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Effects of seed rates and row spacing on yield and yield components of linseed (*Linum usitatissimum* L) at Dabat district of North Gondar Zone, Ethiopia

Abstract

The area coverage and productivity of linseed decreased from time to time; even there is no crop package and recommended row spacing and seed rate at regional level due to lack of attention by researchers and also by farmers. In Ethiopia, linseed has been cultivated for two primary purposes, seed and oil use. Its production in Ethiopia country is characterized by low input, low yield and poor product quality mainly due to attitude and poor management practices such as lack of proper weed management system, poor seed and field hygiene, poor seed bed preparation, inadequate plant nutrition, inappropriate seeding rate and spacing (mostly broad casting), improper threshing ground and improper cleaning. Field experiment was carried out to evaluate the effects of seed rate and row spacing on the yield and yield components of linseed, during 2017/2018 cropping season at Dabat district, North Western Ethiopia. KULUMSA1 (CHILALO) was used as test crop. Factorial combinations of three row spacing, (20, 25, and 30 cm) and three seed rates, (40, 45 and 50kgs) were laid out in RCBD with three replications. Data regarding different parameters were recorded from days to sowing up to different stages. Statistical analysis of data showed that most of the parameters were affected by the main effects of Seed Rates and Row spacing. The main effect of seed rate was highly significant for days maturity, thousand seed weight and harvest index of linseed. More over it was significant for days to flower and number of capsule per plant, but it was not significant to plant height and bio mass yield. The main effect of row spacing was significant for days to maturity. The interaction of seed rate and row spacing was highly significance ($p<0.05$) for number of primarily branch per plant and seed yield. It was not significant on number of seeds per capsule, number of capsule per plant and thousand seed weight. The main finding of this research is highest seed yield (1771 kg ha^{-1}) was obtained at 40kg ha^{-1} x 25 cm of row spacing while the lowest seed yield (752kg ha^{-1}) was recorded at 50 kg ha^{-1} x 30 cm. 40kg ha^{-1} and 25cm is recommended to increase yield of linseed and its components. In conclusion the effect of seed rate and row spacing affects the important yield components of linseed.

Keywords: linseed, row planting, seed rate

Volume 7 Issue 1 - 2020

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Received: November 20, 2019 | **Published:** January 10, 2020

Introduction

Agriculture is the dominant sector for the economy of Ethiopian. It is a means of subsistence for more than 85% of the country's rural population, contributes more than 50% of the national GDP, 90% export earnings and provides employment for 88% of the labor force.[1] Oilseeds are the second export products next to coffee and already more than 3 million small holders are involved in their production.[2] Linseed, *Linum usitatissimum* L., is an oil seed crop in the family Linaceae. Evidence of use by humans' dates back to about 8,000 B.C. in the Fertile Crescent.[2,3] 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.[4] It is now grown primarily for food and to generate revenue, either in local markets or by export. For food, the seeds are usually roasted, ground, mixed with spices and water, and served with various local breads. It is also consumed in soups, with porridges and cooked potatoes, etc. Limited amounts are also pressed locally for its edible oil, which is often blended with other high quality vegetable oils. And it is widely cultivated in higher elevations of Ethiopia where frost is a threat for other oilseeds.[5]

Ethiopia is the fifth largest producer of linseed in the world next to Canada, China, USA and India.[3] In 2016/2017, Ethiopia allocated 81,575.75 hectares of land for linseed and produced 902,761.25 quintals (CSA, 2016). Likewise, Amhara region contribute 21,782.47ha (26%) of land and the yield was 150,400.08quintals (16%) while North Gondar had 4,613.63hectars and production were38,102,.83quintals of linseed was obtained. In other words, 21 % of the areas allocated for linseed production in Amhara Region and 5% of the areas allocated for linseed production in the country as a whole had come from North Gondar Zone. Besides 25% of total linseed production in Amhara Region and 4% of linseed production in Ethiopia was obtained from this zone. Productivity of the crop at national, Amhara region, and North Gondar were 11.07, 6.9, and 8.258q ha^{-1} respectively.[6]

Despite numerous uses of linseed, large areas allocation, and many years production, tradition linseed productivity is very low in Ethiopia (1.1 t ha^{-1}).[6] The production in Ethiopia is characterized by low input, low yield and poor product quality mainly due to attitude and poor management practices such as lack of proper weed management system, poor seed and field hygiene, poor seed bed preparation, inadequate plant nutrition, inappropriate seeding rate, improper threshing ground and improper cleaning. On the other hand, using improved varieties along with good agronomic practices gave as high as 2.2 t ha^{-1} on research fields and some model farmers managed to produce as high as 2.0 t $ha^{-1}$when supported with improved seed of linseed, intensive training and close supervision (KARC, 2012). Currently, there is a huge shortage of edible oil in the country.[7] Hence, concerted research, development and promotion efforts are needed, at all levels, in order to reverse the current situations. The objective of this study is, therefore, to evaluate the effects of row spacing and seed rate on yield and yield components of linseed.

Materials and methods

Experimental site

The experiment was conducted in Dara Kebele. The site is found in Dabat district which about 75 kilometers away from Gondar town north of Gondar town in. It is about 255 kms North West of Bahir dar located in one of the high altitudes and high rainfall area of the Amhara National Regional State. The district has latitude of about 12.9814ºN and longitude of 37.7623ºE. The altitude of the woreda ranges from 1500 to 3200(m.a.s.l). Mean annual rainfall in the district ranges from 800 to 1400 mm. The main rainy season starts at the beginning of June and continues up to the end of September. The minimum and maximum daily temperature of Dabat is 18˚C and 35˚C, respectively (DWOA, 2010).

Experimental design and procedures

The designs were factorial RCBD of three replications, factorial combinations of three row spacing (20, 25 and 30cm) and three seed rates (40, 45, and50 *kg* ha^{-1}). Size of the plot were 3*2m (6 m^2). Spacing between plots (path) was 50cm (it had drainage furrow between plots and between replications Spacing between blocks was 200cm. Sowing was done first week of July fertilizer were applied at the rate of 23 *kg* ha^{-1} p2O5 that was applied during sowing while N 23*kg* ha^{-1} applied one third at sowing and the remaining applied after 35 days to sowing. The fertilizers used were urea (46% N) and TSP (46% P_2O_5), used as a source of Nitrogen and Phosphorus, respectively.

Data collection

Data were collected on different parameters from the net plot area. The net plot area was delineated by leaving two boarder rows at both sides of every plot and 0.5m at both ends of each row as the row spacing varied the net plot area also varied. Therefore, the corresponding net plot area for row spacing of 20, 25, and 30 cm were 1.5 x 2.6 m, 1.5x2.5 m and 1.5x 2.4 m, respectively. At full maturity stage, five plants were taken at random from each plot to estimate plant height (cm), number of primary and secondary branches per plant, number of capsules per plant, 1000-seed weight (g), Seed yield, and biological yield. Straw yields ha^{-1} was estimated from the central area of the respective net plot area, Plants were harvested, tied and left to dry, thereafter it was threshed to remove the capsules and weighted to determine seed yield and straw yield per net plot area and then converted yield in *kg* ha^{-1} after cleaned from straw and other residuals and weighed to the nearest gram and converted to record seed yield in kg ha^{-1}.

Data analysis

First, data normalization test for all phonological, growth and yield components done by SAS software before variance analysis and all data were subjected to statistical analysis by the technique of analysis of variance of the factorial RCBD design according to Gomez and Gomez. Combined analysis of both seed rate and row spacing was done. Main effects and interactions were tested using the error terms appropriate for the combined analysis of factorial RCBD design. Treatment means were compared at 5% level of probability using the least significant difference (LSD) method.

Results and discussions

Days to 50 % flowering

The analysis of variance for days to 50% flowering revealed that it was significantly affected by main effects of row spacing and also seed rate but there is no significant effect on interaction effects (Table 1). Concerning to seed rates the more the seed rate the lesser the days to flower 50 *kg* ha^{-1} required (63.11) days to flower this could be when the plant population increases there is a series competition for nutrient, light, and water as escaping mechanism they fasten their flowering period. Whereas seed rate 40 *kg* ha^{-1} needs more time to flower (72.2). This could be relatively there is less competition to the resources it should not goes forced early flower due to a smaller number of plant population in a unit area.[8] who Reported that there is significant ($P \leq 0.05$) main effects of seed rate occurred on days to flowering of linseed. On the other hand, row spacing significantly affect days to 50% flowering the narrow spacing (20cm) flower early (65.13) days, while wider spacing show late flowering 30cm needs (67.8) days because it can get more light, water, and nutrient relatively than the rest two spacings. Alessi indicated that more numbers of days to flowering were recorded at wider rows than at closer rows of sunflower.

Days to 90 % maturity

Days to 90% physiological maturity were affected by the main effects of row spacing and seed rate but not interaction effects there is significant ($P \leq 0.05$) on days to 90% maturity on both main effects of seed rates and row spacing. On seed rate bases 40 *kg* ha^{-1} it requires more times than other two seed rates (138.22). Whereas the higher seed rate needs shorter time to flower (133.5) days, this might be there is a series competition in higher population than the lower one. Based on row spacing 20cm mature earlier than the other two spacing, which is 30cm required delayed maturity, because there is relatively lesser competition to water, nutrient and aeration. Table 1 illustrate the significance on 90% physiological maturity.

Plant height

Analysis of variance revealed that plant height was affected neither by the main effects of row spacing and seed rate nor by their interaction (Table 1). This could be due to more competition for sun light. Njuguna et al.,[9] reported that seed rates had no significant effects on plant height, spikes/m2 and 1000-seed weight. Table 1 Illustrate ignificance of plant height on both seed rates and row spacing of linseed. Sewnet Ashebir (2005) who reported that there was no significant difference in rice plant height across the sowing densities, there was an increasing trend with increasing levels of sowing density. This result is agree with the above mentioned result. Similarly, Turk and Caliskan also reported similar finding on lentil and sesame, respectively, that plant height was correlated negatively with plant density.

Table 1 Main effects of seed rates and row spacing on days to 50 % flowering, Days to 90% maturity and plant height

Seed rate	Days to 50% flowering	Days to 90% maturity	Plant Height
40	72.2a	138.22a	72.93a
45	66.56b	137.78a	76.56a
50	63.11c	133.56b	83.67a
LSD (5%)	2.39	1.99	NS
Row spacing			
20	65.13b	135b	77.33a
25	67.67a	136.13b	78.27a
30	67.8a	138.2a	77.54a
LSD (5%)	2.4	1.99	Ns
CV (%)	3.4	1.4	16.05
Mean	66.96	136.52	77.72

Where CV Coefficient of variance LSD Least Significant Difference

Number of primary branches

The interaction effects of seed rate and row spacing, revealed a significant influence on the number of primary branches (Table 2). At both seed rate and row spacing, there was an increased in the number of primary branches with increase row spacing, i.e. number of primary branches was increased in row spacing. The highest number of primary branches was obtained at 30 cm x 50 *kg ha*$^{-1}$, whereas the lowest number of primary branches was recorded from 20 cm x50 *kg ha*$^{-1}$. The interaction effect of seed rate and row spacing revealed a highly significant ($p<0.01$) effect on primary branches (Table 2). On, the wider row spacing (30cm) produced higher number of primary branches that was significantly higher than 20 cm and 25 cm. On the other hand, at seed rate, higher number of primary branches was recorded due to (50 *kg ha*$^{-1}$). Generally, the interaction of seed rate and row spacing, higher number of primary branches was observed at the wider row spacing. This could be possibly due to the availability of growth factors resulted from the heaping of the fertile topsoil, which in turn, increased the lateral vegetative growth of the crop.

Table 2 Interaction effects of seed rates and row spacing on primary branches

	Seed rate		
Row spacing	40	45	50
20	5523.9d	6140cd	5466.3d
25	7575.5b	6266c	7448b
30	7582.8b	7716ab	8055ab
Mean	7175.46		
LSD (5%)	755.91		
CV (%)	6.25		

Where CV Coefficient of variance LSD Least Significant Difference

Number of secondary branches

The main effect of seed rate indicated that when the seed rate increased from 40 *kg ha*$^{-1}$ to 50 *kg ha*$^{-1}$ the number of secondary branches decreased from 6.17 to 3.14 and also on row spacing the number of secondary branches increased as spacing increased (Table 3). The number of secondary branches increased from 3.9 to 5.18 on the row spacing increased number of secondary branches as increased spacing from 20cm to 30 cm respectively. This result is in agreement with findings that were worked on other oil crops, such as Pelargonium sp. Availability of abundant space in the wider spacing of Pelargonium sp. encouraged horizontal growth (excessive branching).

Table 3 Main effects of secondary branches, number of seeds per capsule and number of capsules per plant

Seed rate	NSBR	N of seed /plant	NCP
40	6.17a	9.4a	19.81a
45	4.84b	6.02c	14.67b
50	3.14C	7.89b	9.11c
LSD (5%)	1.36	1.41	3.55
Row spacing			
20	3.9a	7.69a	11.89b
25	4.93a	7.84a	16.71a
30	5.18a	7.78a	14.68 ab
LSD (5%)	1.37	NS	NS
CV (%)	27.89	17.48	23.49
Mean	4.72	7.77	14.53

Where, NSBR Number of Secondary Branch per plant, NCP Number of capsules per plant, CV Coefficient of variance, LSD Least Significant Difference

Mean performances of spacing indicated that greater numbers of secondary branches were produced at wider row spacing (Table 3). Spacing of 30 cm produced higher number of secondary branches (5.18). From the result, it can be inferred that wider spacing allows the plant to produce more branches due to higher use of resources. Number of seeds per capsule. Table 3 illustrates the main effect of seed rate on the number of seeds per capsule of linseed. Seed rate significantly affected by the number of seeds per capsule. Higher mean number of seeds per capsule (9.4) was recorded at seed rate of 40 *kg ha*$^{-1}$ compared to the other two seed rates (6.02) and (7.89) for 45 *kg ha*$^{-1}$ and 50 *kg ha*$^{-1}$*, respectively*. This could be due to there is relatively enough nutrient, water and aeration enhanced the conversion of solar energy to chemical energy, which might have stored on the seeds. On the other hand, the main effect of row spacing on this parameter showed non-significant.

The present result agrees with that of.[10] As plant density increases, the amount of dry matter in vegetative parts also increases. Both the biological and economic yields increase with increasing plant population up to a certain point and subsequently no addition in biological yield can be obtained and economic yield decreases. Number of capsules per plant. The analysis of variance on the number of capsules per plant indicated that the main effect of seed rate had a significant effect on the parameter. Higher mean capsule number per plant (19.81) was observed on the seed rate of 40 *kg ha^{-1}* as compared to the other two seed rates. There was 19.81 number of capsules per plant when linseed was grown on the seed rate 40 *kg ha^{-1}* than 50 *kg ha^{-1}*. This might be due to the number of branches and capsule, which were higher on the 40 *kg ha^{-1}*. Moreover, the higher number of branches on 40 *kg ha^{-1}* might lead to the large number of capsules per plant, as photosynthetic surface or vegetative infra-structure before heading or anthesis plays significant role in determining the number of grains per plant. Ashraf A[11] reported that number of capsules per plant has significant difference on number of capsules per plant this research result also proves Ashrafs result (Table 3). Higher mean capsule number per plant (19) was observed on the seed rate 0f 40 a *kg ha^{-1}* compared to that of 50 *kg ha^{-1}*. In general, there was increase in the number of capsules per plant when linseed was grown on the seed rate of 40 *kg ha^{-1}* to 50 *kg ha^{-1}* this result lead to the lesser the seed rate the more number of capsule per plant. The number of capsules per plant was found to increase as plant spacing increased to certain extent. Similarly, Weiss has noted that high population or close spacing in a row tended to reduce both the number of capsules and number of seeds per capsule.

Thousand seed weight

The analysis of variance on thousand seed weight indicated that the main effect of seed rate had a significant effect on the parameter but do not have significant effect on spacing. Njuguna et al.,[9] reported that seed rates had no significant effects on plant height, spikes/m2 and 1000-seed weight. But the research conducted disproves Njugunas result because under this result 1000seed weight significant to seed rate it decreases from 5.48 to (40 kg ha^{-1} to 4.98 (45 kg ha^{-1}) and 4.04 to 50 kg ha^{-1} thus indicates that 40 *kg ha^{-1}* decreases yield but it does not affect on row spacing (Table 4) illustrate the significance on main effects of seed rate and row spacing. Abebe Delesa and Adane Chofere , 2015 conducted research on effects of planting method and spacing on yield of linseed at Kulumsa shows that row spacing has not significant effect on thousand seed weight this result is analogous to the above research.

Table 4 Main effects of 1000 seed weight, biomass yield, harvest index

Seed rate	1000 seed weight	Biomass yield	Harvest Index
40	5.48a	3120.6a	45a
45	4.98b	3484.7a	29b
50	4.04c	3948.9a	22b
LSD (5%)	0.35	NS	0.08
Row spacing			
20	4.77a	3168.5a	31.38ab
25	4.96a	3789.3a	37.88a
30	4.77a	3553a	27.52b
LSD (5%)	NS	NS	NS
CV (%)	7.4	27.21	24.32
Mean	4.8	3518	32

Where, CV Coefficient of variance, LSD Least Significant Difference

Biomass yield

The result of the experiment revealed that there was no significant difference in biomass yield per plant due to seed rates, row spacing and interaction of both. Higher dry biomass per hectare was obtained at the higher seed rate 50 *kg ha^{-1}* (Table 4). Spacing 25 cm resulted higher dry biomass yield per hectare resulted in greater dry biomass yield hectare^{-1}.

Harvest index

The analysis of variance on harvest indicated that main effect of seed rate had a significant effect on the parameter (Table 4). Nevertheless, the main effects of row spacing and the interaction effect had no significant influence on harvest index. When seed rate increases from40 *kg ha^{-1}* to 50 *kg ha^{-1}* harvest index decline, high harvest index indicates that the crop mobilized large amount of assimilates from the biomass to the seed.[10] As plant density increases, the amount of dry matter in vegetative parts also increases. Both the biological and economic yields increase with increasing plant population up to a certain point and subsequently no addition in biological yield can be obtained and economic yield decreases. Similarly this research had got the same result like Singh because at the seed rate of 40 *kg ha^{-1}* there is high harvest index it indicates that there is high amount of assimilates goes to the seed at seed rate of 40 *kg ha^{-1}* gradually decreases as plant population increases.

Seed yield

The interaction effects of seed rate and row spacing, revealed a significant influence on seed yield (Table 5). Seed rate, row spacing and interaction of both had significant effect on seed yield of linseed (Table 5). Higher mean seed yield (1771 *kg ha^{-1}*) was obtained on seed rate of 40 *kg ha^{-1}* and row spacing 25cm while the lower mean seed yield (752 *kg ha^{-1}*) was recorded on seed rate of 50 *kg ha^{-1}* and row spacing of 30cm. The higher seed yield obtained by interaction of 40 *kg ha^{-1}* and 25cm could be probably due to the higher number of branches per plant, number of capsules per plant, and higher number of seeds per capsule, which were predominantly associated with row spacing and seed rate.

Table 5 Interaction effect seed rate and row spacing on seed yield

	Seed rate		
Row spacing	40	45	50
20	1228b	1045.3bc	831.7c
25	1771a	888.9bc	860c
30	1086bc	1042bc	752c
Mean	1056.14		
LSD (5%)	334.46		
CV (%)	19		

Conclusion and recommendation

The response of linseed varied to seed rates and row spacing arrangements with respect to growth, yield and yield components. It is valuable to get information about the seed rate and row spacing of linseed to increase its productivity. Therefore, an experiment was conducted during 2017/18 production year at the farmer field of Dabat district with the objective of evaluating the effects of seed rate and row spacing on the yield and yield components of linseed. The experiment was conducted using factorial RCBD with three replications. Spacing (20 cm, 25cm and 30 cm) were assigned respectively, while the seed rate (40, 45 and 50 *kg ha^{-1})* was allocated. Days to 50% flowering and to 90% maturity varied when linseed was planted on different seed rates and row spacing. Linseed sown on wider spacing (30cm) require longer time in relative to other row spacing in both times to flower and days to maturity on the contrary (20cm) or narrow spacing require lesser time than other row spacing, from this it can be conclude that narrow spacing plants competition for water, nutrient that can speed up their flowering and maturity. On the other hand higher seed rates can flourish and mature early than other seed rates this because of higher seed rate there is high plant population and competition for resources like narrow spacing. Lesser seed rate (40 *kg ha^{-1})* took longer time to flower than the higher seed rates (50 *kg ha^{-1}*). Plant height varied due to seed rates and row spacing. Higher mean height is observed at rate of (50 *kg ha^{-1}*) and the lower mean height of linseed was recorded on (40 *kg ha^{-1})* as compared to (50 *kg ha^{-1}* and45 *kg ha^{-1}*). In relation to row spacing, there is almost less mean difference among 20cm, 25cm and 30 cm. Final plant heights was not significantly influenced by seed rate therefore when the seed rate increases plant height increases due to high population and competition for light this makes shade of one crop to the other and make in efficient photosynthesis input for shorter plants of the same plot.

Seed rate and row spacing significantly affected by number of secondary branches of linseed. Higher mean number of secondary branches was observed at the seed rate of 40 *kg ha^{-1}* (6.17) thus is due to lesser competition to resources where as the plant population becomes higher and higher number of secondary branches decline because of shortage of resources and suffocation for space to expand their branch analogous to seed rates row spacing affect number of secondary branches higher number of secondary branches was recorded at wider spacing (30cm)and lower number of branch was recorded at narrower spacing (20cm) therefore 20cm at50 kg ha^{-1} high plant population it should not recommended in most components of linseed. The number of capsule per plant was affected due to seed rate. Higher mean capsule was recorded on seed rate than row spacing the highest mean high number of capsules was recorded on plants grown at 40 *kg ha^{-1}* and the lower was at5 *kg ha^{-1},* respectively. On the other hand row spacing cannot affect number of capsule per plant. Concerning to 1000 seed weight can affect on seed rates but cannot affect on row spacing from the result it can conclude that it is better to use 4 *kg ha^{-1}* rather than 45 and *kg ha^{-1}* 50 because 1000 seed weight is mainly affected total yield per hectare. When increase the seed rate 1000 seed weight becomes decline because more resources goes to seeds than biomass yield. Biomass yield neither affected on seed rates nor row spacing on both factors of seed rates and row spacing of linseed. Harvest index can affect by seed rates than but cannot affected by row spacing high harvest index was recorded at the seed rate of 4 *kg ha^{-1}* and lower at seed rate of 50 *kg ha^{-1}* more the seed weight the higher the harvest index there is therefore it is recommended to use 40 *kg ha^{-1}* than 45and 50 *kg ha^{-1}*.

Even if the research is done in micro level or one district results of this experiment indicated significant differences in seed yield per hectare. Numerically, the highest seed yield per hectare was recorded due to the combination of 40 *kg ha^{-1}* on seed rate and row spacing of 25cm, but the research is done on one season at one location, required confirmation with further studies to give a valid recommendation. From the forgoing results, seed yield can be substantially improved by the use of 40 *kg ha^{-1}* for seed rate, and 25cm for row spacing at Dabat district and similar agro ecological areas.

Acknowledgments

Authors express their profound appreciation to University of Gondar, particularly College of Agriculture and Environmental Sciences for sponsoring the master's science for agronomy and providing all the necessary materials and logistic support during the study. Authors also, acknowledge the staffs of the Dabat district Agricultural office for cooperation and assistance by providing relevant information during the study period.

Conflicts of interest

No conflicts to declare.

Funding

None.

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