Influence of Seeding Rates on Seed yield, Oil Content, Oil Yield and other Yield Attributes of four Linseed (Linum usitatissimum L), Varieties in Horo Gud eru District, Western Ethiopia

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Abstract: Seed rate is one of the agronomic factors that decreases seed yield by subjecting plants to lodging and competition. The field experiment was conducted in 2019/20, and 2020/22G main cropping seasons on Harato and Gitilo sites to determine the effect of seeding rates on seed yield and oil percentages and to evaluate the interaction effect of varieties and seed rates on seed yields, oil percentages, and yield attributes. The experiment consisted of four linseed varieties (Belay, Berene, Kuma, and local) and five seed rates (20, 25, 30, 20 35, and 40 kg ha⁻¹). The experiment was laid out in a randomized complete block design and replicated three times. The results revealed that seed yield, oil percentage, oil yield, capsules per plant, thousand seed weight, dry biomass, and straw yield of linseed were significantly (p < 0.01) influenced by the main effect of seed rates and varieties. While seed yield, oil percentage, and oil yield had significantly (p < 0.05) affected by the interaction of varieties by seed rate. Maximum seed yield was obtained from improved varieties of Kuma (1819 kg ha⁻¹) at 35 kg ha⁻¹, but the

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PUBLIC INTEREST STATEMENT

Linseed is cultivated mainly for cash crops as well as for human consumption. It is high in oil percentage (33–42%) and (75–91%) unsaturated fatty acid composition, especially the seed oil plentiful by Omega-3 and Omega-6 fatty acid. In addition, the crop has many health benefits in terms of preventing various diseases like antioxidants, gastric, high blood pressure, cancer, and cardiovascular disease. However, the productivity of linseed at study site lower than other areas due to inappropriate seed rate, blanket fertilizer application, untimely sowing date, lack of technology, weeds problems, and soil acidity. Many of these agronomic factors limit the seed yield and oil percentage of linseed crops due to competition effects, poor management activity, and occurrences of unpredicted weather conditions. Linseed production increased with proper management like timely sowing date, optimum seed rates, fertilizers, and using improved seed. However, optimum rates and times not only maximize yield and oil percentage by exploiting resources optimally but also increase the profitability of farmers by reducing seed costs.
lowest seed yield recorded from improved varieties and local cultivar at 20 kg ha$^{-1}$. The highest oil percentage (41.38%) was recorded on Kuma variety at the seed rate of 20 kg ha$^{-1}$, but the lowest oil percentage (35.15% and 35.96%) had obtained from local cultivar at 35 and 40 kg ha$^{-1}$. Therefore, the findings suggested that Kuma variety of linseed was the highest yielder at 35 kg ha$^{-1}$ seed rates, while the oil percentage of the varieties decline as seed rate increased. Thus sowing Kuma variety at 35 kg ha$^{-1}$ seed rates can be recommended at the study area and similar agro ecology.

**Subjects**: Agriculture & Environmental Sciences; Plant & Animal Ecology; Soil Sciences

**Keywords**: genotypes; linseed; plant density; quality parameters; yield attributes

### 1. Introduction
Linseed (Linum usitatissimum L.) is one of the oil crops that has been grown in Ethiopia highlands for many years. It is a multipurpose crop; edible oil is now chosen for its health benefits in the prevention of diseases such as cancer, high blood pressure, diabetes, cardiovascular disease, and others (Alexopoulou & Christou, 2011). Linseed oil also utilized in the making paints, varnishes, soaps, printing inks, oilcloth, and linoleum tiles due to its fast drying oil property (Andruszcak et al., 2015). Linseed seed oil contains approximately 9–11% saturated (5–6% palmitic acid and 4–5% stearic acid) and 75–90% unsaturated fatty acid (50–55% α-linolenic acid, 15–20% oleic acid (Alonso & Maroto, 2000). Compared to other oilseed crops, linseed oil is the richest source of Omega-3 and α-linolenic acid (ALA; Oomah, 2001).

The crop is cultivated mainly for revenue creation in Ethiopia, and the seed oil is used by humans (CSA (Central Statistical Agency of Ethiopia), 2017; Worku et al., 2014). After oil extraction, the cake is used as livestock feed (Mequanint et al., 2020). Linseed grows well in temperate areas with moderate temperatures, high humidity, and well-drained medium-heavy soils (Worku et al., 2014).

Seed yield and oil percentages of linseed were significantly affected by genotypes (Bernacchia et al., 2022; Elayan Sohair et al., 2015) and agro-ecology (Angelini et al., 2016; Demeke & Tesfaye, 2021). Agronomic practices such as seed rates, sowing time, soil fertility status, weeding, and others can affect the seed yield of linseed (Salah & Mohamed, 2015). Genetic and environmental factors also limit the seed yield, oil percentage, and fatty acid profiles of seed oil and the seed press cake (Angelini et al., 2016; Bernacchia et al., 2014). Similarly, Berhanu et al. (2022) who mentioned some biotic and biotic factors which limit the yield of linseed genotypes in Ethiopia; the plant was susceptible to parasitic weeds, wilt, forest, soil acidity, and shortage and excess rainfall. Therefore, screening linseed genotypes to fit various environments is first step before sowing (Dabalo et al., 2017).

Yasemin et al. (2016) reported that an increase in plant population per plot area enhanced competition among them for resources, resulting in fewer branches, reduced number of capsules, and decreased number of plants within the plot, and reduced seed and oil yields. Andruszczak et al. (2015) also reported that individual plant was reduced, but total dry matter obtained per plot area increased due to over seed rate used. Optimum seed rate was increased the plant height, dry biomass, and seed yield of linseed crop (Abebe & Adane, 2016). Even if the recommended optimum seed rate of a variety for one site may not apply to others sites due to variation in environments and soil factors, therefore it needs to develop site-specific recommendations.

Linseed is the fourth useful oilseed next to sesame, Niger seed, and groundnut in terms of area coverage and total production in Ethiopia (Wossen et al., 2016). Among oil seed crops, the area coverage of linseed was about 79, 044.51 hectares and the estimated production was about 846,
493.53 tons (CSA (Central Statistical Agency of Ethiopia), 2017). Similarly, Horo Guduro Wollega Zone has a conducive environment for linseed production. However, the production of this crop is still lower compared to other regions due to poor extension service, inappropriate seed rate, and lack of access to improved seeds are the major problems that hamper seed yield and oil content of linseed (FAO (Food Agricultural Organization), 2017). Therefore, this study aimed to determine the effect of seeding rates on seed yield and oil percentage of four linseed varieties at Harato and Gitilo sites; evaluate the interaction effect of seed rates and varieties on seed yield, and oil percentage at Harato and Gitilo sites in 2019/20 and 2020/21 years; and analyze the partial budget of seed rates and varieties at these study sites.

2. Materials and methods

2.1. Description of study area

The experiment was conducted in 2019/20 and 2020/21GC at Horo Guduro Wollega Zone Jimma Geneti and Horo Districts, respectively. Both districts are found in Horo Guduro Wollega Zone, Western Ethiopia (Figure 1). Harato site is found in Jimma Geneti District Administration at an altitude of 2300 m.a.s.l. Gitilo site is located in Horo District on Gitilo Dale Kebele at an altitude of 2723 m.a.s.l. The mean annual rainfall of both sites is 2,100 mm (Gitilo) and 2,211 mm (Harato) Figure 2. Besides, the mean annual minimum temperature is 17°C on Gitilo and 22°C on Harato sites. While the mean annual maximum temperature is 20°C on Gitilo and 24°C on Harato sites (Figure 3), according to the National Meteorology Agency (http://www.ethiomet.gov.et/). The soil texture of study sites has light clay textural class (HGWZAO 2018).

2.2. Experimental materials

Three linseed varieties, namely, Belay-96 and Berene which were released in 1996 and 2001, respectively, from Holeta agricultural research center and Kuma variety which was released in 2016 from Kulumosa agricultural research center were used as planting material. All the varieties

![Figure 1. Map of study sites.](image)

![Figure 2. Monthly rainfall at Harato and Gitilo sites in 2019/20 and 2020/21 cropping seasons.](image)

![Monthly rainfall of Harato and Gitilo sites in 2019/20 and 2020/21GC](image)
The mean monthly temperature of Harato and Gitilo sites in 2019/20 and 2020/21 GC

Figure 3. Monthly temperature at Harato and Gitilo sites in 2019/20 and 2020/21 cropping seasons.

were adapted to an altitude range of 2200–2800 meter above sea level (m.a.s.l) and temperature range of 15–30°C. Besides this, seed yield and oil percentage potential of each varieties was Belay (16.8–18.9 ha⁻¹, 36.3%), Berene (16.17–19.5 ha⁻¹, 37%), and Kuma (18–20.1 kg ha⁻¹, 39.2%) (MoARD, 2016). The detail description of experimental materials are mentioned in (Appendex table A1).

2.3. Treatment and experimental design
The experiment consisted of 20 treatments combination having two factors: the first factors have four linseed varieties: (Belay-96, Berene, Kuma, and Local cultivar), and the second factors have five levels of seed rates (20 kg ha⁻¹, 25 kg ha⁻¹, 30 kg ha⁻¹, 35 kg ha⁻¹, and 40 kg ha⁻¹). The experimental field was laid out, in a randomized complete block design, with three replications. Treatment combinations were assigned to the experimental plot randomly. The detail description of treatment compenent was listed in Appendix (Table A2). The seeds were sown at 3 m length and 1.6 m width with 20 cm row spacing and having 1 m and 0.5 m space between block and plot, respectively. The gross plot size of each treatment (3 m × 0.20 m × 8 rows = 4.8 m²). The net plot area of each treatment was 1.2 m × 2 m = 2.4 m², from the central six rows, data were collected for statistical analysis and interpretation.

2.4. Experimental procedure
The experimental field was plowing two to three times using oxen-drawn local plows starting from May to June at Harato and Gitilo sites in the 2019/20 and 2020/21 main cropping seasons. The seed drilled in 20 cm row spacing during the 3rd week of June at the 20 kg ha⁻¹, 25 kg ha⁻¹, 30 kg ha⁻¹, 35 kg ha⁻¹, and 40 kg ha⁻¹. The blended fertilizers (NPS) elements used, within 50 kg NPS, nutrient composition is 9 N, 18 P₂O₅, and 3.5 S. To balance 23/23 kg N and P₂O₅ ha⁻¹, urea and TSP fertilizers were applied as supplementary. Other cultural practices were carried out as per the recommendations. Linseed yield was determined per net plot and converted into hectare bases. Seed oil percentage was determined using NMR methods at Holeta Agriculture Research Center in Highland Oil Crop Laboratory.

2.5. Data collection
The number of capsules per plant was determined by counting the total number of capsules from ten tagged plants per net plot area, adding the counted pods together, and dividing by the total number of plants. The number of seeds in a capsule was recorded by taking ten randomly selected capsules from each tagged plant. Each pod was broken carefully by hand, and an average number of seeds per capsule were registered. Thousand seed weights (g) were counted from the representative sample of each treatment drawn, threshed, and clean produced, and weighted the seed by electronics balance and recorded. Dry biomass (kg ha⁻¹) was weighted per plot area upon air-drying the plant for two weeks consecutively and measured constant weight using oven-drying.
Grain yield (kg ha\(^{-1}\)) is the amount of yield per net plot area weighed in kilograms at an adjusted 11% moisture percentage. The harvest index of linseed was obtained by dividing the economic yield (seed yield) by the biological yield (seed and straw yield) and is represented in percent. Seed oil percentage was determined by using the NMR method at the Holeta Agriculture Research Center of High Land Oil Crop Laboratory. Oil yield (kg ha\(^{-1}\)) was the amount of oil in kilogram per hectare obtained by multiplying the seed yield per hectare by the corresponding seed oil percentage obtained from the oil content analysis and divided by one hundred (Legesse, 2013).

2.6. Statistical analysis
The collected data were subjected to the statistical procedures for analysis of variance appropriate to factorial experiments in RCBD (Gomez & Gomez, 2020). Analysis of variance computed using SAS v9.4 software. Before combining across locations, data were used to test the homogeneity of error variance. A combined analysis of sites was done, according to. When ANOVAs showed a significant difference at (P < 0.05) level, the Duncan multiple range tests (DMRT) were used for means separation.

2.7. Partial budget analysis
Variable cost of seeding rates and labor requirement for different operations were used for partial budget analysis. Price fluctuations during the production season were considered. This enables us to identify the optimum seeding rates used for linseed production. Gross return (ET birr ha\(^{-1}\)) the yield of linseed was converted into gross return kg ha\(^{-1}\) based on current price prevailing in the market and approved for the sale of produce at Research form of the institute.

Net profit per hectare was calculated by subtracting total cost of cultivation from gross return. The net return was calculated as: Net return = Gross return—Cost of cultivation.

3. Results and discussion

3.1. Seed yield
The analysis of variance on seed yield was highly significantly (p < 0.01) influenced by seed rates, varieties, and interaction of years by sites. Similarly, other factors such as replication, varieties by sites, varieties by seed rates, and seed rates by sites significantly (p < 0.05) influenced seed yield (Table 1). As shown in Table 2, different linseed gave variable seed yields at different rates. Improved varieties of Belay-96 (1812 kg ha\(^{-1}\)), Berene (1808 kg ha\(^{-1}\)), and Kuma (1819 kg ha\(^{-1}\)) were given was gave high seed yield at 35 kg ha\(^{-1}\) is optimum seed rate and reduced the competition between plants. Optimum plant population per plot uses adequate growth resource, and increased plant height, more number of branches and capsules per plant due to high photo-synthesis occur as a result increased seed yield of linseed varieties. In addition, maximum seed yield was recorded from individual plants rather than a more branched plant. But, minimum seed yield recorded from local cultivars and improved varieties at the seed rates of 20 kg ha\(^{-1}\), this could be due to severe weed infestation at few plant populations per plot. On the other hand, the improved varieties had a higher yield advantage than the local cultivar with Belay-96 (6.63%), Berene (7.03%), and Kuma (7.76%). These could be due to the larger seed size and more numbers of branches per plant.

Similarly, Mequanint et al. (2010) found that the highest seed yield of 1771 kg ha\(^{-1}\) was recorded at seed rate of 40 kg ha\(^{-1}\) and row spacing of 25 cm, while the lowest mean seed yield (752 kg ha\(^{-1}\)) was recorded from seed rate of 50 kg ha\(^{-1}\) and row spacing of 30 cm at Dabat, Northern Ethiopia at each site and years. These show that when plant population exceed optimum seed rate, competition among plants for light and nutrients becomes severe, and consequently, the plant grows slowly, and seed yield was reduced. Ayaz et al. (2017) reported that high plant populations per plot reduce soil fertility and seed yield. The present result agreed with (Bekele et al., 2002; Emam & Dewdar, 2015; Salah & Mohamed, 2015).
Table 1. Mean square values of capsule per plant, thousand seed weight, dry biomass, seed yield, straw yield, harvest index, oil content and oil yield on Harato and Gitilo sites in 2019/20 and 2020/21 years

| Source of variation | Seed yield kg ha$^{-1}$ | Oil (%) | Oil yield Kg ha$^{-1}$ | Capsules Plant$^{-1}$ | Thousand Weig (g) | Dry biomass kg ha$^{-1}$ | Straw yield Kg ha$^{-1}$ |
|---------------------|------------------------|---------|------------------------|-----------------------|-------------------|------------------------|-------------------------|
| Year                | 6748.5                 | 0.7     | 278.5                  | 3015.9**              | 0.001             | 731,891.3*             | 995,365.7*              |
| Site                | 7588.1                 | 25.9**  | 8678.4*                | 1988.9**              | 12.4**            | 34,224.8               | 83,108.5                |
| Rep                 | 15,934.6*              | 0.6     | 2665.5*                | 3572.4**              | 0.3               | 968,534.9**            | 1,161,998.3**           |
| Seed rate           | 189,857.3**            | 72.1**  | 160,153.8**            | 1352.1*               | 11.2**            | 5,048,878.5**           | 3,161,996.2**           |
| Varieties           | 183,697.1**            | 100.5** | 105,907.5**            | 344.2**               | 56.9**            | 2,666,408.7**           | 1,316,668**             |
| Rep(site)           | 38,573.1*              | 3.9*    | 4950.9*                | 343.9**               | 1.6*              | 1,217,084.4**           | 950,223.9**             |
| Year x site         | 156,640.**             | 0.3     | 22,684.6**             | 1773.2**              | 0.01              | 5,192,967.4**           | 5,731,540**             |
| Sr x yr             | 1664.9                 | 2.7     | 771.4                  | 191.5**               | 0.05              | 322,049.5*             | 419,231.7**             |
| Sr x site           | 23,715.8*              | 7.8**   | 1110.2                 | 175.2*                | 0.6               | 175,566.6*             | 212,086.8*              |
| Sr x s x yr         | 7307.2                 | 0.8     | 1909.5                 | 12.4                  | 0.2               | 850,543.1**             | 555,444.8**             |
| Var x yr            | 12,454.7*              | 1.1     | 3719.4*                | 35.7                  | 0.1               | 4681.5                 | 28,375.5                |
| Var x site          | 76.0                   | 1.6     | 578.4                  | 43.6                  | 0.1               | 47,082.0               | 129,845.2               |
| Var x yr x s        | 6542.5                 | 2.5*    | 2976.1**               | 48.6                  | 0.2               | 71,811.6               | 104,470.9               |
| Var x Sr            | 7449.5*                | 1.9*    | 1912.8*                | 5.6                   | 0.2               | 53,701.8*              | 57,367.4*               |
| Var x sr x yr       | 3666.5                 | 0.7     | 441.9                  | 3.2                   | 0.1               | 47,967.8               | 44,311                  |
| Var x sr x s        | 2845.6                 | 0.9     | 566.2                  | 5.8                   | 0.1               | 51,898.5               | 41,573.9                |
| Var x sr x yr xs    | 1536.5                 | 0.9     | 306.9                  | 7.5                   | 0.1               | 23,817.2               | 23,160.8                |
| EMS                 | 408.3                  | 0.65    | 807.75                 | 29.95                 | 0.16              | 59,643.5               | 62,752.9                |
| TSS                 | 9431509.6              | 842.9   | 1,210,888.5            | 27,920.2              | 267               | 238,937,075.1          | 159,993,834.9           |

EMS = Error mean square, TSS = Total sum square, DF = Degree of free dome, NCPP = Number of capsules plant$^{-1}$, NPSC = number of seeds in capsule, TSW = Thousand seed weight (g), DBM = dry biomass (kg ha$^{-1}$), SY = Seed yield (kg ha$^{-1}$), STY = Straw yield (kg ha$^{-1}$), HI = harvest index (%), OC = Oil content (%) and OY = Oil yield (kg ha$^{-1}$), Y = Years, S = Sites, SR = Seed rates, Var = Varieties, Rep = replication.

Similarly, El Naim et al. (2012) found that increasing seed rate significantly reduced the growth and yield parameters by affecting plant height, the number of capsules, and primary branches per plant. Kandil et al. (2008) noticed that the seed yield of flaxseed genotypes was significantly affected by seed rates and cropping seasons.

Improved varieties gave maximum seed yield, but local cultivar gave lower seed yield at both locations (Table 2), improved varieties were broad environmental adaptation and high resource use efficiency than the local cultivar. The difference in seed yield was due to the genetic characteristic of plants, and an improved seed was broad environment adaptation. The present result agreed with Zelalem et al. (2019), who reported that the seed yield of linseed genotypes varies within the study sites. In contrast to this finding, Sakatu et al. (2020) reported that the application of nitrogen fertilizer rates did not make a yield difference in linseed varieties.

Similarly, seed yield is affected due to the interaction of seed rates and sites (Table 2). The minimum seed yield of 1335 kg ha$^{-1}$ and 1356 kg ha$^{-1}$ was obtained on 20 kg ha$^{-1}$ seed rate at both sites because at a low seed rate, linseed plant was highly affected by weed infestation, and also due to adequate growth resources, the plant did not uniformly mature. The maximum seed yields of 1864 kg ha$^{-1}$ were recorded on the Harato site at the seed rates of 35 kg ha$^{-1}$. The soil type and weather conditions of the Harato site fit the optimum seed requirements of linseed crops. Maximum seed yield was obtained at the optimum seed rate used due to the whole plot areas
occupied by the plant. 35 kg ha\(^{-1}\) seed rates as par with 40 kg ha\(^{-1}\) on Gitilo site. In general, the seed yield of the linseed crop was increased when maximum seed rates were used at both sites but gradually declined due to the competition effect. Klimek-Kopyra et al. (2016) noticed that high seed yields recorded from high seed rates of linseed.

### 3.2. Oil content (%)

The analysis of variance in Table 1 indicated that oil percentage showed highly significant (p < 0.01) variations due to seed rates, varieties, sites, and the interactions of seed rates by sites. While other four factors such as replication, varieties by seed rates, seed rates by sites, and varieties by sites by years were significantly (p < 0.05) different for oil percentage. The remaining factors had non-significant effect on oil contents (Table 1). Moreover, Table 3 shows detailed effects of varieties by seed rates, varieties, by sites by years, seed rates by sites, and seed rates by years on the oil contents.

Oil percentage was significantly affected due to the interaction of varieties and seed rates (Table 3). Among the four linseed varieties, Kuma had the highest oil percentage (41.38%), followed by Berene (40%) at the seed rates of 20 kg ha\(^{-1}\); while the lowest oil percentage (35.15%) and (35.96%) were recorded from local check at the seed rates of 35 kg ha\(^{-1}\) and 40 kg ha\(^{-1}\), respectively (Table 3). These could be due to genotypic, plant density, and environments (weather condition, altitude, sites, and years) and their interaction effect. The oil percentage of linseed varieties and local cultivar were declined as the seed rates increased; this may be due to the competition on growth resources like nutrient, water, space, and light energy. In addition to maximum plant population per plot area, it creates high temperature and loss of water; finally it

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Table 2. Effects of varieties by seed rates, varieties by sites, and seed rates by sites on seed yield of linseed varieties on Harato and Gitilo sites in 2019/20 and 2020/21

|                     | Varieties |                       |                       |                       |                       |                       |                       |
|---------------------|-----------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                     |           | Belay-96              | Berene                | Kuma                  | Local                 | Mean                  | Mean                  |
| Seed rates          |           |                       |                       |                       |                       |                       |                       |
| 20 kg ha\(^{-1}\)  | 1344\(^a\) | 1359\(^a\)           | 1367\(^b\)           | 1313\(^a\)           | 1343.25               |                       |
| 25 kg ha\(^{-1}\)  | 1512\(^c\) | 1514\(^d\)           | 1521\(^c\)           | 1426\(^b\)           | 1493.25               |                       |
| 30 kg ha\(^{-1}\)  | 1678\(^e\) | 1703\(^f\)           | 1719\(^e\)           | 1598\(^b\)           | 1674.5                |                       |
| 35 kg ha\(^{-1}\)  | 1812\(^f\) | 1808\(^f\)           | 1819\(^f\)           | 1658\(^b\)           | 1774.25               |                       |
| 40 kg ha\(^{-1}\)  | 1854\(^f\) | 1853\(^f\)           | 1869\(^f\)           | 1701\(^b\)           | 1819.25               |                       |
| Mean                | 1640      | 1647.4               | 1659                 | 1539.2               | 1621.4                |                       |
| DMRT(0.05)          | 60.55     | CV(%)=4.5             |                       |                       |                       |                       |

|                     | Belay-96  | Berene                | Kuma                  | Local                 | Mean                  |
| Sites               |           |                       |                       |                       |                       |
| Harato              |           |                       |                       |                       |                       |
|                     | 1643.2\(^a\) | 1651.24\(^b\)     | 1660.22\(^b\)       | 1512.24\(^a\)       | 1618.98               |
| Gitilo              | 1638.88\(^b\) | 1643.08\(^b\)     | 1656.57\(^b\)       | 1525.79\(^c\)       | 1616.08               |
| Mean                | 1641.04   | 1647.16               | 1658.39              | 1519.02              | 1622.53               |
| DMRT(0.05)          | 99.5      | CV(%)=12.06           |                       |                       |                       |

|                     | Seed rates |                       |                       |                       |                       |                       |
|                     | 20 kg ha\(^{-1}\) | 25 kg ha\(^{-1}\) | 30 kg ha\(^{-1}\) | 35 kg ha\(^{-1}\) | 40 kg ha\(^{-1}\) | Mean                  |
| Sites               | Harato     |                       |                       |                       |                       |                       |
|                     | 1335\(^c\)   | 1492\(^c\)           | 1671\(^c\)           | 1772\(^d\)           | 1864\(^b\)           | 1626.8                |
| Gitilo              | 1356\(^c\)   | 1494\(^c\)           | 1678\(^c\)           | 1776\(^d\)           | 1774\(^d\)           | 1615.6                |
| Mean                | 1345.5     | 1493                 | 1674.5               | 1774                 | 1819                 | 1621.2                |
| DMRT(0.05)          | 49.96      | CV(%)=5.4             |                       |                       |                       |                       |

Mean within column followed by the same letters are non-significant difference at (p > 0.05) level, DMRT = Duncan multiple range test, CV(%) = Coefficient of variation
causes pollen abortion. Oil percentage of linseed varieties were decreased due to competition effects (Andruszczak et al., 2015); (Elayan Sohair et al., 2015). But these effects of lower oil contents were compensated by the reverse effects of seed yields, as depicted in Table 2.

As seed rates increased from 20 to 40 kg ha⁻¹, oil percentage was decreased on average from 39.82 to 36.78%. These effects could be due to competition effects as plant population decreased; fewer plants could have ample resources to fill the seeds with more oils. But, seed rates above 35 kg ha⁻¹ were not statistically significant for oil percentages across sites, years, and varieties; this implies the seed rate is at optimum level.

Statistically, the oil percentage of improved varieties did not significantly differ among sites and cropping seasons (Table 3). Minimum oil percentage was obtained from local cultivars on Gitilo site at both cropping season and on Harato site in 2019 growing year, respectively. Local cultivar was poor in wider environment adaptation, resource use efficiency, and smaller seed size. The current result is in agreement with that of (Sakatu et al., 2020).

Across the two sites, the maximum oil percentage (40.69%) was recorded from Harato at the seed rates of 20 kg ha⁻¹, while the minimum (36.66%) and (36.9%) were from 40 kg ha⁻¹ seed rates at Harato and Gitilo sites (Figure 4). Generally, the Harato site has shown more oil contents than Gitilo this may be due to its optimum amount of rainfall and radiant energy received. Bayrak et al. (2010) reported that the oil percentage of different linseed varieties grown at different agro-climatic zones was ranging from 23.28% to 46%. The oil contents of linseed were significantly influenced by genotypes, cropping season, and locations Choo et al. (2007), by agronomic practices (Klimek-Kopyra et al., 2016). In line with this result Bernacchia et al. (2022), and El-Beltagi et al. (2015), and Zanetti et al. (2018) found that higher and cooler elevations may offer more days for maturing and oil accumulation.
3.3. Oil yield (kg ha\(^{-1}\))

The mean values of oil yield were highly significantly (p < 0.01) influenced by varieties, seed rates, interactions of years by sites, and varieties by seed rates as shown in Table 1. Also, oil yield was significantly (p < 0.05) affected by replication, sites, and interaction of varieties by sites by years, varieties by years, and varieties by seed rates (Table 1).

The minimum oil yield of 497.9 kg ha\(^{-1}\) and 522.1 kg ha\(^{-1}\) had recorded from local cultivars at the seed rates of 20 kg ha\(^{-1}\) and 25 kg ha\(^{-1}\), respectively, and the maximum oil yield were obtained from improved varieties of Belay (686.6 kg ha\(^{-1}\)), Berene (687.1 kg ha\(^{-1}\)), and Kuma (688.1 kg ha\(^{-1}\)) at 35 kg ha\(^{-1}\), respectively (Table 4). This high oil yield was recorded from a mass of plants per plot area rather than a single plant. On the other side, at optimum seed rates, the improved varieties utilize growth resources as a result giving maximum oil yield, but under low plant density due to the occurrence of weed infestation, oil yield declined. In addition, increasing seed rate beyond the optimum levels declined the oil yield of linseed crops due to competition effect on growth resources as a result the number of branches and capsules per plant, thousand seed weight, and seed yields had decreased. Statistically, the oil yields of improved varieties had no significant different seed rates of 35 kg ha\(^{-1}\) and 40 kg ha\(^{-1}\). While increasing seed rate above 30 kg ha\(^{-1}\) did not show a significant difference in oil yield of local cultivars due to the compacted canopy nature and mutual shading effect. At higher seed rates, an individual plant may produce an optimum number of branches per plant, capsules per plant, and seeds per capsule due to severe competition for growth resources and reduced metabolites syntheses (Gabiana et al., 2005).

The amounts of oil yield obtained per hectare could vary due to the plant density of linseed at different sites and growing seasons. At higher plant density, oil yields could reduce due to competition effects for moisture and nutrients. In line with this, Mohammad et al. (2016) reported that low soil moisture limits the growth of a plant and enhances the physiological maturity period, consequently reducing the period of oil synthesis and deposition. But at lower plant density, linseed plants might be affected by weed competition, and the number of oil synthases could be limited (Andrusczczak et al., 2015). Elayan Sohair et al. (2015); Angelini et al. (2016) stated that oil yields were affected by study sites, moisture contents of soil, seeding times, and weather conditions. Therefore, managing soil moisture at adequate levels is essential to maximizing seed yield and oil contents of linseed (Gabiana et al., 2005; Zanetti et al., 2018).

Similarly, oil yield was affected by the interaction effect of varieties by sites by years (Table 4). However, statistically, there was a non-significant difference in oil yields among the improved varieties at both sites and cropping seasons (Table 4). These indicated that the number of weather conditions received at both locations is similar during the 2019/20 and 2020/21 cropping seasons. The differences between the two sites and seasons were not also significant, implying these improved varieties were more adapted to different environments as far as the oil yield is concerned (Table 4). Minimum oil yield was recorded on local cultivars at both sites and years because local seeds narrow environment adaptation.

The varietal effect and cropping years had a significant effect on oil yield (Table 4). Across the two years, the mean minimum oil yields of 557.19 kg ha\(^{-1}\) were recorded on local cultivars, but the mean maximum oil yields were recorded from improved varieties of Belay-96 (631.55 kg ha\(^{-1}\)),

![Figure 4. Interaction effect of seed rate by sites on oil percentage.](image-url)
Table 4. Effects of varieties by seed rates on oil yield of linseed at Harato and Gitilo sites in 2019/20 and 2020/21

| Seed rate | Varieties | Belay -96 | Berene | Kuma | Local | Mean |
|-----------|-----------|-----------|--------|------|-------|-------|
| 20 kg ha^{-1} | | 532^a | 542.7^bc | 564.2^cd | 497.9^ef | 534.20 |
| 25 kg ha^{-1} | | 598.7^f | 600.3^ef | 616.6^f | 522.1^gh | 584.43 |
| 30 kg ha^{-1} | | 646.7^g | 665.3^gh | 683.5^hi | 584^gh | 644.88 |
| 35 kg ha^{-1} | | 686.6^hi | 687.1^hi | 688.7^hi | 596.2^hi | 664.50 |
| 40 kg ha^{-1} | | 693.4^hi | 687.1^hi | 701.1^i | 585.8^gh | 666.85 |
| Mean | | 631.48 | 636.5 | 650.7 | 557.2 | 618.95 |

DMRT(0.05) 25.82 CV(%) = 5.2

Varieties

| Sites | Year | Belay -96 | Berene | Kuma | Local | Mean |
|-------|------|-----------|--------|------|-------|-------|
| Harato | 2019/20 | 653.60^cd | 664.92^cd | 667.49^d | 549.41^a | 633.86 |
| | 2020/21 | 624.01^cd | 626.88^cd | 637.69^cd | 576.29^ab | 616.22 |
| Gitilo | 2019/20 | 613.18^cd | 616.49^cd | 639.60^cd | 539.41^a | 602.23 |
| | 2020/21 | 635.41^cd | 638.42^cd | 657.79^cd | 563.65^a | 623.82 |
| Mean | | 631.55 | 636.68 | 650.64 | 557.19 | 619.03 |

DMRT(0.05) 44.04 CV(%) = 9.89

| Years | Belay -96 | Berene | Kuma | Local | Mean |
|-------|-----------|--------|------|-------|-------|
| 2019/20 | 633.38^o | 640.70^o | 653.64^o | 544.40^a | 618.03 |
| 2020/21 | 629.71^p | 632.65^p | 647.74^p | 569.97^p | 620.02 |
| Mean | | 631.55 | 636.68 | 650.69 | 557.19 | 619.18 |

DMRT(0.05) 31.36 CV(%) = 9.96

Mean within column followed by the same letters are none-significant difference at (p 0.05) levels, DMRT = Duncan multiple range test, CV(%) = Coefficient of variation.

Berene (636.68 kg ha^{-1}), and Kuma (650.69 kg ha^{-1}), respectively (Table 4). These could be due to genetic differences, improved seeds have elongated root systems, and better resource use ability than local seed this favor plants for taller, and the maximum number of branches and capsules per plant. But, the local cultivar was a short root system, plant height, and few capsules per. In contrast, Sakatu et al. (2020) observed that seed rates did not affect the oil yield of linseed.

3.4. Number of capsules per plant

The mean values of capsules per plant were highly significantly (p < 0.01) affected by the varieties, sites, years, replication, and interaction of sites by years, and seed rates by years. Moreover, the interaction effect of seed rates by sites was significantly (p < 0.05) influenced by the number of capsules per plant (Table 1). The average maximum number of capsules per plant (44.24) was counted at the Gitilo site, and the average minimum (38.48) was record at the Harato site at different seed rates (Table 5). These could be due to variations in altitudinal difference, weather conditions, plant population, and fertility status. Increasing the seed rate from 25 kg ha^{-1} to 40 kg ha^{-1} decreased the average number of capsules from 46.01 to 31.13 at both site, this could be due to the competition effect. The Gitilo site received low temperature and optimum soil moisture due to this plant continuously flowering and giving more capsules per plant. But, the Harato site received optimum temperatures the plants complete their life cycle within a time. On the other side, increasing seed rate declined the number of capsules per plant at both sites due to the competition effect. The present result in agreement with (Franklin et al., 2010). Yasemin et al. (2016) found that a maximum number of capsules per plant had recorded in the 2014/15 cropping season rather than 2015/16.
Table 5. Effect of seed rates by sites and seed rates by years on number of capsules per plant at Harato and Gitilo sites in 2019/20 and 2020/21

| Seed rate | Sites       | 20 kg ha⁻¹ | 25 kg ha⁻¹ | 30 kg ha⁻¹ | 35 kg ha⁻¹ | 40 kg ha⁻¹ | Mean  |
|-----------|-------------|------------|------------|------------|------------|------------|-------|
|           | Harato      | 43.79abc   | 45.53abc   | 40.28cde   | 34.75cde   | 28.07a     | 38.48 |
|           | Gitilo      | 46.79abc   | 46.69abc   | 46.52abc   | 42.83cde   | 38.55bc    | 44.24 |
| Mean      |             | 45.29      | 46.01      | 43.4       | 38.79      | 33.31      | 41.36 |
| DMRT(0.05)|             | 5.28       |            |            |            |            |       |
| CV(%)     |             | 7.82       |            |            |            |            |       |

| Seed rate | Year        | 20 kg ha⁻¹ | 25 kg ha⁻¹ | 30 kg ha⁻¹ | 35 kg ha⁻¹ | 40 kg ha⁻¹ | Mean  |
|-----------|-------------|------------|------------|------------|------------|------------|-------|
|           | 2019/20     | 45.81abc   | 48.51abc   | 48.15abc   | 43.86abc   | 38.25bc    | 44.92 |
|           | 2020/21     | 44.78abc   | 43.51abc   | 38.65abc   | 33.72abc   | 28.37abc   | 37.81 |
| Mean      |             | 45.29      | 46.01      | 43.4       | 38.79      | 33.31      | 41.37 |
| DMRT(0.05)|             | 5.13       |            |            |            |            |       |
| CV(%)     |             | 12.82      |            |            |            |            |       |

Mean within column followed by the same letters non significant at (p = 0.05) levels DMRT = Duncan multiple range test, CV(%) = Coefficient of variation

In addition, the number of capsules per plant had significantly influenced by interaction of seed rates by years (Table 5). Increasing seed rates from 20 kg ha⁻¹ to 40 kg ha⁻¹ decreased the average number of capsules per plant from 45.29 to 33.31 in both years. This might be due to the competition effect among plants. At a low seed rate, the number of capsules per plant was high due to enough space between plants and less competition. While increasing seed rates beyond 35 kg ha⁻¹ and 25 kg ha⁻¹ decreased the number of capsules per plant in 2019/20 and 2020/21 years, due to the high competition effect among plants for growth resources. On the other hand, a high plant population per plot causes suffocation and mutual shading as a result, few branches and low number of capsules per plant. Likewise, the 2019/20 cropping season was more suitable for plant growth than 2020/21. Abd El-Mohsen et al. (2013), Jakusko et al. (2013), and Mequanint et al. (2010) also found that growth parameters and capsules per plant were high at a low seed rate. In contrast to this finding, Salah and Mohamed (2015) noticed that seed rate did not affect the number of capsules per plant.

3.5. Thousand seed weight (g)
The mean values of thousand seed weight were significantly (p < 0.05) affected by the main effects of varieties, seed rates, and sites (Figure 5). Gitilo site produced higher thousand seed weight than Harato site could be due to cool daily temperature. The evapo-transpiration rates were declined at growth stage. But Harato site received high daily temperature during reproductive stage then the plant was injured due to water stress and pollen abortion and irregular seed filling happened as a result the seed shrunk small in size and lighter weight.

Thousand seed weight was affected by the main effect of seed rates (Figure 5). The maximum amount of thousand seed weight was recorded from 20 kg ha⁻¹. But, increasing seed rates above 35 kg ha⁻¹ reduced thousand seed weight of linseed crops due to high plant population per plot and increase competition among plants for growth resources (nutrient, space, and moisture), as a result of small seed size, and lighter in seed weight. The present result in agreement with Abebe and Adane (2016); Mequanint et al. (2010) reported that increasing seed rates, beyond the optimum rates declined thousand seed weights. El Naim et al. (2012); Mukesh et al. (2017) indicated that thousand seed weights of sesame and sunflowers were affected by seed rate. Veselinka et al. (2014) reported that increasing seed rate gave maximum thousand seed weight.
on wheat plants at different cropping seasons. In contrast to the present finding, Njuguna et al. (2017) reported that seed rates had no significant effect on the thousand seed weight of linseed.

Thousand seed weight was significantly affected by the main effect of linseed varieties (Figure 5). Improved varieties of Belay (6.23 g), Berene (6.31 g), and Kuma (6.48 g) gave maximum thousand seed weight than local cultivars (4.48 g), due to broad environment adaptation, high resource use efficiency, and genotypic characteristic. While the local cultivar complete their life cycle within a short period than other varieties, due to short root system this may affect plants to develop membranes layers and create smaller seed size. The present results agree with Abebe and Adane (2016); Barbara et al. (2020) who reported thousand seed weight was significantly affected by linseed varieties.

3.6. Above ground dry biomass (kg ha⁻¹)

The analysis of variance in (Table 1) indicated that dry biomass yield was highly significantly (p < 0.01) influenced by seed rates, varieties, replications, sites by years, seed rates by years, and seed rates by sites by years. Other factors such as sites, seed rates, varieties by seed rates, seed rates, and sites had significantly (p < 0.05) influenced dry biomass (Table 1).

The highest dry biomass yield was recorded from improved varieties of Belay-96 (5906.77 kg ha⁻¹ and 6099.49 kg ha⁻¹), Berene (5956.11 kg ha⁻¹ and 6078.93 kg ha⁻¹), and Kuma (5994.91 kg ha⁻¹ and 6123.63 kg ha⁻¹) at 35 kg ha⁻¹ and 40 kg ha⁻¹ seed rates, respectively (Table 6). But, the lowest of 3334.29 kg ha⁻¹ and 3549.08 kg ha⁻¹ were registered on Local and Belay-96 varieties at 20 kg ha⁻¹ seed rates, respectively (Table 6). This could be due to genetic makeup, plant density, and interaction. Improved varieties are broad environment adaptation and high nutrient use efficiency; this may help plants to a taller height, inflorescence length, high thousand seed weight, and grain yield. Increasing seed rates had given maximum dry biomass yield on linseed crops because maximum dry biomass was obtained from individual plants, not from single plants. Statistically, there was no significant difference in dry biomass yields of linseed varieties at 35 kg ha⁻¹ and 40 kg ha⁻¹. Birhanu (2014); Veselinka et al. (2014) reported that the dry biomass of linseed genotypes varies at both sites and cropping seasons.

Likewise, dry biomass yield was significantly (p < 0.05) influenced by the interaction of seed rate sites by the years (Table 6b 7). Minimum dry biomass yield of 3267 kg ha⁻¹ and 3171 kg ha⁻¹ was recorded at a 20 kg ha⁻¹ seed rate on the Harato site in 2020/21 and Gitilo site in the 2019/20 growing seasons; this could be due to low plant density and variation of weather conditions. Moreover, in the 2020/21 cropping season, the Harato site received lower rainfall which caused water stress during vegetative growth; this may face wilting injuries and decrease the dry biomass yield. On the other hand, dry biomass yields are either directly affected by weather conditions and altitudes or indirectly influenced by plant density. In contrast to this study, Gidey et al. (2020); Omer et al. (2020) also found that maximum dry biomass yield registered at broad row spacing due to higher production of tillers in rice crops.

In most cases, the average maximum dry biomass yield of 5803.75 kg ha⁻¹ and 5998.75 kg ha⁻¹ was obtained at 35 kg ha⁻¹ and 40 kg ha⁻¹ at both sites and years.
Increasing seed rates beyond 35 kg ha\(^{-1}\) did not have a positive relationship with dry biomass at both sites and seasons because high plant density leads to lodging, and the competition effect resulting decreases the number of branches and capsules per plant. 35 kg ha\(^{-1}\) was significantly different from 20 kg ha\(^{-1}\), 25 kg ha\(^{-1}\), and 30 kg ha\(^{-1}\) seed rates, but as par with 40 kg ha\(^{-1}\). Therefore, high dry biomass yield was obtained from the individual plants, not from the number of branches per plant. Birhanu (2014) reported different genotypes of linseed did not show significant differences in dry biomass yield in moisture stress areas. In line with this study, Abd El-Mohsen et al. (2013) noticed that high plant density assists plants in effectively utilizing growth resources and elongating their root and shoot systems, resulting increase in dry biomass yield.

### 3.7. Straw yield kg ha\(^{-1}\)

The analysis of variance in Table 1 revealed that straw yields were highly significantly (\(P < 0.01\)) affected by varieties, seed rate, sites by years, and seed rates by sites by years (Table 1). While other factors such as varieties by seed rates, seed rates by sites, and years significantly (\(p < 0.05\)) influence straw yield (Table 1).

The lowest straw yield was obtained from improved varieties of Belay-96 (2184.97 kg ha\(^{-1}\)), Berene (2273.71 kg ha\(^{-1}\)), Kuma (2305.72 kg ha\(^{-1}\)), and local cultivar (2081.72 kg ha\(^{-1}\)) at 20 kg ha\(^{-1}\) seed rate (Table 6). This may be at less plant density within a plot; the weeds infestation was severe. But, the maximum straw yield was recorded from improved varieties of linseed at 35 kg ha\(^{-1}\) and 40 kg ha\(^{-1}\). Improved varieties give maximum straw yield at high plant density. 35 kg ha\(^{-1}\) seed rate was significantly different from 20 kg ha\(^{-1}\), 25 kg ha\(^{-1}\), and 30 kg ha\(^{-1}\) seed rate on straw yields, but 35 kg ha\(^{-1}\) as par with 40 kg ha\(^{-1}\) seed rate on linseed varieties.

In most cases, the highest straw yield was obtained from 35 kg ha\(^{-1}\) seed rates in the 2019/20 cropping seasons at both site and in the 2020/21 cropping seasons at Gitilo sites, respectively (Table 6b). 35 kg ha\(^{-1}\) seed rate was superior on straw yield than 20 kg ha\(^{-1}\), 25 kg ha\(^{-1}\), and 30 kg ha\(^{-1}\), but not differ from 40 kg ha\(^{-1}\) seed rates at both sites and years. Increasing seed rates above

### Table 6a. Effects of seed rates and varieties on dry biomass, straw yield and harvest index at the two sites, 2019/20 and 2020/21

| Seed rates | Dry biomass | Straw yield | Harvest index |
|------------|-------------|-------------|---------------|
| Varieties  | 20 kg ha\(^{-1}\) | 25 kg ha\(^{-1}\) | 30 kg ha\(^{-1}\) | 35 kg ha\(^{-1}\) | 40 kg ha\(^{-1}\) | Mean |
| Belay      | 3549.08\(^{ab}\) | 4394.29\(^{ad}\) | 5260.38\(^{f}\) | 5906.77\(^{xy}\) | 6099.49\(^{d}\) | 5042.01 |
| Berene     | 3632.43\(^{b}\) | 4415.73\(^{ad}\) | 5385.57\(^{f}\) | 5956.11\(^{xy}\) | 6078.93\(^{d}\) | 5093.35 |
| Kuma       | 3665.34\(^{b}\) | 4515\(^{ad}\) | 5442.44\(^{g}\) | 5994.91\(^{xy}\) | 6123.63\(^{i}\) | 5148.26 |
| Local      | 3334.29\(^{a}\) | 4106.36\(^{a}\) | 4923.69\(^{f}\) | 5355.45\(^{f}\) | 5689.96\(^{gh}\) | 4681.95 |
| Mean       | 3545.29 | 4357.85 | 5252.44 | 5803.31 | 5998.0 | 4991.39 |
| DMRT (0.05) = 282.4 | CV(%) = 7.02 | | | | |

| Varieties  | 20 kg ha\(^{-1}\) | 25 kg ha\(^{-1}\) | 30 kg ha\(^{-1}\) | 35 kg ha\(^{-1}\) | 40 kg ha\(^{-1}\) | Mean |
|------------|------------------|------------------|------------------|------------------|------------------|------|
| Belay      | 2184.97\(^{a}\) | 2812.41\(^{b}\) | 3447.28\(^{cd}\) | 4105.48\(^{gh}\) | 4254.56\(^{g}\) | 3360.94 |
| Berene     | 2273.71\(^{a}\) | 2812.41\(^{b}\) | 3599.31\(^{cd}\) | 4117.27\(^{gh}\) | 4242.22\(^{g}\) | 3408.78 |
| Kuma       | 2305.72\(^{a}\) | 2961.19\(^{b}\) | 3630.50\(^{cd}\) | 4104.67\(^{gh}\) | 4255.19\(^{g}\) | 3451.45 |
| Local      | 2081.72\(^{a}\) | 2676.88\(^{b}\) | 3324.23\(^{c}\) | 3676.33\(^{cd}\) | 3872.48\(^{ef}\) | 3126.46 |
| Mean       | 2211.53 | 2815.72 | 3500.33 | 4000.93 | 4155.86 | 3336.91 |
| DMRT (0.05) = 286.8 | CV(%) = 10.6 | | | | |

The mean followed by the same letters are non significant effect at (\(P 0.05\)), DMRT = Duncan multiple range test, CV (%) = Coefficient of variation.
Table 6b. Effects of seed rates on dry biomass, straw yield and harvest index at the two sites, 2019/20 and 2020/21

| Sites  | Treatment | Years | 20 kg ha\(^{-1}\) | 25 kg ha\(^{-1}\) | 30 kg ha\(^{-1}\) | 35 kg ha\(^{-1}\) | 40 kg ha\(^{-1}\) | Mean   |
|--------|-----------|-------|-----------------|-----------------|-----------------|-----------------|-----------------|--------|
| Harato | 2019/20   | 3838b | 4654d           | 5416f           | 5932g           | 6091g           | 5186.2          |
|        | 2020/21   | 3267a | 4164c           | 4947a           | 5518f           | 5976g           | 4774.4          |
| Gitilo | 2019/20   | 3171a | 4064hc          | 5370f           | 5939g           | 6016g           | 4912           |
|        | 2020/21   | 3922bc| 4551d           | 5268f           | 5826g           | 5912g           | 5096.2          |
| Mean   |           |       | 3549.5          | 4358.25         | 5250.25         | 5803.75         | 5998.75         | 4992.2          |
| DMRT(0.05) |      | 263.8 | CV(%) = 6.4     |                 |                 |                 |                 |        |

The mean followed by the same letters are non significant effect at (P > 0.05), DMRT = Duncan multiple range test, CV (%) = Coefficient of variation

35 kg ha\(^{-1}\) reduce straw yield due to the competition effect among linseed plants. The competition of crops with weeds was severe at low plant density and resulting in short height, less number of branches per plant, and low straw yield.

The mean maximum straw yield of 3544.6 kg ha\(^{-1}\) were registered from the Harato site in 2019/20 years, but the minimum of 3101.1 kg ha\(^{-1}\) was record on the Harato in the 2020/21 cropping season (Table 7). The difference could be due to the variation of weather conditions on the same site at different seasons. The current findings agreed with Salah and Mohamed (2015), who found that increasing seed rate increased straw yield on a linseed crop. Zelalem et al. (2013) found that maximum straw yields obtained from high seed rates of rice crops. Grant et al. (1999) reported that the mean performance of straw yield of flax was affected by phosphorus fertilizers source. Anastasiou et al. (2016); Gabiana et al. (2005) found that high temperature influenced on straw yield of linseed. In the 2019/20 cropping season, the weather condition of the Harato site was more suitable for growth and yield attributes but in 2020/21 growing season was conducive for the Gitilo site. This variation might be due to the variability of weather conditions across the sites, and different cropping seasons. The low straw yields of 1983 kg ha\(^{-1}\) and 1858 kg ha\(^{-1}\) were obtained from 20 kg ha\(^{-1}\) seed rates at both sites and seasons. Kandil et al. (2008) straw yield of linseed genotypes didn’t similar at different seed rates and cropping seasons.

3.8. Partial budget analysis

Partial and marginal budget analysis treatment to be considered a worthwhile option for farmers, the marginal rate of return (MRR) needs to be at least between 50% and 100% (CIMMYT, 2007). Partial budget analysis revealed that the seed rate of 35 kg ha\(^{-1}\) on the Kuma variety had given the maximum cost-benefit ratio of 5.53, while the lowest net benefit cost was recorded on linseed crops at 20 kg ha\(^{-1}\) seed rate, respectively (Table 7). Linseed varieties are more productive at a higher seed rate due to being more competitive with weeds and high nutrient use efficiency. In line with this study, Sakatu et al. (2020) reported that maximum net benefit was recorded at 30 kg ha\(^{-1}\) seed rates and 40 kg N ha\(^{-1}\) on linseed crops. In addition, Reta et al. (2020) found that high
Table 7. Partial budget analysis of seed rate and linseed varieties in 2019/20 and 2020/21 at both sites

| Seed rate (kg ha⁻¹) | Varieties | Average yield (Qt ha⁻¹) | Adj yield (Qt ha⁻¹) | Gross yield (ET Birr) | Seed cost ET Birr | Labor cost ET Birr | Total cost ET Birr | Net benefit ET Birr | Benefit ratio |
|---------------------|-----------|-------------------------|---------------------|-----------------------|------------------|-------------------|-------------------|-------------------|---------------|
| 20                  | 1         | 13.44                   | 12.10               | 42,350                | 900              | 7200              | 8100              | 34,250           | 4.23          |
| 20                  | 2         | 13.59                   | 12.23               | 42,805                | 900              | 7200              | 8100              | 34,705           | 4.28          |
| 20                  | 3         | 13.67                   | 12.30               | 43,050                | 900              | 7200              | 8100              | 34,950           | 4.31          |
| 20                  | 4         | 13.13                   | 11.82               | 41,370                | 900              | 7200              | 8100              | 33,270           | 4.11          |
| 25                  | 1         | 15.12                   | 13.61               | 47,635                | 1125             | 7200              | 8325              | 39,310           | 4.72          |
| 25                  | 2         | 15.14                   | 13.63               | 47,705                | 1125             | 7200              | 8325              | 39,380           | 4.73          |
| 25                  | 3         | 15.21                   | 13.69               | 47,915                | 1125             | 7200              | 8325              | 39,590           | 4.76          |
| 25                  | 4         | 14.26                   | 12.83               | 44,905                | 1125             | 7200              | 8325              | 36,355           | 4.37          |
| 30                  | 1         | 16.78                   | 15.10               | 52,850                | 1350             | 7200              | 8550              | 44,300           | 5.18          |
| 30                  | 2         | 17.03                   | 15.33               | 53,655                | 1350             | 7200              | 8550              | 45,105           | 5.28          |
| 30                  | 3         | 17.19                   | 15.47               | 54,145                | 1350             | 7200              | 8550              | 45,595           | 5.33          |
| 30                  | 4         | 15.98                   | 14.38               | 50,330                | 1350             | 7200              | 8550              | 41,555           | 4.86          |
| 35                  | 1         | 18.12                   | 16.31               | 57,085                | 1575             | 7200              | 8775              | 48,310           | 5.51          |
| 35                  | 2         | 18.08                   | 16.27               | 56,945                | 1575             | 7200              | 8775              | 48,170           | 5.49          |
| 35                  | 3         | 18.19                   | 16.37               | 57,295                | 1575             | 7200              | 8775              | 48,520           | 5.53          |
| 35                  | 4         | 16.58                   | 14.92               | 52,220                | 1575             | 7200              | 8775              | 43,445           | 4.95          |
| 40                  | 1         | 18.54                   | 16.69               | 58,415                | 1800             | 7200              | 9000              | 49,415           | 5.49          |
| 40                  | 2         | 18.53                   | 16.68               | 58,380                | 1800             | 7200              | 9000              | 49,380           | 5.49          |
| 40                  | 3         | 18.69                   | 16.82               | 58,870                | 1800             | 7200              | 9000              | 49,870           | 5.34          |
| 40                  | 4         | 17.01                   | 15.31               | 53,585                | 1800             | 7200              | 9000              | 44,585           | 4.95          |

Grain seed prices = 35 ETB kg⁻¹, linseed seed price = 45ETB kg⁻¹, labor cost = 70 ETB per man days, GFB = Gross field benefit, Av = Average yield, Qt = Quintal (1Qt = 100 kg)

net benefit was registered at seed rates of 30 kg ha⁻¹ and 150 kg N ha⁻¹ on linseed crops. While Abebe and Adane (2016) found a maximum net benefit for linseed crops at the seed rates of 40 kg ha⁻¹ during the row sowing method at different sites and cropping seasons.

4. Summary conclusion and recommendation

The maximum seed yield was obtained from improved varieties of Kuma (1819 kg ha⁻¹) at the seed rates of 35 kg ha⁻¹. But improved varieties and local cultivar gave minimum seed yield at 20 kg ha⁻¹ seed rate. The highest oil percentage 41.38% was recorded from Kuma variety at 20 kg ha⁻¹, but the lowest oil percentage (35.15% and 35.96%) had obtained from local cultivar at 35 kg ha⁻¹ and 40 kg ha⁻¹, respectively. The seed yield and oil percentage of improved varieties had not varied across the sites. The maximum net benefit registered from improved varieties of Kuma (48,520 ET Birr); Belay (48,310 ET Birr), and Berene (48,170 ET Birr) at 35 kg ha⁻¹. Therefore, sowing Kuma variety at 35 kg ha⁻₁ seed rate can be recommended at the study area.

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No potential conflict of interest was reported by the author(s).

Geo location information
The experiment conducted in 2019/20 and 2020/21 years, at Haroto and Gitilo sites. Haroto site found in Jima Geneti district at an altitude of 2300 masl latitude 9 22’ 00” and Longitude 37 07’ 00”. Gitilo site found in Gitilo date village of Horo district at an altitude of 2723 masl. Both sites located in Horo Guduru Wollega Zone, Western Ethiopia. Both districts have three agro-ecological classifications: high land area, mid-altitude, and low land. The major crops cultivated in the study areas like cereals, pulse, and high land oil crops like Nger seed, linseed, and rape seed.

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References
Abd El-Mohsen, A. A., Abdallah, A. M., & Mahmoud, G. O. (2013). Optimizing and describing the influence of planting dates and seeding rates on flax cultivars under Middle Egypt region conditions. World Essays Journal, 11, 142–152. http://www.iiste.org
Abebe, D., & Adane, C. (2016). Response of Linseed (Linum usitatissimum L.) to seed rates and seeding methods in South-Eastern Highlands of Ethiopia. Journal of Biology, Agriculture and Healthcare, 5(6–6), 13. http://www.iiste.org
Alexopoulou, E., & Christou, M. (2011). Crops industry: Oil crops that can be produced in EU27. CRES-Center for Renewable Energy Sources, 100.
Alonso, D. L., & Maroto, F. G. (2000). Plants as ‘chemical factories’ for the production of polysaturated fatty acids. Biotechnology Advances, 18(6), 481–497. https://doi.org/10.1016/S0734-9700(00)00048-3
Anastasiou, A. E., Chira, N. A., Banub, L., Jonescuc, N., Stana, R., & Roscaoa, S. I. (2016). Oil productivity of seven romanian linseed varieties as affected by weathern conditions. Ind.CropsProd, 187, 219–230. https://doi.org/10.1016/j.indcrop.2016.03.051
Andruszczak, S., Gowlik-Dziuki, U., K, P., Kwiecien, S. E., Polys, E., & Polys, E. (2015). Yield and quality traits of two linseed (Linum usitatissimum L) cultivars as affected by some agronomic factors. Plant, Soil and Environment, 61 (No. 6), 247–252. https://doi.org/10.17211/11202015
Angelini, L. G., Tavolini, S., Antichi, D., Foschi, L., & Mazzoncin, M. (2016). On-farm evaluation of seed yield and oil quality of linseed (Linum usitatissimum L) in Irianland Areas of Tuscany, Central Italy. Italian Journal of Agronomy, 11(3), 2039-6805.
Ayaz, A. P., Hidayat, A. P., Ghulam, M. L., Arshad, A. K., Mukesh, K. S., Jagdev, K. S., Muhammad, M. R., Afsarullah, A., & Jay, K. S. (2017). Effects of seed rates on the growth and yield of different sunflower varieties. Pure and Applied Biology, 6(4), 1189–1197. http://dx.doi.org/10.19045/bspb.2017.600127
Barbara, C., Salo, S., Aleš, H., & Anita, K. (2020). Impact of linseed variety, location and production. year on seed yield, oil content and its composition. Agronomy Journal, 10(11), 1770. https://doi.org/10.3939/agronomy10111770
Bayrok, A., Kiralan, M., Ipek, A., Arslan, N., Cosge, B., & Khawar, K. M. (2010). Fatty acid compositions of linseed (Linum usitatissimum L.) genotypes of different origin cultivated in Turkey. Biotechnology and Biotechnological Equipment, 24(2), 1836–1842. https://doi.org/10.2478/bbme2008.0287
Bekele, G., Atok, M., Boenziger, P. S., Nelson, L. A., Boltenespeger, D. D., Eskridge, K. M., Shipman, J. M., & Shelton, D. R. (2002). Seeding rate and genotype effect on agronomic performance and end-use quality of winter wheat. Crop Science, 42(3), 827–832. https://doi.org/10.2135/cropsci2002.0827
Berhanu, S., Meaza, T., & Shimeles, M. (2002). Registration of “Welen”, a newly released linseed variety for highlands of Ethiopia. European Journal of Biophysics, 10(1), 12–15. https://doi.org/10.11648/j.ejeb.20221001.14
Bernacchia, R., Preti, R., & Vinci, G. (2011). Chemical composition and health benefits of flaxseed. Austin Journal of Nutrition and Food Sciences, 2, 1045. https://doi.org/10.4172/2155-9610.1000177
Birhanu, A. G. (2020). Yield evaluation and character association of linseed (Linum usitatissimum L.) genotypes in moisture stress areas of South Tigray, Ethiopia. Journal of Cereals and Oilsides, 11(1), 16–20. https://doi.org/10.5897/JCO202010208
Choo, W. S., Brich, J., & Dufour, J. P. (2007). Physicochemical and quality characteristics of cold-pressed flaxseed oils. Journal Food Composition and Analysis, 20(3), 202–211. https://doi.org/10.1016/j.jfca.2006.12.002
CIMMYT. (1989). From agronomic data to farmers recommendation: An economic training manual. (Revised Edition.). F. Google scholar.
CSA (Central Statistical Agency of Ethiopia). (2017). Agricultural sample survey report on area and production of crops. Statistics Bulletin, 1(584). 1. https://doier/10.2478/v10133-010-0034-2
Dabol, D. Y., Singh, C. S., & Weyesso, B. (2020). Genetic variability and association of characters in linseed (Linum usitatissimum L.) Plant Grown in Central Ethiopia Region. Saudi Journal of Biological Sciences, 27(8), 1922–2206. https://doi.org/10.1016/j.sjbs.2020.06.008
Demeke, L., & Tesfaye, B. (2021). Adaptation of improved linseed (Linum usitatissimum L.) varieties for seed yield in kafa and Benchmoji Zones of South Western Ethiopia. Bonga Agricultural Research Center, Bonga, Ethiopia. Asian Journal of Plant Science and Research, 11(1), 30–32. https://doi.org/10.36648/2249-7142.11.130-32
Eloyan Sohair, E. D., Abdallah, A., Naguib, M. A., & Mahmoud, D. I. (2015). Effect of sowing date on yield, fiber and seed quality of eight flax genotypes. American-Eurasian. Journal of Agriculture and Environmental Sciences, 15(1818–6769), 886–895. https://doi.org/10.3939/agronomy10111770
El-Beltagi, H. S., Salama, Z. A., & El-Hariri, D. M. (2011). Variations in oil and some phytochemical contents in flaxseed cultivars (Linum usitatissimum L.). Electronic Journal of Environmental, Agr. and Food Chemistry, 10 (8), 2711–2721. https://www.researchgate.net/publication/225070005
El Naim, A. M., Eldey, E. M., Jabbereldar, A. A., Ahmed, S. E., & Ahmed, A. A. (2012). Determination of suitable variety and seed rate of sesame in sand dunes of Kordofan. International Journal of Agriculture and
Forestry, 2(4), 175–179. https://doi.org/10.5923/j.efaf.20120204.08

Emam, S. M., & Dewdar, M. H. (2015). Seeding rates and phosphorus source effects on straw, seed and oil yields of flax (Linum usitatissimum L.) grown in newly reclaimed soils. International Journal of Current Microbiology and Applied Sciences, 4(3), 334–343. http://www.ijcmas.com

FAO (Food Agricultural Organization). (2017). FAOSTAT database: agricultural crops. The Food and Agriculture Organization of the United Nations.

Franklin, P., Gardner, R., Pearce, B., & Mitchell, R. L. (2010). Physiology of crop plants. Scientific Press.

Gabiano, C., McKenzie, B. A., & Hill, G. D. (2005). The influence of plant population nitrogen and irrigation on yield and yield components of linseed. Agronomy NZ, 35.

Gidey, B., Kohsay, K., & Kidane, N. (2020). Yield evaluation and character association of linseed (Linum usitatissimum L.) genotypes in moisture stress areas of South Tigray. Ethiopia, 11(2141–6591), 16–20. https://doi.org/10.5897/JC02020.0208

Gomez, R. A., & Gomez, A. A. (1984). Statistical procedures for agricultural research. John Wiley and Sons.

Grant, C. A., Dribnenki, J. C. P., & Belay, R. D. (1939). A comparison of the yield response of solin (cv. Linola 947) and flax ( cvs. McGregor and Viny) to application of nitrogen, phosphorus. Canadian Journal of Plant Science, 79(4), 527–533. https://doi.org/10.4141/P98-085

Horro Gudurro Wollega Zone (HOWZAB). (2018). Annual report of Agricultural Office.

Jakosuk, B. B., Usman, B. D., & Mustapha, A. B. (2013). Effect of row spacing on growing and yield of Sesame (Sesamum indicum L.) in Yola, Adamawa State, Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS), 2(3), 36–39. https://doi.org/10.9790/2380-0233639

Kandil, A. A., Hob Allah, A. A., El-Horri, D. M., Zeidan, M. S., & Bakri, A. B. (2008). Effect of seeding rate on yield and quality traits of some flax varieties (Linum usitatissimum L.) grown in newly reclaimed sandy soils. Egyptian Journal of Agricultural Research, 1(1), 69–81. https://www.researchgate.net/publication/264477191

Klein, J., Zikeli, S., Claupin, W., & Gruber, S. (2016). Linseed (Linum usitatissimum) as an oil crop in organic farming: Abiotic impacts on seed ingredients and yield. Organic Agriculture, 7(1), 1–19. https://doi.org/10.1007/s11105-016-0146-6

Klimek, K., Kopara, A., Zaja, c., T. Micke, P., & Borowiec, F. (2013). Effect of mineral fertilization and sowing rate on chemical composition of two linseed varieties. Journal of Agricultural Science, 5(1), 224–229. https://doi.org/10.5281/zenodo.1670691

Legesse, B. (2010). Genetic diversity study of linseed genotypes on acidic soil at Bedi trial site, Central Highlands of Ethiopia, MSc. Thesis, Addis Ababa University, Addis Ababa. http://etd.aau.edu.et/handle/123456789/5872

Mequanint, T., Daniel, T., & Yenus, O. (2020). Effects of seed rates and row spacing on yield and yield components of Linum usitatissimum L. at Dabat district of North Gondar Zone, Ethiopia. Journal of Applied Biotechnology & Bioengineering, 7(1), 1–5. https://doi.org/10.15406/jabb.2020.07.00208

Ministry of Agriculture and Natural Resource (MANR). (2016). Crop variety register (Issue No. 19). Addis Ababa: Plant Variety Release, Protection and Seed Quality Control Directorate.

Mohammad, M., Majnounhussein, N., Amiri, R., Moslehi, A., & Omid, R. Z. (2012). Effects of sowing date and limited irrigation water stress on spring safflower (Carthamus tinctorius L) quantitative traits.

Research Journal of Agricultural Science, 8(2), 100–112. www.SJR.fr

Mukesh, K. S., Ayaz, A. P., Jagdesh, K. S., Muhammad, M. R., Arshadullah, A., & Jay, K. S. (2017). Effects of seed rates on the growth and yield of different sunflower varieties. Bolan Society for Pure and Applied Biology, 6(4), 1189–1197. https://doi.org/10.19045/bpsob.2017.600127

Njungu, M. N., Munene, M., Mwangi, H. G., & Akua, A. K. (2014). Effect of seeding rates and nitrogen fertilizer on wheat grain yield on marginal areas of eastern Kenya. Kenya Agricultural Research Institute –Njoro NPBRC.

Omer, T. A., Amal, M. A., El-Borhomy, M. S., & El-Sadek, A. (2020). Effect of harvesting dates and seeding rates on yield and yield components of some flax varieties. Journal of Plant Production, 11(12), 1501–1505. https://doi.org/10.21608/jpp.2021.55272.1012

Oomah, B. (2001). Flaxseed as a functional food source. Journal of the Science of Food and Agriculture, 81(9), 889–894. https://doi.org/10.1002/jsfa.898

Reta, D., Tamiru, M., & Kissi, W. (2020). Effects of seeding rate and nitrogen fertilization on seed yield, oil content and yield components of Linseed (Linum usitatissimum L.) in the highlands of bale. American Journal of Plant Biology, 5(3), 45–49. https://doi.org/10.11648/j.ajpb.200503.13

Sakatu, H., Legesse, A., Abdissa, M., & Bitahun, M. (2021). Effects of varieties, nitrogen fertilization and seeding rate on growth, seed and oil yield of linseed. Ethiopian institute of agricultural research, p.o.box, 2003.

Ethiopia Journal of Natural Sciences Research. Addis Ababa, 12(15). 2224–3186 (Paper, . www.iiste.org

Salah, M. E., & Mohamed, D. H. D. (2013). Seeding rates and phosphorus source effects on straw, seed and oil yields of flax (Linum usitatissimum L.) grown in newly-reclaimed soils. International Journal of Current Microbiology and Applied Science, 4(3), 334–341. http://www.ijcmas.com

Veselinko, Z., Jelenov, B., Desimr, K., & Danico, M. (2014). Effect of seeding rate on grain quality of winter wheat. Chilean J. Agricultural Research, 74(1), 23–28. http://dx.doi.org/10.4067/S0718-58392014000100004

Worku, N., Heslop-Harrison, J. S., & Adugnu, W. (2015). Diversity in 198 Ethiopian Linseed (Linum Usitatissimum L.) accessions based on morphological characterization and oil characteristics. Genetic Resources and Crop Evolution, 62(1037–1053), 0925–9864. https://doi.org/10.1007/s10722-014-0207-1

Wossen, T., Anley, W., & Habbit, F. (2016). Participatory evaluation of improved varieties of linseed in Dabat District, Northwest highland of Ethiopia. International Journal of Life Sciences Research, 4(3), 100–105.

Yasemin, E., Selviye, Y., & Fadil, O. (2018). The effect of different seeding rates on grain yield and yield components in some flax (Linum usitatissimum L.) Varieties. International Journal of Environmental & Agricultural Research (IJEAR), 4(1), 1850–2454. https://journal-index.org

Zanetti, F., Monti, A., & Berti, M. T. (2013). Challenges and opportunities for new industrial oilseed crops in eu-27: a review. Industrial Crops and Products, 50(40), 580–595. https://doi.org/10.1016/J.INDCROP.203.08.030

Zeldern, T., Tilahun, T., & Habtamu, A. (2019). Effect of seed rate and row spacing on yield and yield components of rain fed lowland oryzasativa l. Variety. International Journal of Research Studies in Agricultural Sciences, 5(12), 18–26. https://doi.org/10.20431/254-6224.0512003
## APPENDIX

### Table A1. Experimental materials description

| S.No | Activities              | Linseed varieties |
|------|-------------------------|-------------------|
|      |                         | Belay-96 | Berene | Kuma | Local seed |
| 1    | Altitude masl           | 2000–2800 | 2000–2800 | 2000–2800 | 2200–2800 |
| 2    | Temperature (°C)        | 15–30     | 18–30  | 15–30 | 18–31     |
| 3    | Rain fall (mm)          | >800      | 700–1200 | 600–1100 | >500      |
| 4    | Row spacing (cm)        | 20        | 20     | 20    | 20        |
| 5    | Flower color            | pink      | blue   | blue  | Pink blue |
| 6    | Date of 90% maturity    | 140       | 141    | 160   | 130       |
| 7    | Plant height            | 78        | 80     | 85    | 45        |
| 8    | Sowing date             | June 15–25| June 15–25| June 15–25| June 20–30|
| 9    | Seed color              | brown     | brown  | brown | brown     |
| 10   | Yield: kun per ha⁻¹     | 16.8–18.9 | 16.17–19.5 | 18–20 | 14.3–17.8 |
| 11   | Thousand seed weight (gm)| 6.7    | 6.8    | 7.2   | 5.2       |
| 12   | Oil percentage          | 36.3      | 37     | 39.2  | NA        |
| 13   | Fertilizer rate NPS + Urea kg/ha | 23/23 kg ha⁻¹ | 23/23 kg ha⁻¹ | 23/23 kg ha⁻¹ | 23/23 kg ha⁻¹ |
| 14   | Diseases and insect pest resistance | Resistance to wilt, & rest | Resistance to rest | Resistance to wilt and rest |
| 15   | Releasing of Year       | 1996      | 2001   | 2016  |

Source (MoARD 1996, 2001 and 2006)
### Table A2. Treatment combination and coding of seed rates and varieties of linseed

| Factor A | Treatment | Coding |
|----------|-----------|--------|
| Seed rate | 20 kg ha⁻¹ | SR1 |
|           | 25 kg ha⁻¹ | SR2 |
|           | 30 kg ha⁻¹ | SR3 |
|           | 35 kg ha⁻¹ | SR4 |
|           | 40 kg ha⁻¹ | SR5 |

| Factor B | Varieties of linseed | Coding |
|----------|----------------------|--------|
|          | Belay-96             | V1     |
|          | Berene               | V2     |
|          | Kuma                 | V3     |
|          | Local                | V4     |

| Treat Com | no | Treat Com | no | Treat Com | no | Treat Com |
|-----------|----|-----------|----|-----------|----|-----------|
| 1         | SR1 V1 | 6 | SR2 V2 | 11 | SR3 V3 | 16 | SR4 V4 |
| 2         | SR1 V2 | 7 | SR2 V3 | 12 | SR3 V4 | 17 | SR5 V1 |
| 3         | SR1 V3 | 8 | SR2 V4 | 13 | SR4 V1 | 18 | SR5 V2 |
| 4         | SR1 V4 | 9 | SR3 V1 | 14 | SR4 V2 | 10 | SR5 V3 |
| 5         | SR2 V1 | 10 | SR3 V2 | 15 | SR4 V3 | 20 | SR5 V4 |