha^{-1}) at depth of 3 cm was seeded on the well prepared fine seedbed on 6th July 2017. Phosphorus was applied at a rate of 23 P_2O_5 kg ha^{-1} uniformly to all treatments at time of sowing, while nitrogen fertilizer was applied based on the treatment in two equal splits, *i.e.*, half was applied at sowing in furrows and the remaining half was applied at the beginning of tillering stage (36 days after sowing).

All necessary agronomic practices as required for linseed crop were carried out as per the standard procedure. Harvesting was performed at 90% physiological maturity (capsules had turned brown and seed rattled in the capsules and shaken) by hand pulling. The harvested produce was sun dried for about 20 days in open fields. Then the dried crop was threshed manually and separated into seed and straw. The seeds were cleaned and weighed for yield determination and laboratory analysis.

Data Collection Procedures

Seed yield (kgha^{-1}**)**: dry seed yield from the net area of 5.2 m^2 of each plot was recorded at 7% moisture content and yield per plot was converted into hectare.

Percent oil content: It is the proportion of oil in the seed to total oven dried seed weight as determined by a nuclear magnetic resonance spectrometer (NMRS). In this experiment, 22 g of seeds were prepared and dried in an oven for two and half hours at 130^0C, cooled for 30 minutes. Then oil contents of seeds were determined using nuclear magnetic resonance (NMR) in Holeta Agricultural Research Center Food and Nutrition Laboratory.

Oil yield (OYH) (kgha^{-1}): The amount of oil in kilogram per hectare was obtained by multiplying the seed yield per hectare by the corresponding seed oil percentage obtained from the oil content analysis and divide by one hundred (Legesse, 2010).

$$\text{Oil yield} = \frac{\text{Seed Yield (kg/ha) x percent oil content (\%)}}{100}$$

Fatty acid profile analysis: it was analyzed using near infrared reflectance spectroscopy (NIRS) to determine the percent of fatty acids composition. The near infrared spectra was corrected with a minochromator (FOSS NIR system 500) by scanning at 1108-2492 nm spectra range with an 8 nm step and all spectra and reference data were recorded and managed with the Win ISI version II software (infra soft international port Matilda, PA, USA).

Statistical Analysis

The yield and quality parameters data were analyzed using SAS computer software version 9.0 (SAS, 2004). Differences among means were determined using the least significance difference (LSD) test at the 0.05 level of significance. Correlation analysis was carried out between seed yield, percent oil content and fatty acid profile of linseed varieties as affected by nitrogen fertilizer application.

Economic Analysis

The economic analysis was undertaken based on the partial budget analysis technique as described by CIMMYT (1988). The average yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same agronomic practices (CIMMYT, 1988). The analysis was done using the prevailing market prices for inputs at planting and for the output at the time of crop harvest. The net benefit was calculated as the difference between the gross field benefit (EB ha^{-1}) and the total variable costs (EB ha^{-1}) that varied.

Results and discussions

Selected soil physicochemical properties of the experimental site before planting

The results of soil analysis indicated that the soil of the study area had a textural class of clay with clay content (65%), silt (18.75%) and sand (16.25%) (Table 1). High clay content in the experimental site may indicate better water and nutrient holding capacity of the soil. The pH (H_2O) of the soil is 4.8, which is within the suitable range for the growth of the crop (Adugna, 2007). The pH showed a strongly acidic reaction according to the rating of Motsara and Roy (2008). The cation exchange capacity of the soil was found to be 21.56 $cmol_{(+)}$ kg^{-1}, which was in medium category (Roy *et al*., 2006).The soil organic carbon content (1.95%) and organic matter (3.36 %),were very low, which indicates a high potential to add nitrogen through mineralization (Landon, 1991). The soil has a medium level of total nitrogen (0.25%) in the study area. The available phosphorus content was also at low level (7.48 mg/ kg) as described by Marx (1996). Hence, this indicates that there is a need to apply fertilizer in the study area for improving production and productivity of linseed.

Table 1. Selected soil physico-chemical properties of soils before planting

Soil Parameter	Value
pH	4.8
Cation exchange capacity	21.56
Total nitrogen	0.25
Available phosphorous	7.45
Organic carbon	1.95
Organic matter	3.36
Texture	
Sand	16.25
Silt	18.75
Clay	65
Textural class	**Clay**

Selected Soil Physico-chemical Properties of Experimental Soil after Harvesting

The post-harvest soil analysis indicated that total nitrogen values did not showed wide variation due to different treatment combinations (Table 2). The total nitrogen content of the soil before planting was 0.25 % and after harvesting it varied from 0.18 to 0.22 %. The highest and the lowest concentrations of total nitrogen content were observed from treatment received 46 kg N ha^{-1} and 11.5 kg N ha^{-1}, respectively. The reason for the reduction of total soil nitrogen may be due to the removal of soil N through grains and other plant parts of the crops (Reta, 2015). However, CEC of the experimental soil 21.56 cmol kg^{-1} before planting was increased to 27.43 cmol kg^{-1} after harvesting. Available phosphorous of the soil before planting was 7.45 (mg kg^{-1}), while after harvest it varied from 8.2 to 11.7 (mg kg^{-1}). The increase in phosphorous content after harvest might be due to its less accumulation in seed and straw, and to some extent this increased its unavailability in the soil. The organic carbon of the soil before planting and after harvest were 1.95 (%) and varied from 1.92 to 2.39 (%), respectively. Similarly, the soil organic matter before planting and after harvest was 3.36 (%) and varied from 3.31 to 4.12 (%), respectively (Table 2).

Table 2. Selected physico-chemical properties of the experimental soil after harvest

Soil parameter							Particle size distribution			
N (kg/ha)	pH (1:2:5 H_2O)	Av.P (mg/ kg)	Tot.N (kg ha-1)	OC (%)	OM (%)	CEC $cmol_{(+)}$/kg	Sand	Silt	Clay	Textural class
0	4.7	8.2	0.2	2.06	3.46	27.43	17.25	18.22	64.53	Clay
11.5	4.7	11.7	0.18	1.92	3.31	19.35	16.23	19.92	63.85	Clay
23	4.9	10.8	0.19	2.39	4.12	23.31	11.92	26.85	61.23	Clay
34.5	4.8	10	0.2	2.04	3.52	25.25	14.58	20.19	65.23	Clay
46	4.8	9.8	0.22	2.09	3.60	22.32	15.21	25.59	59.2	Clay

Effect of Nitrogen Fertilizer on Seed Yield and Oil quality of Linseed Varieties

The analysis of variance showed that there was a significant (P<0.01) effect of nitrogen level on seed yield, percent of oil content, oil yield, and linoleic fatty acid (P<0.05). Similarly, oil yield, palmitiec (P<0.01) and Oleic (P<0.05) fatty acids were significantly affected by the main effect of varieties. The main effects of nitrogen level and varieties significantly (P<0.01) affected oil yield of linseed. Similarly, the interaction effect of main factors significantly (P<0.01) affected seed yield of linseed (Table 3).

Table 3. Levels of significance for seed yield, oil yield and fatty acid composition of linseed as affected by nitrogen level, varieties and their interaction

Source of Variation	Mean squares								
	DF	SY	POC (%)	OLY (Lt ha^{-1})	C16:2 (%)	C18:.0 (%)	C18:1 (%)	C18:2 (%)	C18:3 (%)
Rep	2	NS	NS	NS	NS	NS	NS	NS	NS
V	2	NS	NS	**	**	NS	*	NS	NS
N	4	**	**	**	NS	NS	NS	*	NS
V*N	8	**	NS	NS	NS	NS	NS	NS	NS

Where, DF= Degree of freedom; Rep= Replication; N= Nitrogen level; V= Linseed varieties; N x V= Nitrogen and varieties interaction; SY= Seed yield; POC= percent of oil content; OLY= Oil yield; C16:2= Palmitiec fatty acid; C18:0 = Stearic fatty acid; C18:1 Oleic fatty acid; C18:2 = Linoleic fatty acid; C18:3= Linoliniec fatty acid.

Seed yield

The interaction effect of nitrogen and varieties significantly (P<0.05) influenced seed yield of linseed (Table 4). The highest seed yields (1508 and 1423 kg ha^{-1}) were recorded from the 46 kg N ha^{-1} and 34.5 kg N ha^{-1} with Jeldu variety, respectively. However, the minimum seed yield was recorded from no nitrogen application with Kulumsa-1 (781.9 kg ha^{-1}), Bokoji-14 (833 kg ha^{-1}) and Jeldu (1040 kg ha^{-1}). Thus, application of 46 kg N ha^{-1} had about 92.8% more than the yield advantage than the control treatment. This increase in yield could be the synergetic effect of N fertilizer and the suitability of the improved linseed variety to the growing agro-ecology. Similarly, Reta (2015) reported that nitrogen fertilizer level and improved varieties had a synergetic effect on yield and oil quality of linseed.

Table 4. Interaction effect of nitrogen fertilizer levels and linseed varieties on seed yield (kg ha^{-1}) in Wolmera district

	Varieties			
N (kg ha^{-1})	Bokoji-14	Jeldu	Kulumsa-1	Mean
0	833^{gh}	1040^{cd}	782^{h}	889
11.5	916^{efg}	1327^{b}	893^{fgh}	1045
23	1017^{cde}	1347^{b}	987^{def}	1117
34.5	1312^{b}	1423^{ab}	1109^{c}	1312
46	1365^{b}	1508^{a}	1247^{b}	1427
Mean	10886	1329	1004	
LSD (5%)= 121		CV (%)= 5.3		

Means in rows and columns followed by the same letter are not significantly different at P > 0.05 levels of significance

Seed oil content

The percent seed oil content of linseed was significantly (P<0.01) influenced by the main effect of nitrogen fertilizer levels, however it was not affected by the main effect of varieties and their interactions (Table 5). Increase the levels of nitrogen from zero to 46 kg ha^{-1} significantly reduced percent seed oil content except 11.5kg N ha^{-1}. The lowest percent seed oil content (35%) was recorded from 46 kg ha^{-1}, while the highest seed oil content (36.5%) was recorded from the control treatments. The decrease in oil content with high nitrogen availability could be due to the dilution effect of oil in heavier seeds produced under higher nitrogen. An increase in nitrogen levels promotes protein and starch contents in the seed, which dilute the percent oil content (Sharma *et al.* 2007). Similar, result was reported by Tanwar *et al*. (2011) who obtained the highest oil content from lowest dose of nitrogen levels. Nykter and Kymäläinen, (2006) also reported that the linseed oil content ranged from 26-45%. With regard to varieties, the lowest (35.8 %) and the highest (36.7%) oil content were recorded from Kulumsa-1 and Bokoji-14 varieties, respectively. Linseed has high oil content (20-40%) depending on the varieties (Pali and Mehta, 2014).

Table 5. Main effect of nitrogen fertilizer levels and linseed varieties on percent oil content and seed oil yield of linseed at Wolmera district in 2017 cropping season

Treatment	Seed oil content (%)	Seed oil yield (Lt ha^{-1})
Varieties		
Bokoji-14	36.7	517.9^{b}
Jeldu	36.4	579.7^{a}
Kulumsa-1	35.8	481.3^{c}
LSD (5%)	NS	34.9
N (kg/ha)		
0	36.5^{a}	445.8^{d}
11.5	36.0^{ab}	469.6^{cd}
23	35.9^{b}	509.7^{c}
34.5	35.6^{bc}	561.1^{b}
46	35.2^{c}	604.4^{a}
LSD (5%)	0.6	37.6
CV (%)	1.7	9.1

Means in the columns followed by the same letter are not significantly different at $p < 0.05$ levels

Seed oil yield

The oil yield of linseed was significantly ($P<0.01$) influenced by the main effect of nitrogen and varieties, however it was not significantly affected by their interaction (Table 5). An increase in the levels of nitrogen fertilizer significantly increased the seed oil yield. The maximum (604 Lt ha^{-1}) and minimum (446 Lt ha^{-1}) seed oil yields of linseed were obtained from 46 kg N ha^{-1} and control treatments, respectively. The oil yield obtained from 46 kg N ha^{-1} treatment exceeds by 35.6% over the control. This result agreed with Ozer *et al.* (2004) and Aglave *et al.* (2009) who found increased seed oil yield in response to increasing rate of nitrogen. Cheema *et al.* (2001) and Poonia (2003) also reported the role of nitrogen fertilizer to enhance the seed and oil yields of linseed. In the case of varieties the maximum oil yield (580 Lt ha^{-1}) and the minimum oil yield (481 Lt ha^{-1}) of linseed were obtained from Jeldu and Kulumsa-1 varieties, respectively (Table 5). This showed the existence of genetic variability among varieties in their seed oil yield.

Effect of Nitrogen Fertilizer Levels on Fatty Acid Composition of Linseed Varieties

Palmitic and Stearic fatty acids composition

The analysis of variance showed that the palmitic fatty acid composition of linseed was significantly ($P<0.01$) influenced only by the main effect of varieties, however it was not affected by nitrogen fertilizer level and main factors interaction (Table 6). The maximum (6.1 %) and minimum (5.6 %) percent of palmitic fatty acid composition of linseed were obtained from Jeldu and Kulumsa-1 varieties, respectively. This difference in palmitic fatty acid could be due to the genetic variability of varieties. This is in agreement with Pali and Mehta (2014) who reported the range of palmitic fatty acid in linseed (5.0 - 9.9 %).

The stearic fatty acid composition of linseed was not influenced by the main effect of nitrogen and varieties, as well as by their interaction (Table 6). Increasing the amount of nitrogen from zero to 46 kg ha^{-1} increased the percent stearic fatty acid composition of linseed numerically but it was not statistically significant. Similarly, Gambus *et al.* (2003) reported that linseed oil contains from 4 to 5.4% stearic acid. Pali and Mehta (2014) also stated that stearic acid of linseed ranged from 1.3-7.6 % depending of varieties and soil fertility. Hence, the result of this study is in line with the range of stearic fatty acids of other studies.

Oleic (C18:1) fatty acid composition

The oleic fatty acid composition of linseed was significantly (P<0.05) affected by the main factor of varieties and nitrogen fertilizer level, however not affected by their interaction (Table 6). The highest (19.6 %) and the lowest (18.6 %) percent of oleic fatty acid composition of linseed were obtained from Jeldu and Bokoji-14 varieties, respectively. The varietal difference in oleic fatty acid composition could be due to their inherent characteristics. Pali and Mehta, (2014) also reported that the oleic fatty acid content in linseed genotypes differ and ranged from 13.3 - 35%. As nitrogen level increased from zero to the highest level, it increased percent of oleic fatty acid significantly (Table 6). Accordingly, oleic fatty acid obtained from 46 kg Nha^{-1} was statistically comparable with 23 and 34.5 kg N ha^{-1}, and significantly superior from the control treatment. This result is in agreement with Klimek *et al.,* (2013) who reported that increasing the levels of mineral fertilizer increased the content of oleic fatty acids. Linseed oil contains approximately 15-21% oleic acid (Hume, 1982).

Table 6. Main effect of nitrogen fertilizer levels and varieties on fatty acid composition of linseed at Wolmera district in 2017 cropping season

Treatment	Fatty acids (%)				
	Unsaturated fatty acid		Saturated fatty acid		
	Palmitic	Stearic	Oleic	Linoleic	Linoliniec
Varieties					
Bokoji-14	5.8^{b}	4.8	18.6^{b}	14.2	56.2
Jeldu	6.1^{a}	4.9	19.6^{a}	14.2	55.6
Kulumsa-1	5.6^{b}	4.9	18.7^{b}	14.3	55.8
LSD (5%)	0.2	NS	0.6	NS	NS
N (kg/ha)					
0	5.93	4.83	18.48^{b}	14.12^{b}	55.49
11.5	5.92	4.84	18.57^{b}	14.17^{ab}	55.64
23	5.92	4.87	19.02^{ab}	14.26^{ab}	55.79
34.5	5.86	4.88	19.22^{ab}	14.32^{ab}	56.12
46	5.82	4.89	19.43^{a}	14.37^{a}	56.24
LSD (5%)	NS	NS	0.8	0.23	NS
CV (%)	3.5	3.0	4.4	1.7	1.8

Means in columns followed by the same letter are not significantly different at $p < 0.05$ levels

Linoleic (C18:2) and Linolineic (C18:3) fatty acids composition

The analysis of variance indicated that percent of linoleic fatty acid composition of linseed was significantly (P<0.05) influenced by the main effect of nitrogen, while varieties and the interaction of main factors didn't affected linoleic fatty acid composition (Table 6). As the level of nitrogen fertilizer increased from 11.5 to 46 kg ha^{-1} the percent of linoleic fatty acid did not showed significant differences (Table 6). However, the highest (14.37%) and the lowest (14.12%) linoleic fatty acid compositions were recorded from 46 kg ha^{-1} and control treatments, respectively. An increase in nitrogen fertilizer per plant and unit area leads to increases in the amounts of linoleic acids (Abramovic and Abram, 2005). The result of this study was in agreement with Hosseinian (2004) who reported that the content of linoleic fatty acid of linseed ranged from 11.18 - 16.13%. Similarly,Pali and Mehta (2014) reported that the values of linoleic acids ranged 10.4 - 20.9 % for linseed.

The linolineic fatty acid composition of linseed was not significantly influenced by the main factors of varieties and nitrogen fertilizer levels and their interaction (Table 6). In this study the content of linolineic fatty acid composition ranged from 55.49 to 56.24 %, and it was at optimal range. Similarly, Pali and Mehta (2014) reported that the values of alpha-linolenic acids in linseed range (33.1 to 63.1%).

The Relationship between Oil Yield with Seed Yield and Fatty Acid Composition

Seed oil yield had highly significant positive correlation with seed yield (0.99**), palmitic fatty acid (0.56**), stearic fatty acid (0.44**), and oleic fatty acid (0.62**) (Table 7). Hence, oil yield of linseed can be enhanced through improvement of seed yield, and this also contributes to improve the fatty acids components. However, positive correlation was not established between seed yield and oil content of the seed. The negative correlation between seed yield and seed oil content observed in this study could be the decrease in seed oil content as seed yield increased with application of nitrogen fertilizer.

Table 7. Linear correlation coefficients (r) among yield and percent oil content and fatty acid related traits of linseed.

	SY	OC	OY	PA	SA	OA	LA
SY	1						
OC	-0.26*	1					
OY	0.99**	-0.18ns	1				
PA	0.52**	0.32*	0.56*	1			
SA	0.4**	0.48**	0.44**	0.82**	1		
OA	0.6**	0.12ns	0.62**	0.76**	0.76**	1	
LA	0.29**	-0.07ns	0.29**	0.24*	0.17ns	0.33**	1
LNA	-0.4**	-0.47**	-0.45**	-0.75**	-0.87**	1-081	-0.32**

Where, SY= Seed yield ha^{-1}; OC= percent oil content; OY= seed oil yield ha^{-1}; PA= Palmitic fatty acid; SA= Stearic fatty acid; OA = Oleic fatty acid; LA= Linoleic fatty acid; LNA=Linoliniec fatty acid.

Effects of Nitrogen Fertilizer levels on Economic Feasibility for Linseed Production

The partial budget analysis indicated that the highest net benefit ETB 36865 ha^{-1} with marginal rate return 1738% was recorded from treatment that received 46 kg N ha^{-1} (Table 8). While the lowest net economic return ETB 23890 ha^{-1} was recorded from no nitrogen fertilizer application (Table 8). Therefore, application of 46 kg N ha^{-1} was more profitable than the rest of treatment combinations on farmer field for linseed crop production.

Table 8. Partial budget analysis of different nitrogen levels and linseed varieties under on farm condition

Nitrogen (kg ha^{-1})	Average Seed Yield (kg ha^{-1})	Adjusted Seed yield (kg ha^{-1})	Gross Benefit (ETB ha^{-1})	Total Variable cost (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	MRR (%)
0	885	796	23890	0	23890	0
11.5	1045	940	28210	799	27463	447
23	1130	1017	30520	1436	29187	271
34.5	1109	998	29940	1582	28365D	-
46	1427	1284	38530	2071	36865	1738

Cost of linseed grain = 30ETB kg^{-1}, Urea = 10.9 ETB kg^{-1}, TSP = 13.9 ETB kg^{-1}, Man-day= 32 ETB

Conclusion and recommendation

This experiment has clearly demonstrated that nitrogen had significant effects on seed yield, oil content and fatty acid composition of linseed varieties. The optimum oil yield and percent of fatty acid compositions were obtained in response to application of 46 kg ha^{-1} nitrogen in the study area. The maximum seed (1508 kg ha^{-1}) and oil (604.4 Lt ha^{-1}) yields were recorded from 46 kg N ha^{-1} with Jeldu variety. The fatty acid composition of linseed oil had high level of unsaturated fatty acid such as linolenic (56.24%), oleic (19.43%) and linoleic (14.37%) fatty acids from 46 kg N ha^{-1}, while the saturated fatty acids like palmitiec (5.82 %) and stearic (4.89%) were also to the optimal range. Therefore, based on this study Jeldu variety with 46 kg N ha^{-1} gave high seed and oil yields, and oil quality, thus it can be recommended to the study area and other similar agro-ecology.

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