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Exploration of *Vernonia galamensis* in Ethiopia, and variation in fatty acid composition of seed oil

Tesfaye Baye[1,2,*] and Heiko C.Becker[1]
[1]*Institute of Agronomy and Plant Breeding, University of Göttingen, Von-Siebold-Str. 8, D-37075 Göttingen, Germany;* [2]*Department of Plant Sciences, Alemaya University of Agriculture, P.O. Box 138, Dire Dawa, Ethiopia;* **Author for Correspondence (e-mail: btesfay@gwdg.de; phone: + 49 551 39 2153; fax: + 49 551 39 4601)*

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Abstract

Vernonia galamensis is a new potential industrial crop with very high content of vernolic acid in the seed oil. The species is known to naturally grow as a weed in fields or in woodlands under a wide range of agroecological conditions of Africa. In order to study the existing variability in Ethiopia, germplasm collection was carried out. *Vernonia* grows wild in various ecosystems. Ten regions were explored from North, South, East, Southeast, Southwest and Central Ethiopia. A diverse range of habitats having different altitudes and ecological conditions was explored. Altitude of collecting sites varied between 1250 and 2050 m, and soil pH from 5.1 to 8.5. The most common soil type was sandy loam, and the organic matter content varied from 0.2% to 12.9%. At 80 sites, about 480 accessions were collected including different maturity time, plant type, flower color, and branching patterns as well as fatty acid composition. The mean vernolic acid content of the seed oil of the accessions was 74%, and ranged from 34% to 87%. A wide variability in composition of other fatty acids was observed. It was not possible to find *Vernonia* in some locations that were earlier indicated by herbarium specimens collected since 1840. This could be a sign of change in land use system and environmental degradation and, hence, loss of genetic resources of the species.

Introduction

Ethiopia is characterized by an enormous diversity of biological resources. This richness in species and genetic diversity of both cultivated and wild plants is due to the diverse physiographic and agroclimatic conditions that often occur within relatively short distance (Hawkes and Worede 1991; IBCR 1998). About 7000 plant species have been recorded from Ethiopia, of which 840 are probably endemic (IBCR 2001). To date, the Ethiopian Institute of Biodiversity Conservation and Research, has collected and conserved over 61,000 accessions of about 104 species. The main groups of this collection are cereals, pulses, and oilseeds (IBCR 2001). On the other hand, many potentially useful species, such as *Vernonia*, are represented only by a few accessions. Demissie (1991) has listed the lesser known but potentially valuable crop plants in Ethiopia. He stressed the need for detailed study and proper documentation as a prerequisite for their exploitation.

Vernonia galamensis, Asteraceae, is a potential new industrial oilseed crop. Recent taxonomic work (Robinson 1999) has shown that *Vernonia* is confined to the new world and that the African annual or perennial herbs is better referred to the genus

Centrapalus Cass., as *Centrapalus pauciflorus* (Willd.) H. Rob. (syn. *Centrapalus galamensis* Cass.). It is a tropical, indeterminate annual plant. It requires a well-drained soil and can grow under low-rainfall and marginal conditions and is most suitable for dryland farming (Gilbert 1986; Perdue 1988; Baye 2000). Its importance lies in the unique properties of the seed oil, which make it interesting both economically and ecologically. The oil (35–42% of the seed), contains as the major fatty acid vernolic acid (72–80% of the oil). Vernolic (*cis*-12, 13-epoxy-*cis*-9-octadecenoic or 18 : 1 epoxy) acid, a naturally occurring epoxidized fatty acid, is primarily present in the oil as the triglyceride trivernolin with unique physical properties, in particular, low viscosity. Vernolic acid, beside other uses, is a useful raw material for manufacturing paints and coatings. As a major source of natural vernolic acid, there is no alternative to *Vernonia* and, hence, a wide potential market is available. *Vernonia* oil also contains linoleic acid (12–14%), oleic acid (4–6%), stearic acid (2–3%), palmitic acid (2–3%), and a trace amount of arachidic acid (Thompson et al. 1994).

Attempts to study the naturally existing variability and its utilization in the Ethiopian *Vernonia* improvement program since 1990 are still inadequate. To date, research has been restricted to a narrow genetic base (fewer than 10 accessions), collected in eastern Ethiopia. Among other characters, a seed yield up to 4000 kg/ha and an oil content of 40% using these unimproved local materials were obtained, which seem to be higher than those found elsewhere (Baye 1996, 1997, 2000; Baye et al. 2001). But there are obvious gaps in the existing material, such as lack of difference in maturity group and different morphological plant types. Moreover, the germplasm so far assembled does not represent the entire variability present in the country. There are many unexplored areas, where *Vernonia* grows in different ecosystems.

To exploit the wide variability of *Vernonia* existing in Ethiopia for crop improvement as well as for the development of value-added *Vernonia* oil for industry, a collection was undertaken covering all parts of Ethiopia where *Vernonia* was expected to occur. The major objective of this germplasm collection was to make available a broad genetic base from all ecological niches where the plant grows. This will enable the making of further studies of genetics and breeding on *Vernonia* to improve seed yield, oil content and fatty acid composition.

Materials and methods

Collecting was done in Hararghe, Arsi, Bale, Sidamo, Shewa, Gamogofa, Wollo, Tigray regions and the Rift Valley. Figure 1 show the regions and routes of germplasm collection sites. A total of 80 sites between the latitudes 13° 05′ N and 3° 50′ N and the longitudes 42° 15′ E and 37° 36′ E in the Southwest were considered. Except for the eastern highland, the collecting sites are located in relatively dry areas. The collecting mission covered a distance of ~9000 km during 10 October to 20 December 2000 at altitudes ranging from 600 m (Rift Valley) to 3450 m (Bale Mountains) a.s.l. The collecting plan was based on herbarium specimens, interviews and showing samples to the local Ministry of Agriculture staff, non-governmental organizations involved in agriculture and, most importantly, to farmers, asking them for observations on the wild populations growing in their localities. *Vernonia* was not cultivated in any of the collecting sites.

At each site, seeds of five individual plants, which were a few meters apart from one another, were kept in separate bags and also bulked seeds from about 50 of the remaining plants were collected following the procedure of random sampling (Bogyo et al. 1980; Ladizinsky 1998) for the purpose of comparison in our future reproductive biology research program. But at some of the collecting sites, the populations consisted of very few individuals, and fewer than 50 plants could be collected. An attempt was made to ensure that the distance between any two collecting sites was about 5–10 km. Soil samples were taken randomly from each site and analyzed for pH (electrometrically), soil type (hydrometric method), and organic matter (Wakley–Black method) at Alemaya University of Agriculture, Ethiopia. The seed samples collected varied from a few seeds to enough to run the destructive analytical techniques. One hundred and ninety accessions were further subjected to gas chromatography (GC) for fatty acid analysis (Thies 1971) at the Institute of Agronomy and Plant Breeding, University of Goettingen, Germany.

Results and discussion

Distribution of V. galamensis

Topography of the area where *Vernonia* was found growing naturally includes plains, undulating, on hilly

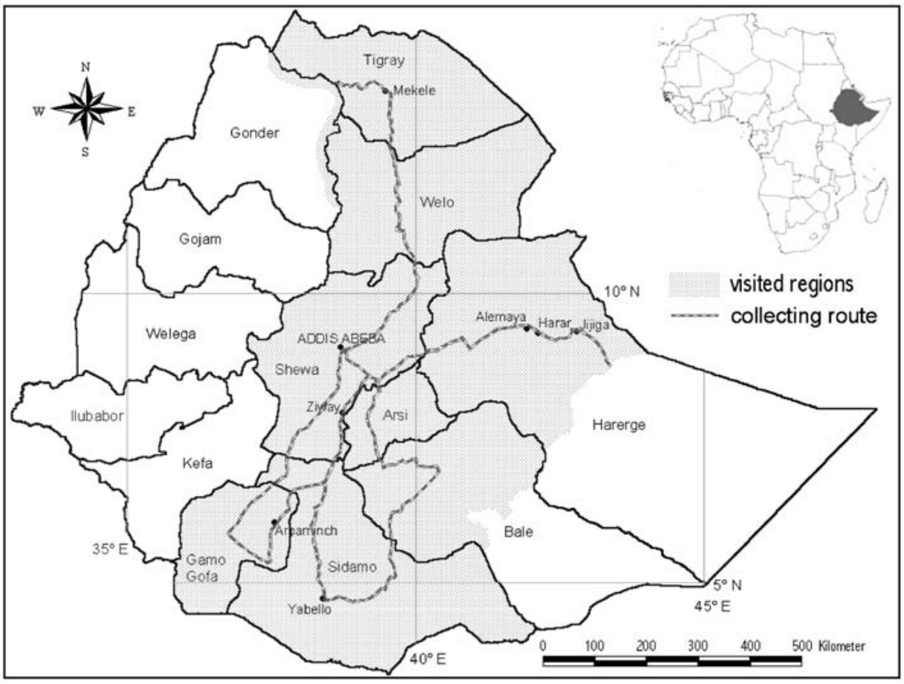

Figure 1. Regions and route of germplasm collection for *V. galamensis* in Ethiopia.

or lower slopes, or open to closed depressions both in disturbed and undisturbed habitats (under forest). Collections were made from agricultural fields, particularly, from maize, sorghum, and chat (*Catha edulis*) fields, grazing lands, garbage dumps, roadsides, fallow and eroded lands, ditches, picnic areas, mixed forests, park lands, farmyards, mountain terraces, upper and lower slopes, river banks, valleys, and in the compounds of mosques and churches, mostly in patchy forms.

As shown in Figure 2, the sites varied considerably in altitude, soil pH, soil types and soil organic matter content. Altitude ranged between 1250 (Arba Minch and Errer Valley) and 2050 (Bedeno area) m asl, although 50% of the sites were below 1600 m asl (Figure 2A). These were the upper and lower limits of sites where material could be collected, but not the limits of distribution of the species. Literature reviews (Gilbert 1986; Jeffrey 1988; Perdue 1988) and personal communications (Mesfin Tadesse; Demel Teketay; Robert Perdue) have shown that the plant can occur above and below those altitudes (700–2400 m a.s.l.). Soil pH ranged from 5.06 to 8.47, with the majority of the sites being mildly acidic to neutral Figure 2B). Organic matter content varied from 0.22% to 12.93% Figure 2C). Soil type was sandy loam at over 57% of the collecting sites Figure 2D).

Variability in V. galamensis

The collection exhibited immense diversity in a number of morphological attributes: plants varied in height from short (50 cm) to very tall (350 cm). Heads varied from open to closed shapes, which may help in selecting a non-dehiscent type. Differences in leaf shape and size and maturity classes were also observed, which are of interest for genetic improvement in *Vernonia*. No major incidence of pests were observed in wild *Vernonia* accessions. A moderate incidence of Helmet bug (*Captosoma* spp.) on the maturing heads was observed in most collecting sites explored.

Variability in fatty acid profile

A wide variability in fatty acid composition was observed. The mean content of vernolic acid of the accessions was 74.3% and ranged from 34% to 87% (Figure 3), and 65% of the accessions had a vernolic

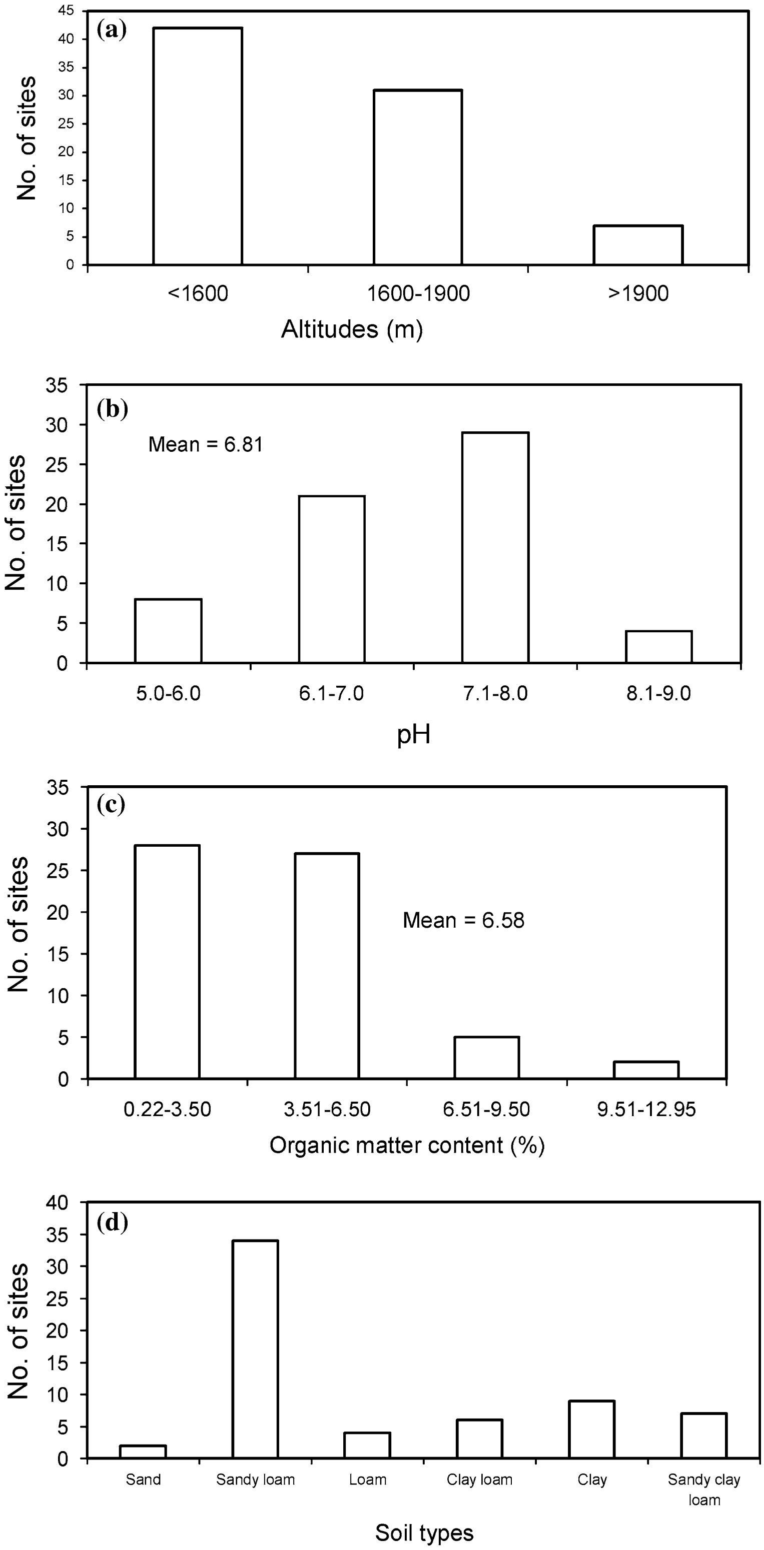

Figure 2. Ecogeographical information of the collecting sites in Ethiopia: altitudes (A), pH value (B), organic matter content (C), and soil type (D).

acid content above the mean. Yabello and Arbaminch collections had the lowest vernolic acid content whereas the Hararghe, Sodo and Ziway collections had the highest. The mean and range for linoleic, oleic, palmitic and stearic acids were 13.75% (7.0–35.5%), 5.01% (2.2–17.7%), 2.95% (1.8–8.3%) and 2.55% (1.4–6.5%), respectively. Trace amounts (less than 2%) of arachidic, linolenic, and palmitoleic acids in descending order, were also observed (Figure 4). Emphasis will be given to the accessions that gave the highest vernolic acid content.

Indicator plants and habitats for collecting V. galamensis

It was observed that the species occured in areas with annual rainfall as low as 250 mm occupied by plantations of Eucalyptus or natural vegetation of *Acacia-Commiphora* bushland/woodland, to areas where annual rainfall was as high as 2000 mm occupied by dense forest. It was confirmed that *Vernonia* is restricted to habitats with well-drained soil and well-defined seasons and relatively warm climate, and is usually associated with species *like Eucalyptus, Coffea arabica, Acacia tortilis, Hyparhenia rufa, Leucas martinicensis, Tagetes minuta, Lantana camara, Catha edulis, Lotus* spp*., Rosa abyssinica, Bidens pilosa, Rumex nervosus, Solanum incanum, Parthenium hysterophorus, Xantium* spp., *Ficus* spp., *Opuntia* spp., *Agave* spp., maize/sorghum/cowpea fields and rarely as a pure stand in an open field. Especially *Tagetes minuta* and *L. camara* have been observed consistently to grow in association with *Vernonia* in most collection areas and can, therefore, serve as indicator species for future *Vernonia* germplasm collecting missions.

Uses and local names of V. galamensis

Most local farmers who were interviewed responded that the plant had no value and they considered it a weed. Only one farmer in the Arsi region reported that it was used for a medicinal purpose, to treat a disease associated with eyes. In addition to the names mentioned by Baye (1996), *Vernonia* has the following vernacular names: Fechatu (shattering), Oromo, Gelile, Sumku, Bucha (plants coming out without sowing), Metaboko (bulged/enlarged heads).

Conclusions

Currently, *Vernonia* has no value to farmers and is regarded as a weed. Thus, most of the wasteland, farm

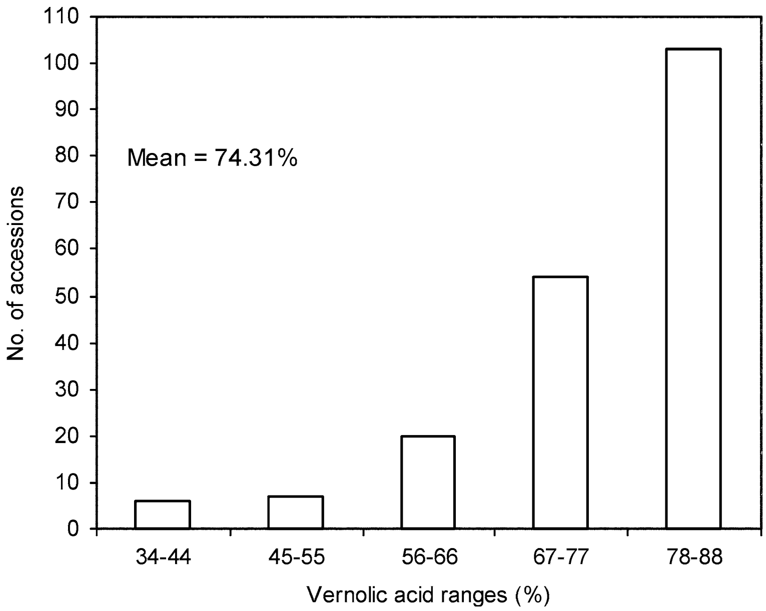

Figure 3. Variation in vernolic acid content of *V. galamensis* accessions collected in Ethiopia.

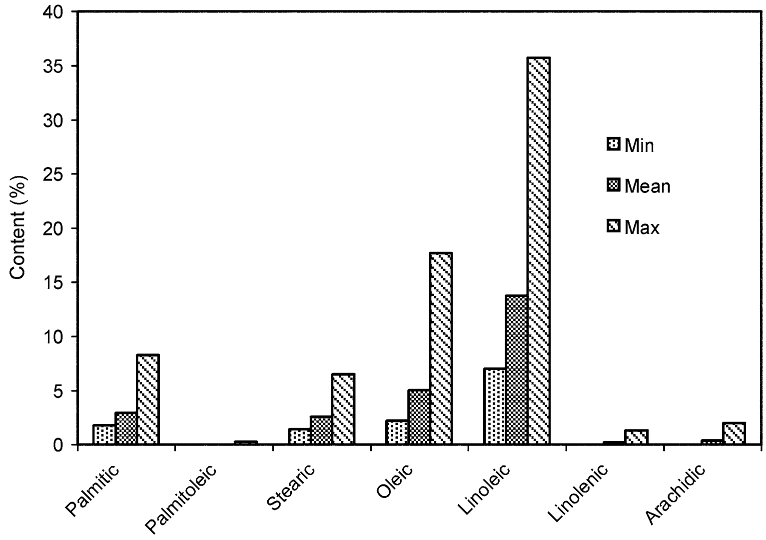

Figure 4. Variation in fatty acids (excluding vernolic acid) of *V. galamensis* accessions collected in Ethiopia.

bunds and roadsides are kept free of weeds in order to prevent their spread. Moreover, land is now becoming a limiting resource because of the rapidly increasing population in Ethiopia. Thus, farmers now try to cultivate as much land as possible, including those hilly sites and river banks, where weedy and wild plants used to grow. This is causing genetic erosion of many important wild and weedy plant species such as *Vernonia*. This has been shown by the fact that at some of the locations visited, no plants could be seen, though the species used to grow abundantly as indicated by herbarium specimens as early as 1840 (Herbarium specimens in Addis Ababa, and Kew).

Vernonia has great potential as a new industrial oil crop. Many accessions were collected with vernolic acid content above 80% of seed oil. Such high quantities of one dominant fatty acid are very interesting for the oleochemical industry and are rarely observed in plant oils; for example, soybean oil contains about 55% linoleic and linseed oil about 57% linolenic acid as principal fatty acids.

Vernonia is a new industrial crop which grows naturally in arid and semi-arid marginal areas, which makes it ideal for developing countries like Ethiopia. There is essentially no competition for land use with food crops, and the diversification of products will benefit local farmers as an insurance against crop failure. In addition to that, developing countries can capitalize on producing new industrial crops for export and for their own industrial development.

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