***Original Research Article***

**Adaptation and Yield Performance of Improved Linseed (*Linum usitatissimum* L.) Varieties Under Rainfed Conditions in the Somali Region, Ethiopia**

**Abstract**

Linseed (Linum usitatissimum L.) is a valuable oilseed crop widely grown across temperate and subtropical regions for its nutritional, industrial, and economic importance. Despite its potential, linseed remains underutilized and under-researched in Ethiopia’s Somali Region, where agro-ecological conditions and rainfed farming systems prevail. To address this gap, a field experiment was conducted during the 2023 main cropping season in the Fafan Zone to assess the adaptability and yield performance of five improved linseed varieties *Kuma, Furtu, Walin, Yaadamo*, and *Bekoju*-14, under rainfed conditions. The study employed a randomized complete block design (RCBD) with three replications. Key agronomic parameters, including days to flowering and maturity, plant height, number of capsules per plant, 1000-seed weight, and grain yield, were recorded and analyzed using Gen-Stat software (version 18.2).

The results indicated statistically significant differences (p < 0.05) among the varieties for all traits measured, except for plant height. Among the tested varieties, Kuma exhibited the highest performance, recording a grain yield of 2135 kg/ha, the highest number of capsules per plant (54), and the heaviest 1000-seed weight (12.0 g). In contrast, Yaadamo consistently showed the lowest values across most parameters, indicating poor adaptation to the local conditions. The superior performance of Kuma suggests its suitability for cultivation in the rainfed areas of the Fafan Zone. Based on these findings, Kuma is recommended for wider dissemination and production in the region to enhance oilseed crop productivity and diversify local agricultural systems. However, further on-farm and participatory variety selection trials are advised to validate its performance across different microenvironments and to encourage farmer adoption.

**Keywords**: linseed, varietal evaluation, yield traits, adaptation, Somali region

1. **Introduction**

Linseed (*Linum usitatissimum* L.), commonly known as flax, is a versatile and ancient oilseed crop belonging to the family *Linaceae*. Believed to have originated in the eastern Mediterranean basin and western Asia, linseed has been cultivated for thousands of years for both its oil-rich seeds and fibrous stalks (Adugna *et al*., 2004). Today, it is globally cultivated across diverse agro-ecological zones, particularly in temperate and subtropical climates, with major producers including Canada, India, Argentina, China, and the United States (Madhusudhan, 2009). The crop is highly valued not only for its nutritionally rich oil, abundant in omega-3 fatty acids and lignans, but also for its industrial uses in the manufacture of textiles, varnishes, linoleum, and paints.

In Ethiopia, linseed ranks as the third most important oilseed crop, following sesame (*Sesamum indicum*) and noug (*Guizotia abyssinica*), playing a significant role in both the national oilseed economy and household-level nutrition (Tsehay,*et al*, 2021). According to the Central Statistical Agency (CSA, 2012), linseed is cultivated on approximately 117,000 hectares annually, contributing over 15% of the national oilseed output. It is traditionally grown in the highland regions of Oromia, Amhara, and Tigray, where it serves as a key source of edible oil and household income. The seeds are consumed in various forms roasted, incorporated into local dishes, or processed into oil using traditional and semi-modern extraction methods (Geleta *et al* 2002).

Despite its multipurpose value, the national productivity of linseed remains low, mainly due to low adoption of improved varieties and minimal input usage. The Food and Agriculture Organization (FAO, 2010) estimates that less than 10% of linseed farmers in Ethiopia use certified improved seeds. Contributing factors include weak seed distribution systems, limited extension support, poor awareness of improved agronomic practices, and challenging environmental conditions. Consequently, many farmers rely on local varieties with low genetic potential and vulnerability to diseases and climate stressors.

The productivity challenge is even more pronounced in lowland and arid areas, such as the Somali Regional State, where linseed is not traditionally cultivated, and empirical data on its performance is virtually nonexistent. These regions typically face erratic rainfall, high temperatures, and poor soil fertility-factors that have historically limited the cultivation of non-traditional crops. However, with increasing efforts to diversify cropping systems and enhance resilience to climate variability, expanding oilseed cultivation, including linseed, into such areas has gained renewed interest. Such expansion holds potential for improving food and nutrition security and boosting rural incomes through cash crop production.

Nonetheless, the success of this strategy depends on a prior understanding of the adaptability and performance of improved linseed varieties under these unique environmental conditions. While several improved varieties have been developed in Ethiopia-featuring traits such as early maturity, drought tolerance, high oil content, and larger seed size, their performance has been extensively studied only in highland and mid-altitude zones, with limited evaluations in marginal environments like those in the Somali Region.

The Fafan Zone, located in the northern part of the Somali Region, presents a strategic opportunity to assess linseed adaptability under rainfed, semi-arid conditions. Generating localized performance data is essential for formulating evidence-based recommendations and guiding future agricultural development initiatives in the region.

Therefore, this study aims to address the existing knowledge gap by evaluating the agronomic performance and adaptability of selected improved linseed varieties under the rain-fed conditions of the Fafan Zone, Somali Region. The results are expected to inform varietal selection for expansion into similar agro-ecological zones and contribute to sustainable oilseed production in Ethiopia’s arid and semi-arid landscapes.

1. **METHODOLOGY**
	1. **Study Area and Experimental Setup**

The study was conducted during the 2023 main cropping season at the Golohajo experimental site, located within the Fafan Agricultural Research Center, in the Somali Region of Ethiopia. The site lies in a typical semi-arid agro-ecological zone, characterized by erratic and low rainfall distribution, moderate ambient temperatures, and the experimental site is characterized by sandy loam soil, which consists of a high proportion of sand mixed with smaller amounts of silt and clay. This texture provides good drainage and aeration, making it favorable for crop cultivation under proper nutrient and moisture management. The organic matter content was 1.98%, and total nitrogen was 0.13%, indicating low to moderate fertility. Available phosphorus was 3.21 ppm, considered low, while available potassium was relatively high at 1025 mg/kg. The cation exchange capacity (CEC) was 29.75 meq/100g, suggesting a moderate to high nutrient-holding capacity, which is favorable for supporting crop growth in sandy loam conditions.

The experiment was designed to evaluate the agronomic and phenological performance of five improved linseeds (*Linum usitatissimum* L.) varieties: *Kuma*, *Furtu*, *Walin*, *Yaadamo*, and *Bekoju-14*. A Randomized Complete Block Design (RCBD) was employed with three replications to account for potential variability across the experimental field. Each experimental unit consisted of ten rows, each 2 meters in length. The row-to-row and plant-to-plant spacing were maintained at 20 cm and 5 cm, respectively, after thinning. Thinning was performed after seedling establishment to ensure optimal plant density.

Standard and recommended agronomic practices were uniformly applied to all plots. These included seedbed preparation, weed control, and fertilizer application, following the nationally approved production package for linseed cultivation in Ethiopia.

* 1. **Trait Measurement and Data Analysis**

A range of phenological and agronomic parameters was measured to assess varietal performance. These included:

* Days to flowering (from sowing to the appearance of the first flower),
* Days to maturity (from sowing to 90% physiological maturity),
* Plant height (cm),
* Number of capsules per plant,
* Thousand-seed weight (g), and
* Grain yield (kg/ha).

Data collection was carried out by selecting five representative plants from the four central rows of each plot to minimize border effects and ensure the reliability of measurements. The collected data were subjected to analysis of variance (ANOVA) using GenStat statistical software, version 18.2. When significant differences among treatments were identified, means were separated using the Least Significant Difference (LSD) test at the 5% level of significance. The statistical approach adhered to the procedures outlined by Gomez and Gomez (1984), ensuring the validity and comparability of results.

1. **RESULTS AND DISCUSSION**
	1. **Phenology and Growth Traits**
* **Days to Flowering**

The analysis revealed a highly significant difference (p < 0.01) among the linseed varieties in terms of days to flowering, indicating substantial genetic variability. The variety Yaadamo was the earliest to flower, initiating bloom at 51 days, whereas *Bekoju-14* exhibited delayed flowering, averaging 56.33 days. This range in flowering time highlights the genetic diversity present among the tested genotypes. The findings are in agreement with Wossen et al. (2017), who similarly reported considerable genetic variation in flowering time among linseed cultivars. Early -flowering varieties like *Yaadamo* may be advantageous in regions with shorter rainy seasons or where terminal drought is a concern, while late-flowering types such as *Bekoju-14* may perform better in areas with extended growing periods. Thus, the selection of suitable varieties based on flowering time is crucial for synchronizing the crop's development with local environmental conditions and agronomic calendars.

* **Days to Maturity**

Significant differences (p < 0.05) were also observed in the number of days to maturity among the linseed varieties. The variety Kuma reached 90%physiological maturity at 101.3 days, representing the earliest maturing genotype, whereas Walin required a considerably longer duration, maturing at 116 days. These results are consistent with the observations of Akbar *et al*. (2003) in chickpea, where significant genotypic differences in maturity period were also reported. The variation in maturity duration is a critical factor in varietal selection, especially in regions with varying climate and rainfall patterns. Early-maturing varieties can escape end-of-season drought or frost, while later-maturing ones may benefit from longer periods of biomass accumulation and potentially higher yields under favorable conditions. Therefore, understanding and utilizing maturity differences can enhance yield stability and cropping system efficiency.

* **Plant Height (cm)**

Although the statistical analysis did not reveal a significant difference in plant height among the linseed varieties tested, observable numerical differences were present. The variety Walin recorded the greatest average height at 90.1 cm, while Yaadamo had the shortest stature at 79.7 cm. Despite the lack of statistical significance, these height differences could be influenced by environmental factors such as soil fertility, water availability, and planting density, which affect vegetative growth. Plant height is often associated with lodging resistance, biomass production, and ease of mechanical harvesting. As such, even non-significant trends in plant height may hold practical implications for varietal selection, especially under diverse agro-ecological settings. However, **Merga *et al*. (2023)** reported significant differences in plant height among linseed varieties in their evaluation, suggesting that genotypic variation plays a more prominent role under certain environmental conditions.

Table 1: Mean performance of Phenological and growth parameters of linseed varieties.

|  |
| --- |
| **Treatments**  **DF DM PH(cm)**   |
| **linseed varieties** Kuma 54.00a 116.0a  88.7aFurtu 53.67ab 115.3a 84.7aWalin 51.67b 101.3b 90.1aYaadamo 51.00b 100.7b 79.7a Bekoju-14 56.33a 110.7a 85.7a |
| **LSD(0.05)** 2.707\*\* 8.82\* NS  |
| **C.V(%)** 2.7 3.5 4.9  |

*Where, \*\*= highly Significant at p ≤ 0.01, \*= Significant at p ≤ 0.05, DF = Days to 50% flowering, DM = days to 90% maturity, PH = Plant Height*

* 1. **Yield and Yield Components**
* **Capsules per Plant**

A highly significant difference (p < 0.01) was observed among the evaluated linseed varieties concerning the number of capsules produced per plant. This indicates strong genetic variability among the tested genotypes. The variety *Kuma* emerged as the most productive in this trait, recording an average of 40.83 capsules per plant, while Yaadamo was the least productive, with an average of 25.13 capsules per plant. The observed differences align with the findings of Dash *et al*. (2016) and Terfa and Gurmu (2020), who also reported notable genotypic variability in capsule formation across various linseed cultivars. Such variation in capsule number is likely a result of not only genetic factors but also interactions with environmental conditions. Key environmental influences include soil nutrient content, water availability, ambient temperature, and microclimatic factors during the plant’s growth and development stages. These findings underscore the importance of both genotype selection and environmental optimization in enhancing linseed productivity.

* **1000-Seed Weight (g)**

Similarly, a significant difference was also noted in the 1000-seed weight among the linseed varieties tested. The variety *Kuma* consistently outperformed others, achieving the highest 1000-seed weight of 12.0 g, whereas Yaadamo again showed the lowest performance, with a weight of 8.67 g. This trend reflects a similar pattern observed in capsule number, indicating that *Kuma* may possess superior genetic traits related to seed development and filling. These results are consistent with those reported by Akbar *et al*.(2003) and corroborated by later studies on linseed, which confirmed that seed weight is a varietal trait with high heritability and is significantly influenced by genotype. Moreover, environmental factors such as photosynthetic availability during plant growth, seed filling, and maturity period may also play crucial roles in determining final seed weight. Hence, the 1000-seed weight, in conjunction with capsule number, serves as an important yield component and selection criterion in linseed breeding programs.

**Table 2: Mean performance of yield and yield components parameters of linseed varieties**

|  |
| --- |
| **Treatments**  **NCPP TSW (g) GY(kg/ha)**   |
| **linseed varieties** Kuma 40.83a 12.00a 2135a Furtu 33.33ba  11.33a 1750b Walin 29.87ab 9.67b 1698b Yadamo 25.13b  8.67b 1458b Bekoju-14 27.40ab 11.67a 1677b |
| **LSD(0.05)** 7.51\*\* 1.649\*\* 331.2\*  |
| **C.V(%)** 12.7 7.6 5.9  |

*Where, \*\*= highly Significant at p ≤ 0.01, \*= Significant at p ≤ 0.05, NCPP = number of Capsules per Plant, TSW = Thousand seed weight and YH = Grain Yield per Hectare.*

* **Grain Yield (kg/ha)**

 Grain yield varied significantly among the tested linseed varieties (p < 0.05). Kuma achieved the highest yield, producing 2135 kg/ha, followed by Walin and Bekoju-14, while Yaadamo recorded the lowest yield at 1458 kg/ha. The superior performance of Kuma is likely due to its favorable combination of agronomic traits, such as higher capsule number and seed weight. These results are in agreement with the findings of Sahito et al. (2022) and Lea & Belay (2021), who also reported higher yields associated with well-adapted and high-performing linseed varieties.

1. **Conclusion**

The findings of this study revealed significant genetic variability among the evaluated linseed varieties under rain-fed conditions in the Fafan Zone, Somali Region. This variation underscores the potential for selecting high-performing genotypes suitable for local agro-ecological conditions. Among the tested varieties, **Kuma** consistently outperformed the others across multiple traits, including early maturity, a higher number of capsules per plant, greater 1000-seed weight, and superior grain yield. These attributes indicate that Kuma possesses a favorable combination of agronomic traits and strong adaptability to the environmental conditions of the study area. On the other hand, **Yaadamo** consistently exhibited the lowest performance across most traits, suggesting limited adaptability and the need for genetic enhancement or alternative use in breeding programs. These results contribute valuable insights into varietal selection for linseed production in semi-arid regions and highlight the importance of continuous variety evaluation to match crops with site-specific growing conditions.

1. **Recommendation**

Based on its outstanding agronomic performance and yield advantage, the **Kuma** variety is strongly recommended for large-scale cultivation in the Fafan Zone and other ecologically similar areas across the Somali Region. To ensure successful adoption and sustained productivity, it is crucial to promote **participatory on-farm trials** involving local farmers. These trials will not only validate the research findings under diverse field conditions and management practices but also foster farmer acceptance and knowledge sharing. Furthermore, stakeholders, including agricultural research institutions, extension services, and development partners, should collaborate to enhance seed multiplication and dissemination efforts for the Kuma variety. Parallel efforts should be made to strengthen agronomic training and technical support for farmers to optimize input use and crop management practices. Such integrated approaches are vital for improving linseed productivity, enhancing food and income security, and promoting climate-resilient agriculture in the Somali Region.

**Ethical Statement**

No ethical concerns were applicable. All authors provided informed consent to participate and publish this study.

**Data Availability**

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request, in line with institutional policies.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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