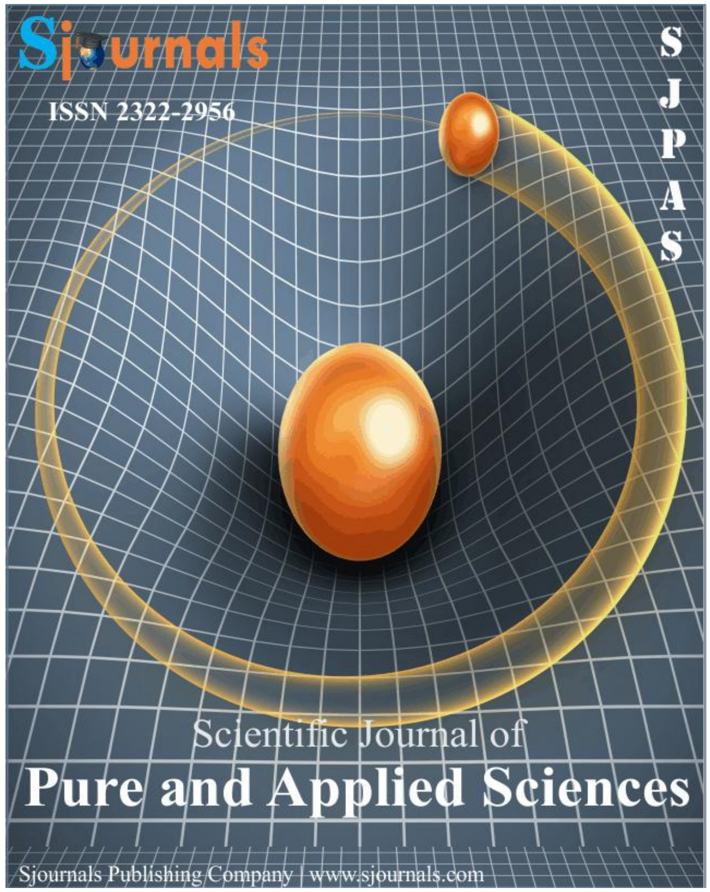
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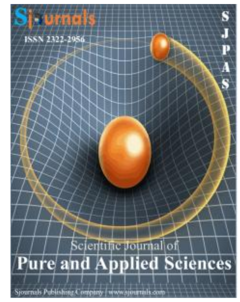

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Original article

Effect of nitrogen and sulphur fertilizer levels on growth, yield and oil content of Linseed (*Linum usitatissimum* L.) in Sinana, South-Eastern Ethiopia

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The experiment was conducted on research field of Sinana Agricultural Research Center (SARC), in the highlands of Bale, South-eastern Ethiopia during the main cropping season of 2013 to investigate the effect of nitrogen and sulphur on growth, yield and oil content of linseed. A factorial combination of four rates of N (0, 23, 46, 69 kg ha^{-1}) with four rates of S (0, 20, 40 and 60 kg ha^{-1}) was applied in randomized complete block in three replications. Analysis of variance revealed that the main effect of nitrogen significantly affected all tested parameters except for days to 50% emergence, number of seeds per capsule and stand count per meter square. In these study, most of yield and yield components of the crop lacked significant response to the application of sulphur. This might be due to the fact that sulphur content of the soil of the study site was medium. On the other hand, the interaction effect between nitrogen and sulphur was only significant for days to 50% emergence. Linseed crop grown without nitrogen application exhibited the highest seed oil content (40.7%). The economic analysis revealed that the highest net return of Birr 31980 ha^{-1} and the highest marginal rate of return 5045.21% were obtained from the treatment that received 23 kg N ha^{-1}. Therefore, for farmers cultivating linseed in Sinana and areas with the same soil chemical and physical conditions, application of 23 kg N ha^{-1} is sufficient for obtaining optimum seed and oil yield of the crop, with no need to apply sulphur as a fertilizer. However, to come up with a conclusive recommendation, the experiment should be repeated over seasons and locations.

1. Introduction

Oilseed crops can be grown in all parts of the country and are currently contributing a larger share to the agrarian economy of Ethiopia. Linseed (*Linum usitatissimum* L.) has been a traditional crop in Ethiopia and it is the second most important oilseed crop in the higher altitudes (Adugna and Adefris, 1995). Ethiopia is the secondary centre of diversity, and the 5th major producer of linseed in the world after Canada, China, United States, and India (Adugna, 2007). In Ethiopia, linseed has been cultivated for two primary purposes, seed and oil use. It has traditionally been used for food and as a cash crop since ancient times. It is now grown primarily for food and to generate revenue, either in local markets or by export. The pressed cake, after the extraction of oil is a good protein rich livestock feed. The oil is also used as a raw material for a number of industrial products, such as drying agents, paintings and varnishes, soap manufacture, printing inks etc.

The Bale highlands are one of the potential areas for the production of highland oil crops in Ethiopia, and linseed is the main oil crop grown in the zone. The crop is grown mainly in rotation with major cereals. Linseed is a crop used by local food oil processors, is the second profitable crop following wheat. Despite its potential and profitability, the crop has been traditionally grown on marginal lands with or without fertilizers. Increasing linseed yield as well as oil yield requires optimum balanced nutrition including sulphur, which is a key nutrient for linseed oil quality (Franzen, 2004).

Both nitrogen and sulphur are vital constituents of plant proteins and are closely associated in the synthesis and play a key role in plant oil production. Application of nitrogen in the absence of sufficient sulphur leads to the production of amino acids that are not incorporated into proteins, and plants synthesize the required amounts of sulphur-containing amino acids when sulphur is applied (Finlayson et al., 1970). Sulphur is best known for its role in the formation of amino acids methionine (21% S) and cysteine (27% S); synthesis of proteins and chlorophyll; and oil content of the seeds. When soils are deficient in available sulphur, growth of all crops is drastically reduced. While nitrogen directly affects the photosynthesis efficiency of plants, sulphur affects the photosynthesis efficiency indirectly by improving the nitrogen use efficiency of the plants, as it is evident from the relationship between nitrogen content and photosynthetic rate in the leaves of with sulphur and without sulphur treated Brassica plants (Ahmad and Abdin, 2000).

The deficiency of S has been reported with increasing frequency in the past several years over the entire world due to introduction of high yielding varieties, use of high grade S free fertilizers, declining use of S containing fungicides and reduced emission of S from industrial units (Scherer, 2001). Oilseeds are more sensitive to sulphur deficiency and more responsive to sulphur fertilization than legumes and cereals due to their higher requirements for the nutrient (Marschner, 1995). The amount of N fertilizer used in the country has been increasing. However, this increase in N use has not been accompanied by increase in the use of nutrients like sulphur which has been found to be sub-optimal and deficient in most of the soils investigated so far (Itanna, 2005). The shortage of sulphur supplies to crops decreases their NUE from fertilizers. This is due to the fact that sulphur is an important nutrient for plant growth and its uptake by plants accounts 9 to 15% of N uptake (Inal et al., 2003).

Studies elsewhere by different researchers regarding the influence of nitrogen and sulphur on seed and oil production show that the interaction between nitrogen and sulphur metabolism is stronger and their combined effects on oil crops could be synergistic (Fazli et al., 2008). However, in Sinana, research regarding sulphur and its effect when applied with nitrogen on growth, yield and oil content of linseed is absent and only little attention has been paid towards investigating the response of nitrogen and phosphorus. Keeping in view the importance of N and S, the present study was aimed at evaluating different N and S rates and their interactions on growth, yield and oil content of linseed in Sinana, highlands of Bale, south-eastern Ethiopia.

2. Materials and methods

2.1. Experimental site

The experiment was conducted on research field of Sinana Agricultural Research Center in the highlands of Bale, South-eastern Ethiopia during the main cropping season of 2013. Sinana is located at a distance of 463 km from Addis Ababa at about $7^0$07'N latitude, $40^0$10'E longitude, and at an altitude of about 2400 meters above sea level. The area is characterized by a bimodal rainfall pattern. There are two growing seasons locally called '*Bona'* and '*Gana'* based on the time of crop harvest. *Bona* extends from August to December and *Gana* from March to July.

2.2. Treatments and experimental design

The treatments consisted of four rates of nitrogen (0, 23, 46, and 69 kg N ha^{-1}) and four rates of sulphur (0, 20, 40, and 60 kg S ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement replicated three times. The field layout was prepared and the treatments were assigned to each experimental plot randomly within a block. Each plot consisted of 4-metre long 10 rows spaced 20cm apart. The size of each plot was 4.0m x 2.0m ($8m^2$). Adjacent replications, blocks, and plots were separated by a 1.5m, 1m, and 1m, distances, respectively. The net central unit area of each plot consisted of 6 rows for sample measurements, leaving aside plants in the four outer rows and those at both ends of each of the rows to avoid border effects. The linseed variety used for the study was *Jiituu* (CI-1652 x Omega/B/53), which was released by Sinana Agricultural Research Centre in 2012. Urea was used as a source of N fertilizer and gypsum as S fertilizer. A uniform rate of 23 kg P_2O_5 ha^{-1} was also applied uniformly for all plots as a basal.

2.3. Experimental procedures

2.3.1. Field activities and treatment application

All field activities were carried out following the standard production practices. Linseed seed was sown into rows at the recommended rate of 25 kg ha^{-1} on the prepared fine seedbed on August 09, 2013. Nitrogen fertilizer in the form of urea was applied at the specified rates in two equal parts, *i.e.*, half was applied at sowing and the remaining half was top-dressed just at the start of flowering stage. Sulphur was applied in the form of gypsum ($CaSO_4.2H_2O$) at the specified rates at sowing. The full dose of P was applied uniformly to all plots at the recommended rate of 23 kg P_2O_5 ha^{-1} at sowing.

2.3.2. Soil sampling and analysis

One composite soil sample per replication, each made from five sub-samples, was collected from the depth of 0-30 cm before planting. The samples were air-dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve. The samples were analyzed for selected physico-chemical properties mainly organic carbon, total nitrogen, available sulphur, available P, exchangeable bases (Na, K, Ca and Mg), cation exchange capacity (CEC), pH, bulk density and particle size distribution, using standard laboratory procedures. Samples were also collected from experimental field in each treatment. The samples from the plots with the same treatment were bulked and analyzed for total N and available S.

Organic carbon content was determined by the volumetric method (Walkley and Black, 1934). Total nitrogen was analyzed and determined by the Micro-Kjeldahl digestion method with sulphuric acid (Jackson, 1962). Sulphur was analyzed by turbidimetric method (Ajwa and Tabatabai, 1993). Available phosphorus was determined by the Olsen method (Olsen et al., 1954). The exchangeable bases, Ca^{++} and Mg^{++} values were found from Atomic Absorption Spectrophotometer reading, whereas Na^+ and K^+ were determined using flame photometer. Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Chapman, 1965). The pH of the soil was determined at 1:2 (weight/volume) soil samples to water ratio using a pH meter (Motsara and Roy, 2008). Soil bulk density was determined by core sampler method and Particle size distribution was done by the hydrometer method using particles less than 2 mm diameter. The procedure measures percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm) and clay (<0.002 mm) fractions in soils (Hazelton and Murphy, 2007).

2.3.3. Statistical analysis

All data were subjected to analysis of variance (ANOVA) using GENSTAT computer software (GenStat, 2012.Version 15.1.0.8035) to identify main effects and interactions in response to nitrogen and sulphur fertilizer levels. Differences among means were determined using the least significant difference (LSD) test at the 0.05 level of significance.

3. Results and discussion

3.1. Soil pysico-chemical properties

The results of soil analysis which were done before sowing of linseed are presented in Table 1. The results indicated that texture of the soil of the study area is dominated by clay in texture, 1.02 gcm^{-3} in bulk density, low in pH, very high in CEC, medium in OC, medium levels of available sulphur and phosphorus, high Ca, very high exchangeable K, Mg, and Na.

Table 1

Selected physic-chemical properties of the experimental soil before planting.

Parameter	Method	Unit	Value
pH	Potentiometric	1:2.5	6.73
Na^+	Neutral Ammonium acetate-Flame photometry	cmol(+) kg^{-1}	4.20
K^+	Neutral Ammonium acetate-Flame photometry	cmol(+)kg^{-1}	2.82
Mg^+	Atomic Absorption Spectrophotometer	cmol (+)kg^{-1}	8.1
Ca^+	Atomic Absorption Spectrophotometer	cmol (+)kg^{-1}	17.8
CEC	Neutral Ammonium acetate -Ammonia distillation	cmol(+)kg^{-1}	48.56
Tot. N	KjeldahlBremmer, J.M. and C.S. Mulvancy, 1982	%	0.17
Av. S	Monocalcium phosphate extract-Turbidimetry	mg kg^{-1}	22.17
Av. P	Olsen method	ppm	10.12
OC	Walkley, A., and Black, I.A. 1934	%	2.77
Bulk density	Core sampler method	gcm^{-3}	1.02
Texture	Hydrometer	%	Sand= 26
			Silt= 23
			Clay= 53
		Textural class	Clay

3.1.1. Total nitrogen and available sulphur contents of the soil after harvest

Soil total nitrogen and available sulphur contents were analyzed for composited soil samples from each treatment to assess the post harvest status of the soil. Total nitrogen values did not show wide variation due to different treatment combinations. The total nitrogen content of the soil before planting was 0.17% and after planting it varied from 0.16 to 0.18%. The N accumulation in seed and straw of the crop to some extent may be responsible for such a decline in nitrogen content of the soil. Although soil analysis after harvest showed inconsistent results, higher rates of sulphur application resulted in more available soil sulphur content. However, the values were lower than those recorded before planting (Table 2). This may be attributed to increased plant uptake and, thus, concentration of sulphur in the crop.

Table 2

Effect of nitrogen and sulphur on total nitrogen and available sulphur of the soil.

N levels (kg ha^{-1})	Total nitrogen (%) S levels (kg ha^{-1}) 0	20	40	60	Mean	Available sulphur (mg kg^{-1}) S levels (kg ha^{-1}) 0	20	40	60	Mean
0	0.17	0.16	0.16	0.17	0.165	8.87	11.08	8.87	22.17	12.75
23	0.17	0.18	0.17	0.17	0.173	7.76	6.1	16.62	6.65	9.28
46	0.17	0.18	0.16	0.17	0.170	4.43	9.98	8.87	18.84	10.53
69	0.16	0.18	0.17	0.17	0.170	6.10	8.87	7.76	12.19	8.73
Mean	0.168	0.175	0.165	0.170		6.79	9.00	10.53	14.96	

3.2. Effect on crop phenology

3.2.1. Days to emergence

The results of the analysis of variance showed that the main effect of nitrogen had no significant influence on days to 50% emergence, whereas sulphur had a significant ($P<0.05$) influence on this parameter. The two factors also interacted to influence this parameter significantly ($P<0.05$). Increasing the rate of sulphur application generally prolonged the days required for the seedlings to emerge with increasing rates of nitrogen, although the trend was not consistent. Thus, plants treated with the highest rates of sulphur and nitrogen generally required the maximum number of days to emerge from the soil.

3.2.2. Days to 50% flowering

The main effects of nitrogen and sulphur significantly ($P<0.05$) influenced days to 50% flowering, which was not affected by the interaction of the two factors. Increasing the rate of nitrogen from nil to 23 and 46 kg ha^{-1} did not affect the number of days required by the plant to reach 50% flowering. However, increasing the rate of the fertilizer from nil to 69 kg ha^{-1} significantly prolonged the days to 50% flowering.

3.2.3. Days to 50% boll formation

The main effect of nitrogen had a significant ($P<0.05$) influence on days to 50% boll formation. However, the main effect of sulphur as well as the interaction of nitrogen and sulphur did not influence the values of this parameter. The number of days required for boll formation was unaffected by the increase in the rate of nitrogen from nil to 23 kg N ha^{-1}. However, when the rate of N was increased from nil further to 46 and 69 kg N ha^{-1}, the number of days required for 50% boll formation was significantly prolonged.

3.2.4. Days to 90% physiological maturity

The main effect of nitrogen significantly ($P<0.05$) influenced the number of days required to reach physiological maturity. However, the main effect of sulphur and the interaction effects of nitrogen and sulphur did not affect this parameter. Increasing the rate of nitrogen significantly prolonged the duration required to reach physiological maturity. Thus, plants with no application of the fertilizer required the lowest number of days to reach physiological maturity, whereas those treated required the longest durations to reach physiological maturity (Table 3). The increased number of days required to reach physiological maturity in response to increased rates of nitrogen fertilizer may be attributed to the enhanced availability of the nutrient in the soil and its increased uptake by the linseed plants, which may have resulted in a more luxurious vegetative growth that might have resulted in delayed maturity. Kutcher et al. (2005) have also found delayed maturity in response to increasing rate of nitrogen in canola.

3.3. Effect on growth parameters

3.3.1. Plant height

The main effect of nitrogen significantly ($P<0.01$) influenced plant height, which was not affected by effect of sulphur as well as by the interaction between nitrogen and sulphur. Increasing the rate of nitrogen from nil to 69 kg N ha^{-1} significantly increased plant height. Accordingly, the shortest linseed plants were recorded for the treatment that received no nitrogen, whereas the tallest plants were recorded from the treatments of 69 kg N ha^{-1}. The increase in plant height with the increase in the rate of nitrogen may be attributed to enhanced vegetative growth. Similar result have been observed by Sharief et al. (2005) who reported that plant height of flax cultivars significantly increased in response to increasing rate of nitrogen fertilizer application.

3.3.2. Number of tillers per plant

The number of tillers per plant was significantly ($P\leq0.05$) affected by either nitrogen or sulphur application. However, the two fertilizers did not interact to influence this parameter. Increasing the rate of nitrogen from nil to 23 kg ha^{-1} decreased the number of tillers per plant, but further increasing the rate of the fertilizer from 23 kg ha^{-1} to 69 kg ha^{-1} increased the number of tillers per plant significantly (Table 4).

Table 3
Effect of nitrogen and sulphur fertilizers on phenological parameters of linseed.

	Days to 50% flowering	Days to 50% boll formation	Days to 90% maturity
Nitrogen (kg ha^{-1})			
0	79.83^{b}	86.67^{b}	115.25^{b}
23	80.42^{ab}	88.42^{b}	116.50^{a}
46	80.50^{ab}	91.75^{a}	116.65^{ab}
69	81.33^{a}	94.42^{a}	117.57^{a}
SEm$\pm$	0.32	0.994	0.59
$LSD_{0.05}$	0.92	2.9	1.7
Sulphur (kg ha^{-1})			
0	79.67^{b}	88.83	114.75
20	80.42^{ab}	90.25	114.92
40	81.25^{a}	91.33	115.42
60	80.75^{a}	90.83	115.5
SEm$\pm$	0.32	0.994	0.588
$LSD_{0.05}$	0.92	ns	ns
CV (%)	1.4	3.8	1.8

Means in a column with the same letter are not significantly different at 5% probability level; SEm±=Standard error of means; LSD=Least significance difference at 5% probability level; ns = Not significant; CV=Coefficient of variation.

3.3.3. Number of primary branches per plant

The main effect of nitrogen was significant (P<0.01) for number of primary branches produced per plant. However, neither the main effect of sulphur nor the interaction effect of nitrogen and sulphur influenced this parameter. The number of primary branches significantly increased with the increase in nitrogen rate from nil to 23 and 46 kg ha^{-1}. However, when the rate of nitrogen was increased from nil to 69 kg N ha^{-1}, the number of primary branches remained unchanged (Table 4).

3.3.4. Number of secondary branches per plant

Similar to the case with number of primary branches, a significant (P<0.01) main effect of nitrogen was observed, whereas the effect of sulphur as well as the interaction between nitrogen and sulphur was not significant for number of secondary branches per plant. When the rate of nitrogen increased from nil to 23 kg ha^{-1}, the number of primary branches was unaffected. However, when the rate of the fertilizer increased from nil to 46 and 69 kg ha^{-1}, the number of primary branches significantly increased (Table 4). The observed increase in the number of secondary branches of the plant in response to the increasing rate of nitrogen might be attributed to enhanced production of photosynthetic assimilates from increased photosynthetic rate.

3.4. Effect on yield components and yield

3.4.1. Stand count at harvest

Plant density is one of the most important factors on which grain yield and other yield contributing attributes of crops are dependent. The analysis of variance revealed that the number of plants per meter square was unaffected by the main effects of both nitrogen and sulphur as well as by their interaction. This indicates that each treatment had no significant influence on emergence of the seeds from the soil and survival rates of the seedlings. These results confirm the findings of Nazir (1998), who reported no significant differences in plant population per square meter in response to different rates of fertilizers.

3.4.2. Number of capsules per plant

The number of capsules per plant is an important character, which directly influences the seed yield. The analysis of variance showed that the number of capsules per plant was significantly affected by the main effects of nitrogen ($P\leq0.01$) and sulphur. Increasing the rate of nitrogen from nil to 23 kg ha^{-1} did not change the number of capsules per plant. However, increasing the rate of nitrogen further from 23 to 46 and 69 kg ha^{-1} significantly increased the number of capsules per plant. This result agrees with the findings of Sharief et al. (2005) who have reported that nitrogen application significantly increased the number of capsules per plant of flax.

Increasing the rate of sulphur from nil to 20 kg ha^{-1} did not affect the number of capsules per plant. However, increasing the rate of the fertilizer from 20 to 40 kg S ha^{-1} significantly increased the number of capsules per plant with further increases to 60 kg ha^{-1} the value decreased (Table 5). Possible reason for the decrease may be due to nutritional imbalance caused by highest level of sulphur, i.e., 60 kg ha^{-1}.

Table 4
Effect of nitrogen and sulphur application on growth parameters of linseed.

	Tiller number per plant	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant
Nitrogen (kg ha^{-1})				
0	3.617^{b}	95.1^{c}	5.483^{b}	5.567^{c}
23	3.567^{b}	100.8^{b}	5.908^{a}	6.750^{bc}
46	4.067^{ab}	101.5^{ab}	6.092^{a}	7.333^{ab}
69	4.3^{a}	105.2^{a}	5.483^{b}	8.483^{a}
SEM$\pm$	0.1763	1.338	0.1342	0.564
$LSD_{0.05}$	0.5092	3.864	0.3877	1.628
Sulphur (kg ha^{-1})				
0	3.733^{b}	101.06	5.825	6.63
20	3.925^{ab}	100.07	5.892	6.62
40	4.292^{a}	102.22	6.175	8.22
60	3.6^{b}	99.31	5.833	6.67
SEM$\pm$	0.1763	1.338	0.1342	0.564
$LSD_{0.05}$	0.5092	ns	ns	ns
CV (%)	15.7	4.6	7.8	27.8

3.4.3. Number of seeds per capsule

The analysis of variance showed that neither the main effects of nitrogen and sulphur nor their interactions caused any significant difference in the number of seeds per capsule. Non significant effects on number of seeds per capsule may be more attributed to genetic factors in effects of genetic factors in controlling of this trait rather than environmental and management factors.

3.4.4. Biological yield

The analysis of variance showed a non significant difference due to the main effect of sulphur and its interaction with nitrogen for biological yield. However, biological yield was significantly ($P \leq 0.01$) affected by the main effect of nitrogen. The maximum biological yield was obtained at 69 kg N ha^{-1}, which exceeded the biological yield produced by plants in the control treatment by about 32.2% (Table 6). These results are in agreement with the findings of Leleu (2000) who observed that plant height, number of leaves, leaf area, fresh and dry weight of shoot and number of flowers of canola increased in response to the increasing rate of N application.

3.4.5. Seed yield

The main effect of nitrogen was significant ($P<0.05$) for seed yield of the crop. However, neither sulphur alone nor its interaction with nitrogen influenced seed yield (Appendix Table 7). Increasing the rate of nitrogen from nil to 23 kg ha^{-1} significantly increased seed yield. However, increasing the rate of the fertilizer further to the higher rates did not affect seed yield. Hence that the optimum seed yield was obtained at 23 kg N ha^{-1} and increasing the rate of the fertilizer beyond this level was not beneficial for the crop in terms of seed yield (Table 4). Accordingly, the seed yield obtained at 23 kg N ha^{-1} exceeded that of the control plot by about 17.3%. Lack of significant response beyond 23 kg N ha^{-1} could be attributed to the phenomenon that excess nitrogen leads to vegetative growth at the expense of reproductive growth.

Nevertheless, the linseed yield obtained in response to application of 69 kg N ha^{-1} was by 21% more than the yield obtained from the central treatment. Consistent with the results of this study, Freer (1993) has reported that the N requirement of linseed was less than that of the other crops. This result was also in agreement with the finding of Lafond (1993) who has reported a limited response of linseed to the application of high rates of nitrogen.

3.4.6. Harvest Index

Application of nitrogen significantly (P<0.01) influenced harvest index. However, sulphur alone as well as its interaction with nitrogen did not affect this parameter. Increasing the rate of nitrogen from nil to 46 kg ha^{-1} did not affect harvest index. However, increasing the rate of the fertilizer further from 46 to 69 kg ha^{-1} significantly reduced harvest index. Accordingly, the highest harvest index values were obtained at nil, 23, and 46 kg N ha^{-1}, whereas the lowest was obtained at 69 kg N ha^{-1} (Table 5). The decrease in harvest index with the higher nitrogen application might be due to changing the stability between vegetative and reproductive growth towards unnecessary vegetative growth, and hence reduced seed fill (Hocking et al., 1987).

3.4.7. Thousand seed weight

In this study, the main effect of nitrogen significantly influenced thousand seed weight (P≤0.01). However, neither Application of sulphur alone nor its interaction with nitrogen affected this parameter. Generally, increasing the rate of nitrogen significantly decreased thousand seed weight of the crop. Thus, the maximum mean value of thousand seeds weight was obtained from plants grown without nitrogen application, whereas the minimum was obtained from plants grown at the highest rate of nitrogen (Table 5).

Reduction in seed weight with increasing rates of N is probably the result of insufficient supply of carbohydrates to individual capsules due to strong competition, due to vigorous growth of the plants and increased number of capsule. This effect further resulted in poor dry matter accumulation in the capsules and, thus, in the seeds of linseed. This result was in agreement with the findings of Hocking and Pinkerton (1991), who reported that N deficiency had no significant effect on thousand seed weight or on the number of seeds per capsule of linseed. However, the result was in contrast to that of Sharief (1999), who reported that thousand seed weight of flax (linseed) increased with increasing nitrogen levels.

Table 5
Effect of nitrogen and sulphur application on yield and yield components.

Treatment	Stand count ha^{-1}	No. of capsules plant^{-1}	No. of seeds Capsule^{-1}	Thousand seed weight (g)	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	Percent oil content (%)
Nitrogen (kg ha^{-1})								
0	2070833	48.25^{b}	8.59	6.308^{a}	7535^{c}	1706^{b}	23.02^{a}	40.66^{a}
23	2029167	55.85^{b}	8.78	6.258^{ab}	9757^{ab}	2062^{a}	21.46^{a}	39.64^{b}
46	1937500	70.99^{a}	8.87	6.208^{b}	9670b	2052^{a}	21.89^{a}	40.31^{a}
69	1804167	73.87^{a}	8.87	6.083^{c}	11111^{a}	2152^{a}	18.47^{b}	39.47^{b}
SEM±	280658.8	4.17	0.096	0.0317	471.16	92.22	0.75	0.2
$LSD_{0.05}$	ns	12.05	ns	0.0915	1362.10	266.35	2.18	1.18
Sulphur (kg ha^{-1})								
0	2325000	58.04^{b}	8.69	6.207	9479.2	1942.6	21.1	39.9
20	1820833	59.06^{b}	8.77	6.200	9357.6	1918.7	21.0	40.2
40	1787500	73.43^{a}	8.82	6.208	9531.3	2012.9	21.4	39.8
60	280658.8	58.43^{b}	8.82	6.233	9704.9	2020.2	21.4	40.1
SEm±	396911.5	4.17	0.096	0.0317	471.61	92.22	0.75	0.2
$LSD_{0.05}$	ns	12.05	ns	ns	ns	ns	ns	ns
CV (%)	29.8	23.2	3.8	1.8	17.2	16.1	12.3	

Means in a column sharing the same letter (s) are not significantly different at 5% probability level; SEm±=Standard error of means; ns=non-significant; LSD=Least significance difference at 5% probability levels; ns = Not significant; CV=Coefficient of variation.

3.4.8. Percent seed oil content

Application of nitrogen significantly ($P \leq 0.01$) influenced percent seed oil content, whereas the main effect of sulphur and its interaction with nitrogen was not significant. Generally, the effect of nitrogen on seed oil content was not consistent with significantly higher values obtained at nil and 46 kg N ha^{-1} and the lowest at 23 and 69 kg N ha^{-1} (Table 5). Linseed crop grown without nitrogen application exhibited the highest seed oil content (40.7%). This result agrees with the findings of Agegnehu and Honermeier (1997), who reported that increasing N application rate from 0 to 120 kg ha^{-1} at a seed rate of 400 seeds m^{-2}, decreased the oil content of false flax from 41 to 39%. Several other authors have also reported negative influences of N on linseed oil concentration. This might be attributed to greater accumulation of protein in plants due to increased availability of nitrogen that reduced availability of carbohydrates for polymerization into fatty acids, which, in turn, lowered the oil content of the seeds. This means that protein and oil contents are inversely related in linseed.

Differences in percent seed oil content due to sulphur treatment and its interaction with nitrogen were not statistically significant. Sulphur fertilization may be needed to optimize yields of crop plants which grow on sulphur deficient soils (Spencer, 1975). Several other studies on sulphur fertilization of oilseed crops have also shown increases in both yield and oil contents of seeds. However, in the present study, sulphur fertilization did not significantly affect oil content of the seeds. However, in contrast to N, sulphur application tended to increase percent oil content of the seed (Table 5). This might be due to the fact that sulphur content of the soil of the study site was medium. But, further testing is required to substantiate this finding.

Table 6
Partial budget and dominance analysis of nitrogen and sulphur treatments.

N (kg N ha^{-1})	S (kg S ha^{-1})	Average grain yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Gross field benefits (kg ha^{-1})	Costs that vary (Birr ha^{-1})			Net benefits (Birr ha^{-1})	Dominance
					Fertilizer	Labour	Total cost		
0	0	1670	1419	24131	0	0	0	24132	
0	20	1765.2	1500	25507	372.96	56.04	429	25078	
23	0	2073.3	1762	29959	505	35	540	29419	
0	40	1601.8	1362	23146	745.92	65.4	811.3	22335	Dominated
23	20	1842.6	1566	26626	878.013	72.3	950.3	25676	D
46	0	2152.3	1829	31101	1010	49	1059	30042	
0	60	1785.7	1518	25803	1118.88	70.02	1188.9	24614	D
23	40	2305.6	1960	33315	1250.92	83.98	1334.9	31980	
46	20	2142	1821	30952	1382.96	88.64	1471.6	29480	D
69	0	1874.8	1594	27091	1515	70	1585	25506	D
23	60	2025.1	1721	29262	1623.93	86.4	1710.3	27552	D
46	40	2098.1	1783	30318	1755.92	93.4	1849.3	28469	D
69	20	1924.9	1636	27814	1888.01	104.98	1993	25821	D
46	60	2028.3	1724	29308	2128.93	109.67	2238.6	27070	D
69	40	2166.2	1841	31301	2260.92	102.68	2363.6	28938	D
69	60	2241.6	1905	32391	2634.04	135.26	2769.3	29622	D

3.5. Economic evaluation of nitrogen and sulphur fertilizers

Partial budget analysis revealed that the highest net benefit was recorded for the treatment that received 23 kg N ha^{-1} (Birr 31980 ha^{-1}), followed by 46 kg N ha^{-1} (Birr 30042 ha^{-1}), 69 kg N ha^{-1} (Birr 29622 ha^{-1}) (Table 6 and 7). From economic point of view, it was apparent from the above results those treatments with 23 kg N ha^{-1} and 46 kg N ha^{-1} were more profitable than the rest of treatment combinations.

The dominated treatments according to the dominance analysis were eliminated from further economic analysis. To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a worthwhile option to farmers, the marginal rates of return (MRR) need to be at least between 50% and 100% (CIMMYT, 1988). Some scholars also suggested MRR of 100% as realistic. Thus, to draw farmers' recommendations from marginal analysis in this study, 100% return to the investment is reasonable minimum acceptable rate of return, since farmers' in the study area usually not apply N and S for linseed production.

Accordingly, application of 23 kg N ha^{-1} (5045.21%MRR) and 46 kg N ha^{-1} (4016.56%MRR) are above the minimum acceptable rate of return (Table 7). Therefore, application of 23 kg N ha^{-1} is superior rewarding treatment and this fertilizer level can be recommended for farmers in Sinana and other areas with similar agro-ecology condition.

Table 7
Marginal analysis of nitrogen and sulphur treatments.

N (kg N ha^{-1})	S (kg S ha^{-1})	Total variable cost (Birr ha^{-1})	Net benefits (Birr ha^{-1})	Marginal variable cost	Marginal net benefit	Marginal rate of return (%)
0	0	0	24132	0	0	0
0	20	429	25078	429	946	220.513
23	0	540	29419	111	4341	3910.81
0	40	811.3	22335	271.3		
23	20	950.3	25676	139		
46	0	1059	30042	108.7	4366	4016.56
0	60	1188.9	24614	129.9		
23	40	1334.9	31980	146	7366	5045.21
46	20	1471.6	29480	136.7		
69	0	1585	25506	113.4		
23	60	1710.3	27552	125.3		
46	40	1849.3	28469	139		
69	20	1993	25821	143.7		
46	60	2238.6	27070	245.6		
69	40	2363.6	28938	125		
69	60	2769.3	29622	405.7		

4. Conclusion and recommemdations

The needs for applying fertilizers are becoming obvious, as soil fertility has declined from time to time. Excessive use of fertilizers also affects farmers' economy, as the crop is relatively low yielder. Hence, identifying economically optimum levels of nitrogen and sulphur fertilizers are the most important means to be dealt with. In this regard, a field experiment was conducted to evaluate effect of nitrogen and sulphur fertilizer on growth, seed yield, and oil yield of linseed at Sinana.

The present study demonstrated that nitrogen had significant effects on growth and yields of linseed, with sulphur having much less effect. The optimum growth, seed yield, and oil yield were obtained in response to the application of 23 kg N ha^{-1}. Therefore, farmers in the study area should apply only 23 kg N ha^{-1} for obtaining economical seed and oil yields of the crop. However, to come up with a conclusive recommendation, the experiment should be repeated over seasons and locations.

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References

Adugna Wakjira and Adefris Tekle Wolde, 1995. Agronomic performance of linseed regenerants at two locations in Ethiopia. In: Sebil. Proceedings of the 7th Annual Conference of the Crop Science Society of Ethiopia (CSSE), 27-28 April 1995, Addis Ababa, Ethiopia, 9-21.

Adugna Wakjira, 2007. Linseed (*Linum usitatissimum* L.) In: van der Vossen H.A.M. and Mikilamo G.S. (Eds.) Plant Resources of Tropical Africa 14. Vegetable oils. PROTA Foundation, Wageningen, Netherlands/ Backhuys Publishers, Leiden, Netherlands, 108-115.

Agegnehu, M., Honermeier, B., 1997. Effects of seeding rates and nitrogen fertilization on seed yield. Seed quality and yield components of false flax (*Camelina sativa* Crtz.). Bodenkultur. 4, 15-21.

Ajwa, H.A., Tabatabai, M.A., 1993. Comparison of some methods for determination of sulfate in soils. Comm. Soil. Sci. Plant. Anal., 1817-1832. WCC-103 Publication, WREP-125, 2nd Edition.

Chapman, H.D., 1965. Cation exchange capacity. pp 891-901. In: Black, C.A., Ensminger, L.E. and Clark, F.E. (Eds). Methods of soil analysis. Agronomy No. 9, *American Society of Agronomy*, Madison, Wisconsin. Washington State University Press.

CIMMYT, 1988. From agronomic data to farmers recommendation: An economic training manual. Revised Edition. Mexico, D.F.

Fazli, I.S., Jamal, A., Ahmad, S., Masoodi, M., Khan, J.S., Abdin, M.Z., 2008. Interactive effect of sulphur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. J. Plant. Nutr., 31, 1203-1220.

Finlayson, A.J., Christ, C.M., Downey, R.K., 1970. Changes in the nitrogenous components of rapeseed (*Brassica napus* L.) grown on a nitrogen and sulphur deficient soil. Can. J. Plant. Sci., 50, 705-709.

Franzen, D., 2004. Fertilizing flax in North Dakota. North Dakota Agricultural Experimental Station, Extension Service SF-717, North Dakota, and USA.

Freer, J.B.S., 1993. Linseed husbandry: A UK perspective. Indust. Crop. Prod., 1, 211-217.

Hazelton, P., Murphy, B., 2007. Interpreting Soil Test Results, CSIRO Publishing, 150 Oxford Street Collingwood VIC 3066, Australia.

Hocking, P.J., Pinkerton, A., 1991. Response of growth and yield components of linseed to the onset or relief of nitrogen stress at several stages of crop development. Field. Crop. Res., 27, 83-102.

Hocking, P.J., Randall, P.J., Pinkerton, A., 1987. Mineral nutrition of linseed and fibre flax. Adv. Agron., 41, 221-296.

Inal, A., Gunes, A., Alpaaslan, M., Adak, M.S., Taban, S., Eraslan, F., 2003. Diagnosis of sulphur deficiency and effects of sulphur on yield and yield components of wheat grown in central Anatolia. Turkey J. Plant. Nutr., 26, 1483-1498.

Itanna, F., 2005. Sulfur distribution in five Ethiopian Rift Valley soils under humid and semi arid climate. J. Arid. Environ., 62, 597-612.

Kutcher, H.R., Malhi, S.S., Gill, K.S., 2005. Topography and management of nitrogen and fungicide affects diseases and productivity of canola. Agron. J., 97, 533-541.

Lafond, G.P., 1993. The effects of nitrogen, row spacing and seeding rate on the yield of flax under a zero-till production system*.* Can. J. Plant. Sci., 73, 375-382.

Marschner, H., 1995. Mineral Nutrition of Higher Plants, 2nd ed. Academic press Limited. London.

Marschner, H., 1995. Mineral Nutrition of Higher Plants, 2nd ed. Academic press Limited. London.

Motsara, M.R., Roy, R.N., 2008. Guide to laboratory establishment for plant nutrient analysis. FAO Fertilizer and Plant Nutrition Bulletin 19. Rome. 204p.

Nazir, S., 1998. Effect of time and rate of fertilizer application on the growth, seed yield and oil percentage of canola (*Brassica napus* L.). M. Sc. Thesis, Department of Agronomy University of Agriculture Faisalabad, Pakistan.

Olsen, S.R., Cole, F.S., Dean, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. No. 939, Washington DC.

Scherer, H.W., 2001. Sulphur in crop production - invited paper. Eur. J. Agron., 14, 81-11.

Sharief, A.E., 1999. Performance of some flax cultivars in response to nitrogen fertilizer rates and yield analysis. Bull. Fac. Agr. Cairo. Univ., 50, 394-415.

Sharief, A.E., EL-Hindi, M.H., EL-Moursy, S.A., Seadh, A.K., 2005. Response of Two Flax Cultivars to N, P and K Fertilizer Levels. Sci. J. King Faisal Uni. (Basic and Appl. Sci.), 6, 1406-1426.

Walkley, A.J., Black, I.A., 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil. Sci., 37, 29-38.

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