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# Highland Oilcrops

A three-decade research experience in Ethiopia


Getinet Alemaw
and
Nigussie Alemayehu


Research Report No. 30

Institute of Agricultural Research

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Language editor: Abebe Kirub
Design and layout: Abebe Kirub and Kidanemariam Hagos

Published 1997
Institute of Agricultural Research
P.O. Box 2003
Fax: 251-1-611222
e-mail: IAR@padis.gn.apc.org
Addis Abeba, Ethiopia

*Citation:*

Getinet Alemaw and Negusse Alamayehu. 1997. Highland oilcrops: a two-decade research experience in Ethiopia. Research Report No. 30. Institute of Agricultural Research, Addis Abeba, Ethiopia.

# Contents

# Introduction

Three-hundred twenty-eight oil-bearing plant species are known to exist in Ethiopia and fifteen of them are cultivated and the rest may have uses other than oil and may be wild or cultivated. An additional nine-oil bearing plants which are not yet cultivated commercially have been also catalogued (Table 1). Oilseed crops such as noug, gomenzer, rapeseed, sunflower, safflower, sesame, groundnut and castor are currently cultivated in Ethiopia.

Factors such as climate, soil topography, pests, diseases and market requirements determine the kind of oilseed crop to be grown in a certain area. An oilseed crop should be treated as one of the crops grown in a particular cropping system, not a specialty, and should be planted in a rotational cycle. The cropping plan should also include crops that can make best use of shared resources.

## Importance of Oilseeds in Ethiopia

In Ethiopia oilseeds are used as cash crop, export commodity, raw materials for industries and as source of employment opportunity. A sizable portion of the population, therefore, generates income from oilseeds farming, trade, and processing. The majority of Ethiopians obtain most of their energy from carbohydrates and therefore the component of vegetable oil in the diet is very important.

In Ethiopia oilseeds are largely processed in home-made backward technique using small expellers. In the village, seeds are sifted, conditioned on *mitad*, crushed and stirred in *mukecha* ( traditional mortar and pistol) in hot water, and centrifuged in *ensira* (clay-made container). The oil is then decanted and the meal that settles at the bottom is used as animal feed and sometimes as food.

## The Chemical Nature of Vegetable Oils

Vegetable oils consist of mainly triacylglycerols which make up 95% of the total lipid. In addition monoacylglycerols, diacylglycerols, free fatty acids, glycolipids, phospholipids, sterols, sterol esters and waxes are found as minor components (Åppelqvist 1989). Triacylglycerols consist of identical or different fatty acids esterified on the three OH-positions on the glycerol molecule. They are characterized by their overall fatty acid composition. Fatty acids are straight chain carbon, hydrogen and oxygen atoms without or with one or more double bonds (Table 2). The first figure (third column on Table 2) shows the number of carbon atoms and the one following the colon indicates the number of double bonds. The nutritional as well as industrial values of a vegetable oil are entirely dependent on its fatty acid composition. Fatty acid composition of oil is a species characteristics and is largely controlled by genetic factors with very little environmental influence. Vegetable oils have numerous food and industrial applications (Table 3). Coconut, linseed, castor and tall oil are extensively used for non food uses. Coconut is half edible and half non edible where as others are entirely used as industrial oils. Some unusual fatty acids such as (+)-vernolic acid which are not found in cultivated crops, but can be converted from other 18 carbon fatty acid oils using engineering means (Sonnet and Foglia 1996). However, the technology still incurs production cost. Recently the gene coding (+)-vernolic and ricinoleic acids have been cloned from wild plants and transformed into cultivated species (Kinney 1996).

Table 1. Some oil-bearing plants species in Ethiopia.

| Scientific name | Common name | Local name |
|---|---|---|
| *Arachis hypogaea* L. | groundnut, peanut | lewz |
| *Argemone mexicana* L. | pricky Poppy | medafe |
| *Brassica carinata* A. Braun | ethiopian mustard | gomenzer |
| *Brassica napus* L. | rapeseed | rapeseed |
| *Crambe abyssinica Hochst* | crambe | |
| *Eruca sativa Hill* | eruca | |
| *Lepidium sativum* L. | lepidium | feto |
| *Maesa lanceolata Forsk.* | | |
| *Var. lanceolata* | - | yrenja Kolo |
| *Salvia nilotica Jacq.* | | besobila |
| *Sinapis* spp. | | |
| *Carthamus tinctorius* L. | safflower | suf |
| *Curcurbita maxima* L. | pumpkin | duba |
| *Glycine max* L. | soybean | akure ater |
| *Gossypium* spp. | cotton seed | tifre |
| *Guizotiz abyssinica* L. (Cass) | niger seed | noug |
| *Helianthus annuus* L. | sunflower | yeferenga Suf |
| *Linum usitatissimum* L. | linseed | telba |
| *Ricinus communis* L. | castor | gullo |
| *Sesamum indicum* L. | sesame | selit |

Table 2. The systematic and trivial names and symbol for some fatty acids of vegetable oils (Åppelqvist 1989).

| Systematic name | Trivial name | Symbol |
|---|---|---|
| **Saturated** | | |
| Octanoic | caprylic | 8:0 |
| Decanoic | capric | 10:0 |
| Dodecanoic | lauric | 12:0 |
| Tetradecanoic | myristic | 14:0 |
| Hexadecanoic | palmitic | 16:0 |
| Octadecanoic | stearic | 18:0 |
| Eicosanoic | arachidic | 22:0 |
| Decosanoic | behenic | 22:0 |
| Tetracosanoic | lignoceric | 24:0 |
| **Unsaturated** | | |
| *cis*-9-dodecenoic | lauroleic | 12:1(n-3) |
| *cis*-9-tetradecenoic | myristoleic | 14:1(n-5) |
| *cis*-9-hexadecenoic | palmitoleic | 16:1(n-7) |
| *cis*-9-octadecenoic | petroselenic | 18:1 (n-12) |
| *cis*-6-octadecenoic | petroselenic | 18:1(n-12) |
| *trans*-9-octadecenoic | elaidic | 18:1* |
| *cis*-11-octadecenoic | cis-vaccenic | 18:1(n-7) |
| *trans*-11-octadecenoic | trans-vaccenic | 18:1* |
| | ricinoleic | 18:1† |
| | (+)-vernoic | 18:1†† |
| *cis*-9-eicosenoic | gadoleic | 20:1(n-11) |
| *cis*-13-docosenoic | erucic | 22:1(n-9) |
| *cis*-15-tetracosenoic | nervonic | 24:1(n-9) |

**trans* fatty acids and n-x symbol is used only for *cis* fatty acids, †contains OH group, ††Epoxy fatty acid.

Table 3. Some non food uses of plant fatty acids (Ohlogge 1994).

| Chain | Example | Major source | Major use | Approximate* US market size Medium |
|---|---|---|---|---|
| Chain | Lauric acid (12:0) | Coconut, palm kernel | Soap, detergents, surfactants | 350 |
| Long chain | Erucic acid (22:1) | Rapeseed | Lubricants, anti slip agents | 100 |
| Epoxy | Vernolic acid (18:1) | Epoxidized soybean oil | plasticisers | 70 |
| Hydroxy | Ricinoleic acid (18:1) | Castor | Coatings, lubricants | 50 |
| Trienoic | Linolenic acid (18:3) | Linseed | Paints, varnishes coatings | 45 |
| Wax easters | Jojoba oil (wax) | Jojoba | Lubricants, cosmetics | 10 |

* *In US$*

# Noug

## Distribution

Noug is oil crop of Ethiopian origin. It is among the earliest of the domesticated crops in Ethiopia along with tef, enset, finger millet and coffee (Doggett 1987). Noug belongs to the family of compositae and genus *guizotia*. The genus guizotia is a small genus of six species, five of which are found in Ethiopia (Baagøe 1974). Noug is extensively cultivated in Ethiopia and India. The two countries together produce 2.04 million quintals of noug seed per year. The crop is also grown as a minor crop in the Sudan, Uganda, Zimbabwe, Zaire, Tanzania, Malawi, Nepal, Pakistan, Bangladesh and West Indies (Weiss 1983). Noug is grown in mid altitudes of all regions of the country but about 90% of the production comes from Gojam, Gonder, Shewa and Welega (Fig. 1).

## Ecological Adaptability

Major noug producing areas are characterized by the moderate temperature ranging from 15°C to 23°C during the growing season (Table 4). The crop may not flower at a temperature of more than 28°C. A soil temperature of 17 to 21°C has been found best for noug (Prinz 1976). Noug is a short day or day neutral plant and will not flower if the day length is longer than 14 hours. At a shorter day lengths of 10-12 hours and with lower temperatures of 15 to 21°C, noug flowers readily (Abebe 1975).

Noug is well adapted to areas where rainfall does not exceed 1000 mm per year. A higher precipitation of 1000-1200 mm and lower level of about 500 mm may be suitable, depending on the variety and distribution of rainfall (Hiruy and Getinet 1989). The crop is resistant to waterlogging, as it grows equally well on either well drained soils or waterlogged clays. In both cases, the plant has to sustain itself after flowering on the remaining soil moisture. Rainfall during seed setting and maturity may have a profound negative effect on grain yield.

Table 4. Environmental requirements of noug in Ethiopia (Hiruy and Getinet 1989)

| Parameter/ Land characteristics | Range of suitability | | |
|---|---|---|---|
| | Highly | Moderately | Marginally |
| Altitude (m) | 1600-2200 | 1400-1600<br>2200-2500 | 500-1600<br>2500-2900 |
| Temperature (°C) | 8.5-13.5 | 6.5-8.5 | |
| minimum | | 13.5-15.5 | |
| maximum | 21.5-24.5 | 19.5-21.5<br>24.0-26.0 | |
| mean | 15-19 | 13-15<br>19-21 | 21-23 |
| Length of growing period (days) | 130-200 | 110-130 | 80-110 |
| Soils | | | |
| texture | heavy or light clay | | |
| color | black, brown, red | | |
| pH | 6.8-7.3 | 5.2-6.8 | |
| Rainfall (mm) | 600-1000 | 500-600<br>1000-1200 | 350-500<br>1200-1500 |

Noug grows on almost any soil as long as it is not coarse textured or extremely heavy. It is usually sown on poor soil or clay soil under a minimum cultural practice. The crop is not responsive to fertilizers for its as yield. It grows well at pH ranging between 5.2 and 7.3 (Prinz 1976). Noug is grown mainly in mid altitudes and highland areas (1600 to 2200m). However it can also be found in altitudes as high as 2980 and as low as 500 m of elevation.

Different types of noug are known to be widely cultivated in Ethiopia (Getinet and Sharma 1996b). The predominant and main type is *abat* noug grown during the main season from May - June to December. It is late maturing adapted to mid to high altitude, higher yielder and bears high oil than *bungne*. *Bungne* noug is adapted to lowland and is much earlier than *abat*, lower yielding and bears lighter seed with much lower oil content. A third type of noug, *mesno* was identified during germplasm collection around Dangla in Gojam. The farmer who was planting his mesno noug in September described it as tolerant to frost and which grows on residual soil moisture. It is usually planted in late September and harvested in February.

## Varieties

Noug is completely cross pollinated and the breeding procedures are mass selection, recurrent selection. composite and synthetic variety development. These selection methods were used to some extent to develop noug varieties at Holetta (IAR 1966-1994a, 1966-1994b). Four varieties namely Sendafa, Fogera-1, Esete-1 and Kuyu are available for cultivation in the Central highlands. Kuyu is the earliest and most recent. The seed yield of these cultivars could reach up to 10 q $ha^{-1}$ with oil content of 40%. The fatty acid composition of these cultivars is similar and contains 75% linoleic acid. Noug is a species which can benefit a lot from microspore culture and gene manipulation. Microspore technique can be utilized to develop inbred lines in a single generation. Noug is also the only species within the Compositae family which possesses excellent regeneration indicating (Simmonds and Keller 1987) that the potential of gene transformation is very good. In short possibilities of improving this species using molecular and tissue culture techniques is unlimited.

## Crop Performance

Noug is widely grown as a sole crop on large production fields with minimum cultivation and input. Noug is not responsive to fertilizer as far as seed yield is concerned (Table 5). Application of fertilizer causes luxurious vegetative growth, but there is an indication that efficient genotypes can be selected. Recent cultivars respond much better than land races on poor soils. Noug also has a mychorrizal association on water logged poor soils (Yantasath 1975).

The seed yield of noug is lower than linseed and gomenzer, however research in various ecologies of Central, Eastern, Western and Northwestern Ethiopia showed that seed yields of up to 12 q $ha^{-1}$ can e obtained.

## Parasitic Weeds, Insect Pests, and Diseases

The parasitic weed known as Dodder (*Cuscuta campestris*) has become to be a serious threat of noug production throughout Ethiopia. Dodder was also a major threat to Indian production. In orissa, Dodder (*Cuscuta chinensis* Damk) infestation caused stunted slow growth, inhibited branching, reduced number and size of flower heads and seeds per plant (Rath and Mahanthy 1986). Early infestations and infestation at 30 days after seeding and 45 days after emergence caused total yield losses. Tosh and Patro (1975) reported that Dodder *(Cuscuta chinensis)* can be controlled by the application of the herbicide Chlorpropham as a granular, at the initiation of Dodder germination, and at a rate of 4 kg $ha^{-1}$. A 90% control of Dodder (Cuscuta chinensis) was achieved using Propyzamide applied as a post-emergence, 20-25 days after sowing at a rate of 1.5-2.0 kg $ha^{-1}$ with no phytotoxicity (Tosh *et al.* 1977, 1978). Dodder could also be controlled by sifting seed before sowing.

*Orobanche minor* is also a parasitic weed often found in noug fields.

However its competitiveness and yield loss do not warrant any special control methods other than recommended for other general weeds.

A total of 24 insects are recorded on noug both in Ethiopia and India (Table 6). Of these the noug fly (*Dioxyna sororcula* and *Eutretosoma* sp.), black pollen beetles (*Meligethus* sp.) are the most important (Bayeh unpublished data). *Dioxina sororcula* is the most serious insect pest of noug both in Ethiopia and India. The flies start mating when the flower is blooming (Bayeh unpublished data). Eggs are laid within the disc florets hence interfere seed setting. The damaged flowers turn red brown and when dissected larvae or pupae are recovered. At maturity the damaged disc florets become stony and when dissected pupae are obtained. The noug black pollen beetle (*Meligethus* sp.) is also reported from all noug growing areas of Ethiopia. Although precise identification is lacking, five species are suspected. These insects feed on pollen grain of noug, hence interfering in fertilization of ovules. The adult beetles are adapted to live within the disc florets. Some of the insect pests found in Ethiopia are not yet identified.

There are 29 fungal, one bacterial, and one nematode diseases recorded (Table 7). Of these noug blight (*Alternaria* sp.) and leaf spot are the most serious diseases. In India control measures for cercospora leafspot, powdery mildew, alternaria leafspot and root rot are developed.

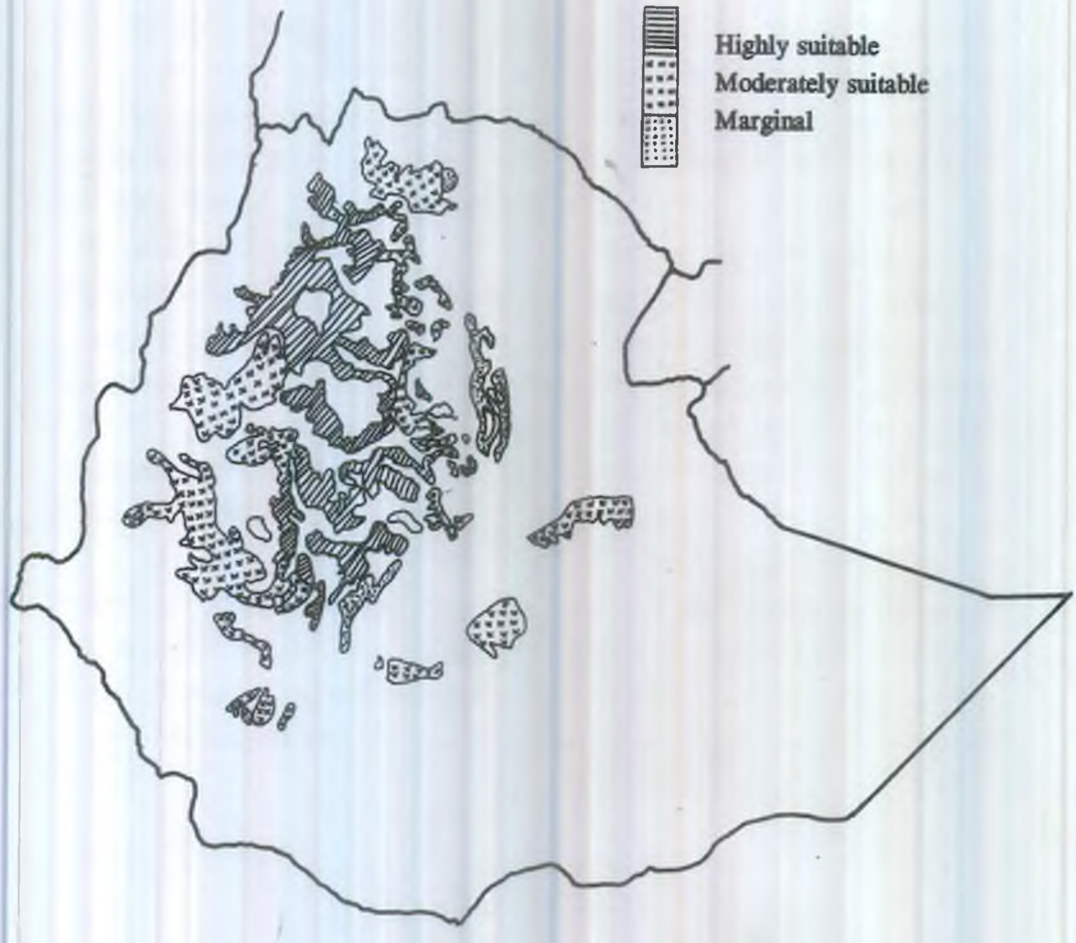


Fig. 1. Noug growing areas in Ethiopia

Table 5. Summery of seed yield (Kg ha⁻¹) of two varieties (improved and local) at two fertilizer rates (with 23/23, $N/P_2O_5$, and without) in the Noug National and Extension Variety Trials grown at 13 locations during 1983-87.

| | Varieties | | | | | |
|---|---|---|---|---|---|---|
| | Improved | | | Local | | |
| Location | Without | With | Mean | Without | With | Mean |
| Holetta | 883 | 1013 | 948 | 762 | 768 | 765 |
| Ginchi | 765 | 831 | 794 | 726 | 800 | 763 |
| Debre Zeit | 598 | 463 | 530 | 614 | 494 | 554 |
| Goha Tsion | 535 | 725 | 630 | 471 | 642 | 557 |
| Tefki | 617 | 844 | 731 | 670 | 940 | 805 |
| **Mean** | 978 | 775 | 727 | 649 | 728 | 689 |
| Kulumsa | 468 | 451 | 460 | 492 | 466 | 479 |
| Robe | 579 | 864 | 722 | 544 | 839 | 692 |
| **Mean** | 524 | 669 | 591 | 518 | 652 | 586 |
| Bichena | 727 | 826 | 777 | 719 | 761 | 740 |
| Motta | 674 | 627 | 651 | 648 | 660 | 654 |
| Adet | 570 | 662 | 616 | 638 | 600 | 619 |
| **Mean** | 65 | 705 | 681 | 668 | 674 | 671 |
| Bako | 372 | 417 | 395 | 374 | 388 | 381 |
| Shambu | 584 | 625 | 605 | 834 | 500 | 667 |
| Mean | 478 | 521 | 500 | 604 | 444 | 624 |
| Woldya | 1201 | 1164 | 1183 | 1001 | 1163 | 1082 |

Table 6. Noug insects pests in Ethiopia

| Scientific | Common name | References |
|---|---|---|
| *Eutretosoma* sp. | Noug fly | Bayeh unpublished |
| *Piezotrachelus milkoi* | Apionid weevil | Bayeh unpublished |
| *Meligethes* sp. | Black pollen bettle | Bayeh unpublished |
| *Haplothrips articulosus* (Bagn.) | Noug flower trips | Schmutterer 1971, |
| *Synaptothrips* sp. | Trips | Bayeh and Tadesse 1992 |
| *Medicogryllus* spp. | Crickets | Bayeh and Tadesse 1992 |
| *Taylorilygus pallidus* | Mirid bug | Bayeh and Tadesse 1992 |
| *Decaria abolominalis* | Chrysomelid beetle | Bayeh unpublished |
| *Dioxyna sorercula* (Widedemann.) | Noug fly | Schmutterer 1971 |
| *Chrysodeixis circumflexa* | Plusia worm | Bayeh and Tadesse 1992 |
| *Trichoplusia orichalcea* | Golder plusia | Bayeh and Tadesse 1992 |
| *Gryllus bimaculatus* | Crickets | Bayeh and Tadesse 1992 |
| *Pemphigus* sp. | | Bayeh and Tadesse 1992 |
| *Diacrisia obliqua* (Wlk.) | Hairy caterpillar | Bayeh 1995 unpublished |
| *Prospalta capensis* (Guen.) | | Bayeh and Tadesse 1992 |
| *Sphaeroderma guizotae* | | Haile 1995 |

Table 7. Noug diseases in Ethiopia

| Pathogen | Disease | References |
|---|---|---|
| *Alternaria dauci*(Kuhn) Groves and Skolko | on seeds | Stewart and Yirgu (1967) |
| *Alternaria porri* (Ell.) Ciferrif sp. Dauci (Kuhn) Neerg. | leafspot | Yirgu (1964) |
| *Alternaria sp*. stem and leaf blight | | Yitbarek (1992) |
| *Bremia lactucae* (Regal.) | downey mildew | Steward and Yirgu (1967) |
| *Cercospora guizoticola* Govindu and Thirmulachar | leafspot | Yirgu (1964) |
| *Cladosporium* sp. | | Yirgu (1964) |
| *Macrophoina phaseolina* (Mauba) Ashby | | Yirgu (1964) |
| Phoma sp. stem lesion, wilting | | Yitbarek (1992) |
| *Phyllosticta spp.* | tarspot | Yirgu (1964) |
| *Plasmopara halstedii* | downy mildew | Yitbarek (1992) |
| *Puccinia guizotiae* Cumm. | rust | Yirgu (1964) |
| *Rhizoctonia solani* Kuhn | root rot nematode | Yirgu (1964) |
| *Xanthomonbas campestris* pv. guizotiae (Yirgu) Dye | leafspot | Yirgu (1964) |
| *Anguina amsinckia* | leafgal | Stewart and Yirgu (1967) |
| *Epicoccum nigrum* L.K. | | Yirgu (1964) |
| *Erysiphe cichoraceurum* D.C. | | Yirgu (1964) |
| *Penicillium* spp. | | Yirgu (1964) |
| *Septoria* sp. | | Stewart and Yirgu (1967) |

## Chemical Composition and Utilization

Noug seed yields yellow, edible and semi-drying oil with nutty taste and pleasant odor. The oil is mainly used for cooking. It is also used in soap manufacturing and to a limited extent in paints. Noug provides about 50 to 60% of the oil consumption in Ethiopia (Riley and Hiruy 1989).

Depending on the genotype and environment oil content of noug ranges from about 35% to 47% (Getinet and Adefris 1995). Generally cooler growth temperature promotes higher oil synthesis, while husky seeds and bungne type noug contains lower oil (Getinet and Hiruy 1989). The fatty acid composition of a typical noug oil is presented in Table 8. Linoleic acid is not synthesized by monogastric animals including human being and is considered as essential fatty acid. Noug oil has a good potential in cosmetics and pharmaceutical industry due to its stability. The seed remaining after the oil extraction contains 25% protein and 24% crude fiber.

Table 8. Range mean and standard deviation (±SD) of oil content and fatty acid composition of 241 noug accessions grown at Ginchi, in 1989 (Getinet and Adefris 1995)

| Component | Range | Mean | ±SD |
|---|---|---|---|
| Oil | 39.9-47.0 | 43.1 | 1.4 |
| Fatty acids | | | |
| Palmitic | 7.6-8.7 | 8.2 | 0.2 |
| Stearic | 5.6-7.5 | 6.5 | 0.3 |
| Oleic | 4.8-8.3 | 6.6 | 0.6 |
| Linoleic | 74.9-79.1 | 76.6 | 0.8 |
| Linolenic | 0.0-0.9 | 0.5 | 0.1 |
| Arachidic | 0.4-0.8 | 0.5 | 0.1 |
| Behenic | 0.4-1.5 | 0.7 | 0.1 |

# Oilseed *Brassica*

## Distribution

The genus *Brassica* includes six economically important species namely *Brassica rapa* (AA), *B. oleracea* (CC), *B. nigra* (BB), *B. juncea* (AABB), *B. napus* (AACC) and *B. carinata* (BBCC). *B. oleracea* is used as vegetable and B. nigra as a condiment. *B. napus* is an amphidiploid between *B. rapa* and *B. oleracea* and *B. carinata* between *B. nigra* and *B. oleracea*. *B. carinata* is the most adapted one in Ethiopia and is locally known as *gomenzer*. Gomenzer is a commercial crop only in Ethiopia. Outside Ethiopia, it has been tested in Canada, India, Spain and California and was found to be very low maturing and lower yielder than *B. napus* and *B. juncea*. In Spain and California gomenzer had lower harvest index than the two species indicating the potential for improvement through breeding is essential (Cohen and Knowles 1983). In Ethiopia gomenzer yields up to 10 q $ha^{-1}$ of more seed than its next competitor *B. napus*. It is cultivated in all regions of Ethiopia particularly Arsi, Bale, Gojam, Gonder, Shewa and Welega (Fig. 2).

## Ecological Adaptability

Mostly Brassica grows best in cool moist climate and at higher altitudes in the tropics. In general, a cool season with a mean temperature of about 20°C is required for better growth of brassica. Cooler temperatures are especially important up to flowering, but during seed filling, warmer temperatures can be tolerated. However, very high temperature during seed development can reduce seed yield and oil content. The species perform especially well when cool nights follow warm days (<25°C). On the other hand, heavy frost during the night and very dry air in the day may kill the brassica plants.

Gomenzer and rapeseed grow very well where rainfall during the growing season is above 600 mm with even distribution (Table 9).

Gomenzer grows well in either a heavy type of sandy loam or a light clay soil with good drainage. The soil should not be extremely acidic or alkaline, near neutral soil reactions are most favorable. The surface soil structure is important for proper emergence; too fine may form a crust, if rain follows and prevents seeding emergence. Too coarse a seedbed will also reduce seedling emergence. Since oilseed Brassica is a heavy user of both nitrogen and phosphorous, its production can be limited in part by soil fertility.

## Crop Performance

Gomenzer is widely grown by small farmers in more fertile well drained soils. Research conducted at various locations revealed that impressive yield can result (Table 10) from employing improved variety of gomenzer along with improved management practices such as; sowing date, seed rate, weeding practices and fertilizer levels (Hiruy *et al.* 1989a).

Gomenzer is a good rotation crop for cereals and pulses. The general practice is that gomenzer should not be planted at the same field for at least four years.

Table 9. Environmental requirements for gomenzer in Ethiopia (Hiruy and Getinet 1989)

| Parameter/ Land characteristics | Range of suitability | | |
|---|---|---|---|
| | Highly | Moderately | Marginally |
| Altitude (m) | 2000-2600 | 1700-2000<br>2600-2800 | 1100-1700<br>2800-3200 |
| Temp. (°C) | | | |
| minimum | 8.0-12.0 | 6.0-8.0 | 12.0-15.0 |
| maximum | 20.0-23.0 | 18.0-20.0 | 23.0-25.0 |
| mean | 14.0-17.5 | 12.0-14.0 | 17.5-20.0 |
| Length of growing period (days) | 150-221 | 125-150 | 110-125 |
| Soils | | | |
| texture | medium | | |
| type | light clay, sandy loam | | |
| color | brown, red | | |
| pH | 6.0-7.5 | 5.2-6.8 | |
| Rainfall (mm) | 600-900 | 500-600<br>900-1450 | 400-500<br>1200-1450 |

Table 10. Summery of seed yield (Kg $ha^{-1}$) of two improved and local varieties at two fertilizer rates (with 46/69, $N/P_2O_5$, and without) in the Gomenzer National and Extension Variety Yield Trial grown at different locations during 1984-86.

| Location | Without | With | Mean | Without | With | Mean |
|---|---|---|---|---|---|---|
| Holetta | 2150 | 3544 | 2847 | 2168 | 3180 | 2674 |
| Debre Zeit | 2496 | 2439 | 2468 | 2120 | 2268 | 2194 |
| **Mean** | **2323** | **2992** | **2658** | **2144** | **2724** | **2434** |
| Bekoji | 466 | 3204 | 1835 | 572 | 2849 | 1711 |
| Kulumsa | 1700 | 2253 | 1977 | 1594 | 1677 | 1636 |
| Robe | 1794 | 2358 | 2076 | 1229 | 1165 | 1197 |
| **Mean** | 1320 | 2605 | 1963 | 1132 | 1897 | 1515 |
| Dabat | 435 | 1351 | 893 | 312 | 1042 | 677 |
| Motta | 477 | 1693 | 1085 | 139 | 1647 | 893 |
| Bure | 621 | 1866 | 1244 | 386 | 1585 | 986 |
| Debre Tabor | 2741 | 3226 | 2984 | 2036 | 2522 | 2279 |
| **Mean** | **1069** | **2034** | **1552** | 718 | **1699** | **1209** |
| Shambu | 291 | 2899 | 1595 | 183 | 2018 | 1101 |

## Varieties

Gomenzer is the highest yielding oilseed crop in the central highlands. Seed yields of up to 30 q $ha^{-1}$ on demonstration plots were achieved. There are six double high cultivars (containing high erucic acid in the oil and glucosinolate in the meal) namely; Awasa population, S-67, S-115, S-71, Dodolla and Yellow Dodolla. S-67 and Yellow Dodolla are the most recent ones (Getinet et. al 1992). Rapeseed varieties are released for their higher oil content and earlier maturity over the gomenzer types. However, the recent gomenzer varieties are as early as rapeseed with much tolerance to diseases and high seed yield.

## Parasitic Weeds, Insect Pests, and Diseases

Gomenzer is relatively more robust to weed competition once seedlings establish under weed-free conditions which can be achieved by an early stage (3-4 weeks after planting) of weeding. At times gomenzer is parasitized by *Orobanche ramosa* and thus whenever this parasitic weed is encountered, it should be pulled and burned before setting seed. Eleven insect pests are known to be potential treat of gomenzer and rapeseed in Ethiopia (Table 11). Of these Diamond back moth and flea beetles are the most important.

A total of 15 diseases are known to attack gomenzer (Table 12). Of these blackleg and leafspot cause substantial yield loss. A complete yield loss could result from blackleg infestation on rapeseed. Although gomenzer is tolerant to blackleg, it is not immune and a five-year field rotation is necessary.

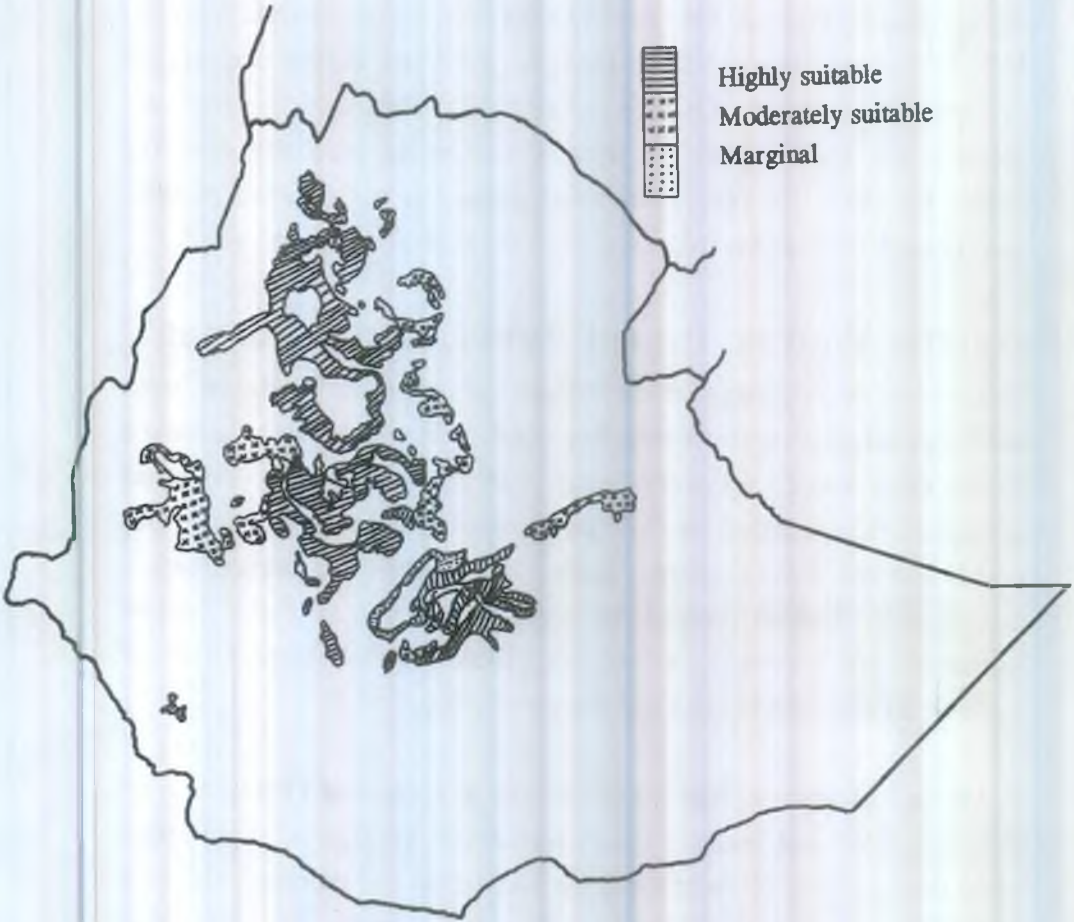


Fig. 2. Mustard growing areas in Ethiopia

Table 11. Insect pests of Gomenzer in Ethiopia

| Scientific name | Common name | Author |
|---|---|---|
| *Brevicoryne brassica* | Cabbage aphid | Crow, Tadesse and Tsedeke (1977) |
| *Lipaphis erysimi* | Mustard aphid | Crow, Tadesse and Tsedeke (1977) |
| *Phyllotreta mashonana* | Cabbage flea beatle | Crow, Tadesse and Tsedeke (1977) |
| *Phyllotreta weisei* | Cabbage flea beatle | Crow, Tadesse and Tsedeke (1977) |
| *Plutella xylostella* | Diamond back moth | Crow, Tadesse and Tsedeke (1977) |
| *Trichoplusia orichalcea* | Golden plusia | Crow, Tadesse and Tsedeke (1977) |
| *Pieis brassicoidesi* | Cabage white | Kemal Ali and Tadesse (1987) |
| *Liriomyza brassicae* | Cabbage leaaf minor | Crow, Tadesse and Tsedeke (1977) |
| *Bagrada hilaris* | Bagrada bug | Crow, Tadesse and Tsedeke (1977) |
| *Lixus latro* | Cabbage weevil | Crow, Tadesse and Tsedeke (1977) |
| *Mylabris spp.* | Pollen beatle | Tadesse and Bayeh (Unpublished) |

Table 12. Disease causing pathogens of gomenzer in Ethiopia.

| Pathogen | Diseases | Author |
|---|---|---|
| *Albugo candida* | White rust | Stewart and Yergu 1967 |
| *Alternaria brassicae* | Leaf and pod spot | Kranz 1969, Stewart and Yergu 1967 |
| *Alternaria tenuissima* | Leaf spot | Stewart and Yergu 1967 |
| *Cercosporella albomaculans* | White leaf spot | Stewart and Yergu 1967 |
| *Leptospheria maculans* | Black leg | Awgechew and Eshetu 1987 |
| *Mycosphaerella brassicicola* | Ringspot | Kranz 1969, Stewart and Yergu 1967 |
| *Oidium* sp. | Powdery mildew | Kranz 1969, Stewart and Yergu 1967 |
| *Peronospora parasitica* | Downey mildew | Kranz 1969, Stewart and Yergu 1967 |
| *Sclerotenia sclerotiorum* | Stem rot | Awgechew K. and Eshetu Bekele 1987 |
| *Xanthomonas campestris* | Black rot | Kranz 1969 |
| *Meloidegyne* spp. | Root knot nematode | Stewart and Yergu 1967 |

# Chemical Composition and Utilization

Oil from gomenzer contains about 40% erucic, 6 to 10% eicosenoic, 11 to 19% linoleic, 7 to 20% linolenic, 6 to 13% oleic, 2 to 5% palmitic and 0.3 to 1.0% stearic acids (Table 13). Based on nutritional studies of high erucic acid oils, it has been general accepted that low erucic oils are beneficial for human consumption (Vles 1974). Therefore, reduction of erucic acid has been a major part of plant breeding research. Nowadays Varieties of *B. napus* and *B. rapa* grown in most parts of the world contains <1% erucic acid in their oil. Breeding to develop gomenzer varieties containing 0.5% erucic acid in their oil has been successful (Table 14). The zero erucic acid trait in gomenzer is controlled by two loci, with additive effect and no dominance (Getinet et al. 1997a).

The major problem in gomenzer production is glucosinolate content in the seed. Glucosinolates are sulfur containing compounds which yield nitriles, isothiocyonates, thiocyonates and elemental sulfur upon myrosinace enzyme hydrolysis during crushing of the seed. Glucosinolates are lipophilic and hydrophilic, which make the oil pungent. Glucosinolates by themselves are not innocuous but the hydrolytic products cause antinutritional effect when feed to animals. The beneficial effect of glucosinolates is only their flavor in green vegetables. Glucosinolate content of 263 gomenzer accessions grown at Holetta contained 2-propenyl glucosinolate as a major glucosinolate. The range in 2-propenyl glucosinolate was 69.8 to 158.0$\mu$moles $g^{-1}$ meal with a mean of 100.2 $\mu$moles $g^{-1}$ which accounted for 97% of the total glucosinolate in the meal (Getinet *et al.* 1996b). The mean 3-butenyl was <1 $\mu$moles, 2-hydroxy 3-butenyl 1.9 $\mu$moles $g^{-1}$ meal.

Table 13. Fatty acid composition of gomenzer oil

| Fatty acid | Getinet *et al* (1996a) | Seegeler (1983) | Ryden (1972) |
|---|---|---|---|
| Palmitic | 3.8 | 3.4 | 4.2 |
| Stearic | 1.1 | 1.1 | 0.8 |
| Oleic | 10.4 | 11.3 | 13.3 |
| Linoleic | 16.9 | 18.0 | 18.9 |
| Linolenic | 15.0 | 11.7 | 20.4 |
| Eicosenoic | 8.5 | 8.1 | 9.0 |
| Erucic | 41.0 | 43.9 | 45.3 |
| No. of samples | 16 | 47 | 6 |

Table 14. Fatty acid contents (mean and ±SD) of 13 $BC_4F_2$ zero erucic acid gomenzer (*B. carinata*) plants grown in the greenhouse and high erucic acid cultivars S-67 and Yellow Dodolla, *B. juncea* Zem 2330 and *B. napus* cv. AC Elect (Getinet *et al.* 1994)

| Line or | Fatty acid (% of total) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Palmitic | Stearic | Oleic | Linoleic | Linolenic | Eicosenoic | Erucic |
| *B. carinata* | | | | | | | |
| $BC_4F_2$ | 6.0±0.7 | 1.7±0.3 | 28.3±2.0 | 38.1±2.9 | 22.9±2.4 | 1.1±0.1 | 0.1±0.0 |
| S-67 | 3.7±0.1 | 1.0±0.0 | 8.9±0.4 | 20.6±1.2 | 14.7±0.4 | 8.1±0.3 | 39.0±0.4 |
| Dodolla | 3.7±0.3 | 1.1±0.1 | 8.0±0.2 | 20.0±1.4 | 16.5±0.7 | 7.5±0.2 | 38.8±1.2 |
| *B. juncea* | | | | | | | |
| Zem 2330 | 3.2±0.0 | 2.0±0.0 | 46.8±0.6 | 28.8±0.6 | 16.5±0.2 | 1.8±0.2 | 0.1±0.0 |
| *B. napus* | | | | | | | |
| AC Elect | 3.9±0.1 | 2.0±0.0 | 62.0±0.6 | 18.8±0.4 | 10.1±0.7 | 1.5±0.0 | 0.1±0.0 |

Plants containing significantly low level of 2-propenyl glucosinolate in their meal were isolated at $BC_1F_3$ generation from [(*B. carinata x B. juncea) B. carinata*] (Getinet *et al.* 1997b). The meal remaining after oil extraction contains about 34% protein and 12% crude fiber with balanced amino acid composition.

# Linseed

## Distribution

Linseed is member of the Linaceae family, which has 14 genera and about 150 species. *L. usitatissimum* is the only economically important cultivated species. It is thought that the seed types originated from southern Asia, fiber types from Mediterranean and intermediate types from Asia Minor. Ethiopia is considered as the center of diversity for linseed. In Ethiopia it is usually cultivated in higher elevations where frost is a treat for other oil seeds such as noug and gomenzer. Linseed is a major oilseed and rotation crop for barley in high elevations of Arsi, Bale, Gojam, Gonder, Welo, Shewa and Welega (Fig. 3).

## Ecological Adaptability

Linseed performs best from 2200 to 2800 meters of elevation but also found in areas as low as 1200 meters and as high as 2420 meters (Table 15). Cool temperature during the growing season produces high yields. Mean temperature can range from 10°C to 30°C, but linseed does best at temperatures from 21°C to 22°C. It grows well at 12 to 18 hour photoperiod. Linseed prefers dry and sunny weather with well distributed moderate rain over the growing season. Precipitation of 500 to 700 mm is most suitable for the crop but lower levels of 450 to 500 mm suffice. Once the crop is closed regular rain is not needed, since it can sustain itself on soil water and dew. Linseed is highly sensitive to both drought and standing water.

## Varieties

The breeding program at Holetta in collaboration with Kulumsa, Adet and Sinana Research Centers has released for cultivars namely; Concurrent, Victory, CI 1525, CI, 1652 and Chilallo (IAR 1966-1994a; Adefris et al. 1992). These cultivars are widely adapted highlands of Arsi, Bale, Gojam, Gonder, Shewa and Welo as well as Welega (Adefris et al. 1992). The seed yields of these cultivars could reach up to 15 q $ha^{-1}$ on farmers fields with oil content of 38%.

Table 15. Environmental requirements for linseed (Hiruy and Getinet 1989).

| Parameter/ Land characteristics | Range of suitability | | |
|---|---|---|---|
| | Highly | Moderately | Marginally |
| Altitude (m) | 2200-2800 | 1800-2200 | 1200-1800 |
| | | 2800-3000 | 3000-3500 |
| Temperature (°C) | | | |
| minimum | 6.0-10.0 | 4.5-6.0 | |
| | | 10.0-13.0 | |
| maximum | 18.0-25.0 | 15.5-18.0 | |
| | | 25.0-27.0 | 27-30 |
| mean | 12.0-17.5 | 10-12 | |
| | | 17.5-20.0 | |
| Length of growing period (days) | 140-204 | 120-140 | 90-120 |
| Soils | | | |
| texture | medium | | |
| type | clay loam | | |
| color | brown, red | | |
| pH | 6.6-7.6 | 5.5-6.6 | 4.9-5.5 |
| Rain fall (mm) | 500-700 | 400-500 | |
| | | 700-1000 | 1000-1200 |

## Crop Performance

Linseed has been a traditional oilseed in Ethiopia for many centuries. It occupies the second position among the oilseed crops next to noug. The average area under this crop is about 73,000 ha with an average yield of 400 kg $ha^{-1}$. The crop is traditionally grown on marginal and submarginal rained soils although it does best on well drained clay loam. The crop yield trials carried out a various ecologies (Hiruy *et al.* 1989b) had shown high yields (Table 16). Days to maturity way generally longest at higher altitudes and shorter at lower elevations.

Table 16. Summery of seed yield (kg $ha^{-1}$) of two varieties (improved) and local) at two fertilizer rates (with 23/23, $N/P_2O_5$, and without) in the linseed National and Extension Variety Trials grown at 16 locations during 1984-86.

| | Varieties | | | | | |
|---|---|---|---|---|---|---|
| | Improved | | | Local | | |
| Location | Without | With | Mean | Without | With | Mean |
| Holetta | 1719 | 1860 | 1790 | 1450 | 1633 | 1542 |
| Debre Zeit | 1615 | 1487 | 1551 | 1296 | 1233 | 1265 |
| Sheno | 858 | 967 | 913 | 705 | 871 | 788 |
| Goha Tsion | 961 | 1163 | 1062 | 813 | 900 | 857 |
| Tefki | 852 | 1192 | 1022 | 930 | 1158 | 1044 |
| Shashemene | 690 | 821 | 756 | 786 | 938 | 862 |
| Inwarie | 536 | 842 | 689 | 492 | 834 | 663 |
| Mean | 1033 | 1190 | 1112 | 925 | 1081 | 1003 |
| Bekoji | 1457 | 1398 | 1428 | 1499 | 1379 | 1439 |
| Kulumsa | 1374 | 1322 | 1348 | 1145 | 1068 | 1107 |
| Robe | 1234 | 1131 | 1183 | 912 | 990 | 951 |
| Mean | 1355 | 1284 | 1320 | 1185 | 1145 | 1165 |
| Dabat | 1014 | 1424 | 1219 | 754 | 1050 | 902 |
| Debre Tabor | 1652 | 1896 | 1774 | 1252 | 1592 | 1422 |
| Motta | 1295 | 1354 | 1325 | 1076 | 911 | 994 |
| Buire | 1356 | 1479 | 1418 | 773 | 1096 | 934 |
| Mean | 1329 | 1538 | 1434 | 964 | 1162 | 1063 |
| Shambu | 1463 | 1884 | 1674 | 950 | 1092 | 1021 |
| Wacho | 860 | 902 | 881 | 762 | 718 | 740 |

High seed yields of wheat, barley and tef can be obtained following linseed. The crop is often used in rotation with cereals to prevent diseases buildup, as it is immune to diseases that attack cereals. linseed should not follow linseed as weeds and wilt may build up.

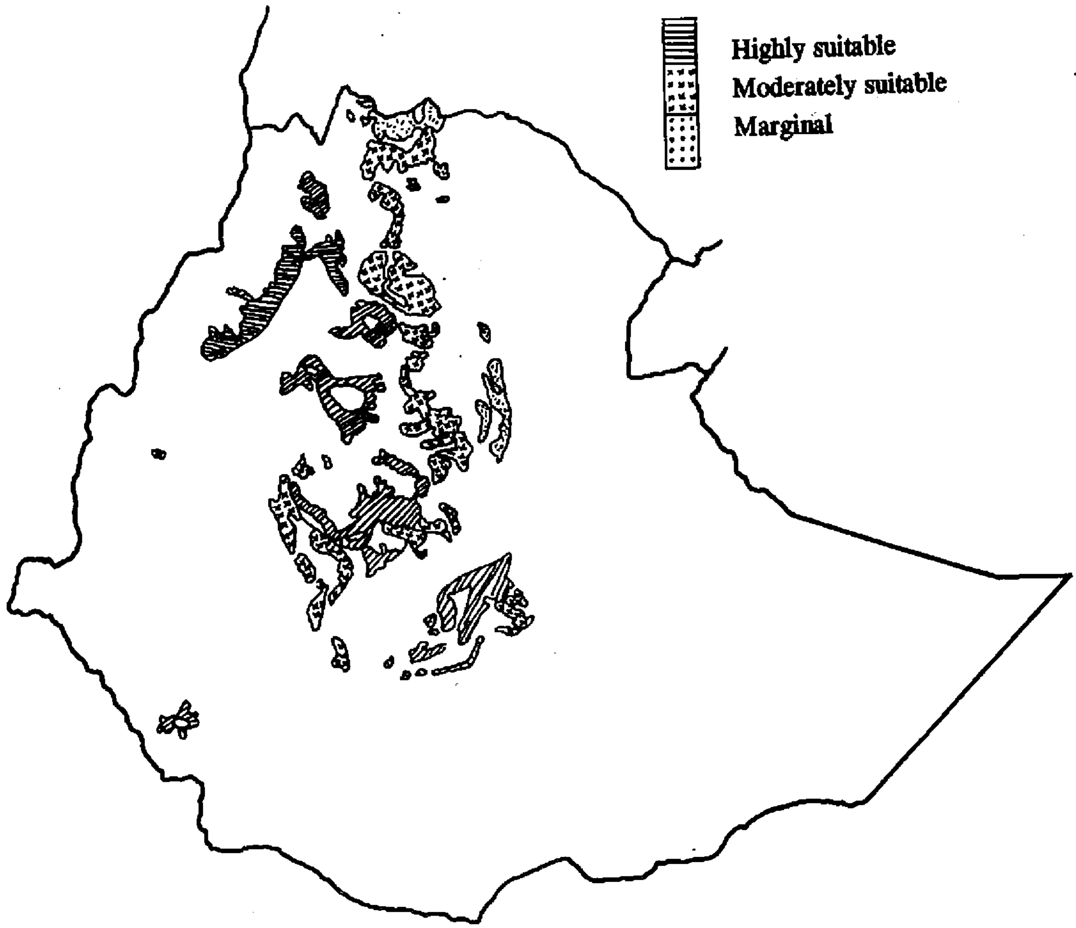


Fig. 1. Linseed growing areas in Ethiopia

## Parasitic Weeds, Insect pests and Diseases

Linseed is a poor competitor to weeds as compared to other oilseed crops. The critical period of competition is the time from early establishment to early flowering stage. The crop should therefore, receive an early (3-4 weeks after planting) weeding to be followed by a one mid season one. In many linseed growing parts of Ethiopia, the parasitic weed Dodder (*Cuscuta* sp.) is virtually becoming a serious problem. It is now believed that an integrated approach of controlling the pest should be devised.

Four insect pests namely linseed flea beatle (*Altica pyritosa*), the blue bug (*Calidea duodecimpunctata*), African boll (*helicoptera armigera* and plusia worms (*Chrysodexis acuta*) were recorded on linseed. Of these African boll worm results in substantial yield loss. The major problem of linseed production is diseases particularly wilt and pasmo (Table 17). The linseed varietal development at Holetta involves testing germplasm and segregating materials on artificially wilt infested sick plot followed by agronomic evaluation.

## Chemical Composition and Utilization

The oil content of linseed ranges from 34 to 40% based on the genotype and environment. Its fatty acid composition includes 50% linolenic acid which rapidly oxidizes in air to polymerize into relatively flexible film. Therefore linseed has its greatest potential in paints, and industrial coatings. Linseed is mostly used in Ethiopia as edible oil. The high linolenic acid content of linseed oil also causes off flavor and poor keeping quality. However the level of linolenic acid can be reduced to <2% and linolenic acid can be increased correspondingly to about 50% through plant breeding (Green 1984).

Traditionally linseed is used for cooking oil extraction when noug is in short supply. The ground seeds are used to prepare stew or wot. The crushed seeds may be mixed with water to prepare beverage. The mean remaining after oil extraction is an excellent source of animal feed.

Table 17. Diseases of linseed in Ethiopia

| Pathogen | Disease | Author |
|---|---|---|
| *Alternaria cinicola* | Leafspot | |
| *Cladosporium sp.* | - | Kranz (1969) |
| *Colletotrichum linicolum* | Anthracnose | Stewart and Yergu (1967) |
| *Fusarium oxysporium* | Wilt | IAR (1966-1994) |
| *Melampsora lini* | Rust | Stewart and Yergu (1967) |
| *Mycosphaerella linorum* | - | Kranz (1969) |
| *Oidium sp./ Erysiphe cichoracearum* | Powdery mildew | Stewart and Yergu (1967) |
| *Rhizoctonia solani* | Root rot | Stewart and Yergu (1967) |
| *Septoria linicola* | Pasmo | Kranz (1969) |

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