Registration of *Kulumsa-1* Linseed (*Linum usitatissimum* L.) Variety

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Abstract: *Kulumsa-1* is a common name for the linseed variety developed through selection from the variety known as Chilallo, the linseed variety released nationally in 1992, which is a population. *Kulumsa-1* was selected, developed and released by Kulumsa Agricultural Research Center for major linseed growing areas of Ethiopia. Specifically, it was tested at Kulumsa, Bekoji, Asasa, Sinana, Holetta, Adet and Areka for three years (2002/2003-2004/2005) and verified in 2005/2006 on these locations for official release. Consequently, *Kulumsa-1* consistently produced better mean seed yield than the standard check *(Belay-96)* and the local check over three years. Likewise, it proved to be more resistant to powdery mildew *(Oidium sp.)* and pasmo *(Septoria linicola)* diseases than the checks. The results of the multi-location trials revealed that *Kulumsa-1* was superior in seed yield performance across years and locations. Besides, it is stable variety based upon the two stability parameters, deviation from regression (S^2_{di}) and coefficient of determination (R^2_i).

Keywords: Edible Oil; *Kulumsa-1*; Linseed; Variety Registration

1. Introduction

Linseed (*Linum usitatissimum* L.) is one of the oldest oilseeds cultivated for food and fiber (Lay and Dybing, 1989). Ethiopia is considered the secondary center of diversity, and now the 5th major producer of linseed in the world after Canada, China, United States and India (Adugna, 2007). It is a self-pollinated crop. Linseed has long history of cultivation by smallholder farmers, exclusively for its oil in the traditional agriculture of Ethiopia (Hiruy and Nigussie, 1988). It is a major oilseed and the second most important oil crop after noug (*Guizotia abyssinica* Cass.) in Ethiopia. The crop performs best in altitudes ranging from 2200 to 2800 meters above sea level (masl). Linseed grows well within temperature ranges of 10 to 30 ^oC; but it performs best between 21 to 22 ^oC. Optimum soils for linseed are well drained but moisture retentive and medium to heavy textured such as clay loams and silty clays. Linseed will not perform well on soils with pH less than 5 and above 7 and is sensitive to soil salinity (Adugna, 2007). It is widely cultivated in the high elevations area of Arsi, Bale, Shewa, Gojam, Gonder, Wollo and Wellega (Getinet and Nigussie, 1997).

Linseed oil is suitable for human consumption, and is used as a nutritional supplement. It is rich in omega-3 fatty acids, especially alpha-linolenic acid (C18:3) that is beneficial for heart disease, inflammatory bowel disease, arthritis and a variety of other health conditions. It also contains a group of chemicals called lignans that play a significant role in the prevention of cancer (Budwing, 1994). The meal, which remains after oil extraction, is a valuable feed to animals as a protein supplement (Getinet and Nigussie, 1997). There is also a growing demand in the world market for linseed due to its numerous health benefits, especially in Europe (Wijnands *et al.*, 2007). However, opportunities for oilseeds export are not fully exploited yet because of low productivity, inadequate quality, improper post-harvest handling, poor infrastructure and poor market information.

The Ethiopian edible oil sector consists of two groups of producers: the local, small-scale processors (>1000) and a few medium and large scale enterprises (~20). The entire sector produces approximately 20,000 tons of edible oil annually; while domestic demand is estimated at 200,000 tons. Consequently, Ethiopia imports up to 160,000 tons of edible oil annually and this figure is increasing every year (PPPO, 2009). The increase of import suggests a potentially large domestic market. Main edible oil imports are palm and soybean oils from Malaysia and Indonesia. Substitution of these oils by domestic production is encouraged by high domestic prices. Export oil (like sesame and linseed) is hardly being produced locally, since the export price of seed is usually very attractive and sesame seed is hardly locally consumed (PPPO, 2009). It can be seen as a business opportunity to increase the local capacity to produce linseed and sesame oils for export, increasing added value, foreign exchange and employment opportunity. In order to improve the Ethiopian edible oil sector, the Government should create equal taxation system for both domestically produced and imported edible oils, undertake feasibility study for increased production of oilseeds, and develop good manufacturing practices for the Ethiopian mill sector.

Area of linseed was increased from 142,899 hectares (ha) in 2003/2004 to 180,873 ha in 2008/2009. In the same years, its production and average yield were also increased from 0.77 to 1.56 million quintals and from 541 to 863 kg ha^{-1}, respectively. Despite the wide values of linseed in terms of nutritional, industrial, and export earnings; productivity and production of linseed is still low (CSA, 2004, 2009). Currently, there is a huge shortage of edible oil in the country (PPPO, 2009). Hence, concerted research, development and promotion efforts are needed, at all levels, in order to reverse the current situations. This paper presents the overall performances of the recently developed and released linseed variety (*Kulumsa-1*) with the aim to play a significant role in solving the chronic edible oil shortage in the country, and to exploit its linseed production capacity for domestic uses and export purposes.

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ISSN 1992-0407

2. Varietal Evaluation

Chilallo/16 or *Kulumsa-1* was derived through selection from earlier *Chilallo* linseed variety, which is a population and released nationally in 1992. As *Kulumsa-1* outshined several linseed selections, accessions and lines in observation and preliminary yield trials, it was advanced to national variety trial to be tested across wide locations over years to further test its overall performances. The linseed national variety trial consisting 12 linseed genotypes including the standard check (*Belay-96*) and the local check was conducted at major linseed growing regions including Shewa (Holetta), Arsi (Kulumsa, Bekoji and Asasa), Bale (Sinana), Gojam (Adet) and SNNPR (Areka) for three growing seasons (2002/2003 to 2004/2005). In these locations, the altitude ranges from 2200 masl (Kulumsa) to 2780 masl (Bekoji), and average annual rainfall ranges from 620 mm in Asasa to 1100 mm in Bekoji. The genotypes were tested across seven locations in RCB design with four replications. Plot size was six rows of 20 cm apart and 5 m long. A seed rate of 25 kg ha^{-1} and fertilizer rate of 23/23 kg ha^{-1} N/P_2O_5 was applied at planting at each location. Other recommended cultural practices were also applied. Necessary agronomic performances and disease reactions were recorded.

Kulumsa-1 consistently out yielded other tested linseed entries over three years. The average yield of *Kulumsa-1* was 1,151, 1,514 and 1,467 kg ha^{-1} in 2002/2003, 2003/2004 and 2004/2005 across seven locations (data not shown). Mean seed yield of the tested genotypes in 2002/03 cropping season was low (1,151 kg ha^{-1}) mainly due to moisture stresses at several locations. Combined years over locations analysis revealed that it had produced an average yield of 1,348 kg ha^{-1} (Table 2). Thus, *Kulumsa-1* was verified at seven locations (at on-station and two on-farms at each location) in 2005/2006 for official release. Consequently, *Kulumsa-1* showed superior overall agronomic performances over the standard check (*Belay-96*) and the local check under verification trial too. Likewise, it proved to be more resistant to powdery mildew (*Oidium sp.*) and pasmo (*Septoria linicola*) diseases than the checks. The results of the multi-location trials revealed that *Kulumsa-1* was superior in seed yield performance, oil content and diseases resistance across years and locations. Besides, it is stable variety based upon the two stability parameters, deviation from regression (S^2_{di}) and coefficient of determination (R^2_i). Thus, it is logical and important to register and promote *Kulumsa-1*.

3. Agronomic and Morphological Characteristics

In an attempt to develop *Kulumsa-1*, higher yield and resistance to major linseed diseases were important traits of consideration. *Kulumsa-1* flowered from 68 to 93 days and matured from 136 to 161 days after emergence depending on growing environment (Table 1). The standard check, *Belay-96*, matured earlier than *Kulumsa-1* by two days. On average, *Kulumsa-1* was 85 cm tall, but *Belay-96* was 77 cm tall, implying better competitive ability of *Kulumsa-1* with weed species. Besides, *Kulumsa-1* possessed 41 to 72 pods per plant with a mean of 57 pods per plant and eight seeds per pod. Both *Kulumsa-1* and *Belay-96* are brown and bold seeded. The average weight of 1000-seeds was 5.54 g for *Kulumsa-1*, which is greater by two and fifteen percent than that of *Belay-96* and the local check, respectively (Table 3). *Kulumsa-1* is a variety suitable for rain-fed, low inputs and organic farming on different soil types as long as the pH value is within the range of 6.0 to 7.6. However, it is not suitable for water logged or poorly drained soils. A summary of agronomic and morphological characteristics of the variety are presented in Table 1.

4. Yield Performance

Considering the over all seed yields, *Kulumsa-1* (Chilalo/16) produced better seed yield than the standard check (*Belay-96*) across locations (Table 2). This variety consistently performed better than the checks over three years. *Kulumsa-1* was 6.8% high yielder than the standard check (*Belay-96*) and 29.7% high yielder than the local check. It had 5.0% oil yield and 2.8% oil content advantage over *Belay-96*. Likewise, it had 22.4% oil yield and 5.5% oil content advantage over the local check. It was taller than checks, implying its better competence with weeds.

5. Stability Performance

Yield stability in 12 genotypes of linseed was studied for two years (2003/2004 and 2004/2005) at four locations (Kulumsa, Bekojji, Asasa and Holetta) using different stability parameters such as (*bi*) the regression coefficient (Finlay and Wilkinson, 1963), (S^2_{di}) deviation from regression (Eberhart and Russel, 1966) and (R^2_i) coefficient of determination (Pinthus, 1973) as shown on Table 4. The stability of varieties was defined by high mean yield, regression coefficient (*bi* = 1.0) and deviations from regression ($S^2_{di} = 0$) as small as possible (Akcura *et al.*, 2005) and maximum coefficient of determination (R^2_i). The results of the study showed that *Kulumsa-1* and *Belay-96* were stable linseed varieties based upon the two stability parameters (S^2_{di} and R^2_i) and were superior in mean seed yield. However, these varieties are unstable based upon regression coefficient (*bi*), indicating greater specificity of adaptability to high yielding environments.

6. Disease Reaction

On the standard rating scale of 0-5, 0 being highly resistant, and 5 highly susceptible, *Kulumsa-1* scored mean of 0.98, 0.75 and 0.81 for wilt (*Fusarium oxysporium*), powdery mildew (*Oidium sp.*) and pasmo (*Septoria linicola*) diseases, respectively (Table 2), indicating that the variety is resistant to major diseases of linseed. The resistance reaction of the variety could be integrated with other disease management methods such as crop rotation, managing infested debris, and fungicide seed treatments for better results.

7. Quality Analysis

Typically, linseed consists of approximately 40% fat, 28% dietary fiber, 21% protein, 4% ash and 6% carbohydrates such as sugars, phenolic acids, lignans, and hemi-cellulose (Vaisey-Genser and Morris, 2010). Linseed is rich in polyunsaturated fatty acids, particularly alpha-linolenic acid (ALA), the essential omega-3 fatty acid, and linoleic acid (LA), the essential omega-6 fatty acid. These two polyunsaturated fatty acids are essential for humans-that is, they must be obtained from the fats and oils in foods because our bodies can not make them. The omega-3 fatty acids have many biological effects that make them useful in preventing and managing chronic conditions such as type 2 diabetes, kidney disease, rheumatoid arthritis, high blood pressure, coronary heart disease, stroke and certain types of cancer (Connor, 2000). The composition of linseed can vary with genetics, growing environment, seed processing and method of analysis (Daun, *et al*., 2003). The protein content of the seed decreases as the oil content increases (Daun and Declercq, 1994). The oil content of linseed can be altered through traditional breeding methods, and it is affected by geography. Linseed requires moderate to cool temperatures and adequate moisture during the growing season for optimum seed yield and quality. Good yield can be achieved with a temperature range of 10-30 °C, and a mid-day relative humidity of 60-70%, and a rainfall of 150-200 mm distributed over the growing periods. Extensive scientific research over the past few decades has revealed numerous nutritional benefits of linseed due primarily to its fat, lignan, dietary fiber, and protein contents.

In the present study, the results of laboratory tests (Table 2) indicated that *Kulumsa-1* had 9.8% oil yield and 2.8% oil content advantages over *Belay-96*. Likewise, it had 37% oil yield and 5.5% oil content advantages over the local check. Besides, *Kulumsa-1* had 2% and 15% more 1000 seeds weight than *Belay-96* (the standard check) and the local check, respectively. *Kulumsa-1* is also rich in essential fatty acids, lignan, fiber and protein. Hence, *Kulumsa-1* has better health, industrial and nutritional values.

8. Conclusions

Kulumsa-1 was the best yielding linseed variety. It is stable in seed yield performance over locations and years. It was resistant to major diseases of linseed that prevailed in the growing areas. *Kulumsa-1* possessed better number of pods per plant, produced higher seed and oil yields and contained better oil content. Farmers also preferred the variety for its superior performance over the existing local variety, which is manifested by tall plant height, better pods load and number of branches per plant. Likewise, the variety has better industrial and nutritional values. Hence, *Kulumsa-1* was verified and officially released for large scale production in major linseed growing areas of Ethiopia.

9. Acknowledgements

The Ethiopian Institute of Agricultural Research offered the financial support to develop and release the variety. Collaborating national and regional agricultural research centers such as Holetta, Sinana, Adet, and Areka are duly acknowledged for smooth implementation of trials over years. The authors would like to acknowledge Dr. Bulcha Woyessa, Mr. Tarekegn Itana, Mr. Shemelis Mebrate, Mr. Kasahun Kumsa, Mr. Edosa Fikiru, Mr. Agidew Bekele and Dr. Tsigie Genet for their assistance in field data collection and management. They also extend their special thanks to the Highland Oil Crops Improvement Project of Holetta Agricultural Research Center for its assistance in analysis of oil content.

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Table 1. Agronomic and morphological characteristics of *Kulumsa-1* linseed variety.

Adaptation area	
Altitude (masl)	2000-2800
Rainfall (mm)	600-1100
Temperature (°C)	9.5-22.0
Soil pH	6.0-7.6
Fertilizer rate	
N (kg ha^{-1})	23
P_2O_5 (kg ha^{-1})	23
Planting date	Early to late June
Seed rate (kg ha^{-1})	
Row planting (20 cm between rows)	25
Broadcasting	35-40
Days to flowering	68-93
Days to maturity	136-161
Plant height (cm)	78-89
Number of pods per plant	41-72
Seed color	brown
Weight of 1000 seeds (g)	5.54
Reaction to major diseases	<1.0 (Resistant)
Oil content (%)	35.9-38.5
Seed yield (kg ha^{-1}) at research stations	985-2063
Seed yield (kg ha^{-1}) on farmers fields	730-1600
Year of release	2006
Breeder/Maintainer	Kulumsa Agri. Research Center

Table 2. Mean agronomic performance and disease reactions of 12 linseed genotypes tested in seven locations in Ethiopia in the years, 2002/2003-2004/2005.

No.	Genotype	Days to		Plant	SY (kg	OC	Oil yield	Diseases (0-5 scale)		
		Flower	Mature	height	ha^{-1})	(%)*	(kg ha^{-1})*	P. mildew	Pasmo	Wilt
1	PGRC/E 11382	81	140	79	1223	36.1	397	1.23	0.95	0.38
2	Chilallo/18	83	141	82	1187	35.7	382	1.41	0.78	0.52
3	CI-1525 X CI-1133/1	81	140	77	1055	35.3	352	1.34	1.08	0.53
4	PGRC/E 10052/3	83	142	79	1178	36	389	1.57	0.96	0.64
5	PGRC/E 11045/4	81	140	81	1141	36.6	385	0.98	0.90	0.47
6	Chilallo/16	82	141	85	1348	36.5	442	0.75	0.81	0.98
7	CDC 1747 V & E	83	141	78	1185	35.1	381	1.36	0.93	0.44
8	PGRC/E 11429/3	86	144	83	1004	35.2	334	1.29	0.92	0.40
9	CI-1525 X CI-13612/1	81	140	84	1204	36.9	400	1.75	0.89	0.42
10	PGRC/E 11263/1	79	138	80	1073	35.9	363	1.14	1.26	0.60
11	*Belay-96* (std. check)	78	139	77	1262	35.5	421	1.03	1.16	0.61
12	Local check	84	141	74	1039	34.6	361	1.66	1.07	0.67
	Grand mean	82	141	80	1158	-	-	-	-	-
	LSD (0.05)	0.547	0.661	1.487	60.12	-	-	-	-	-
	MSE	2.79	4.083	20.64	37496	-	-	-	-	-
	SED	1.18	1.43	3.21	136.92					
	CV%	2.04	1.44	5.69	16.72	-	-	-	-	-

** = Oil content and oil yield are based on data of 2 years at 4 locations; SY = Seed yield; OC = Oil content*

Table 3. Summary of pooled mean seed and oil yields, other data and disease reaction of *Kulumsa-1* and the checks across years and locations.

Variety	Days to flower	Days to maturity	Plant height (cm)	TSW (g)	SY (*kg ha*$^{-1}$)	OC (%)	OY (*kg ha*$^{-1}$)	Reaction to disease		
								PM	Pasmo	Wilt
Kulumsa-1	82	141	85	5.54	1348	36.5	492	0.75	0.81	0.98
Belay-96	78	139	77	5.43	1262	35.5	448	1.03	1.16	0.61
Local check	84	141	74	4.83	1039	34.6	359	1.66	1.07	0.67

TSW = 1000 seeds weight; SY = Seed yield; OC = Oil content; OY = Oil yield; PM = Powdery mildew

Table 4. Mean seed yield, regression coefficient (b_i), deviation from regression (S^2_{di}) & coefficient of determination (R^2_i) of 12 linseed genotypes tested at eight environments in Ethiopia (2003/04 and 2004/05).

No.	Genotype	Mean	b_i	S^2_{di}	R^2_i
1	PGRC/E 11382	1344.47	1.0429	7917.6684	98.3038
2	Chilallo/18	1326.41	0.8007	7805.9579	97.1945
3	CI-1525 X CI-1133/1	1189.59	0.9232	7645.7608	97.9177
4	PGRC/E 10052/3	1369.50	0.9669	17205.6889	95.8196
5	PGRC/E 11045/4	1187.59	0.9963	8965.7872	97.9037
6	Chilallo/16	1512.47	1.1526	9023.0168	98.4156
7	CDC 1747 V & E	1303.78	1.122	10548.5719	98.0523
8	PGRC/E 11429/3	1135.34	1.0381	11879.2832	97.4533
9	CI-1525 X CI-13612/1	1393.63	0.9781	15237.5148	96.3619
10	PGRC/E 11263/1	1306.41	1.0223	11491.9606	97.4597
11	Belay-96	1538.41	1.0662	6410.5599	98.6808
12	Local check	1256.97	0.8908	6256.7756	98.1651
	Mean	1322.05	1.000		

Linseed genotypes with values in bold are considered stable