Vitellaria paradoxa: a multipurpose industrial oilseed tree

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Vitellaria paradoxa subsp. *nilotica*, a multipurpose industrial oilseed tree: Botany, Distribution, Ecology and Uses

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Abstract

Vitellaria paradoxa is a tree with multitude of products obtained from its different parts. However, the product with the highest traditional and industrial use is the oil derived from the kernels known commercially as 'shea butter' or 'karite'. Two subspecies of the species have been recognized occurring in 18 different countries in Sub-Saharan Africa, including Ethiopia. The purpose of this review paper is to provide relevant information on: (i) *Vitellaria paradoxa* in general, i.e. geographic distribution and ecology, contents and food values of its fruits, traditional and industrial uses as well as processing, marketing and future demand of shea butter; and (ii) *Vitellaria paradoxa* subsp. *nilotica* (VPN)in Ethiopia, i.e. botanical description, geographic distribution and ecology, ethnobotany, traditional processing of shea butter and its market prospects, status of its populations and the recent research work initiated. The available information indicates that the populations of VPN in Ethiopia are declining due to anthropogenic and natural factors, especially the annually recurring fire in their habitat. If measures are not taken urgently, there is a geeat danger that the species might disappear from its highly restricted distribution in the southwestern part of the country. Therefore, it is hoped that the information provided in this paper would motivate concerned bodies to start research on various aspects of this extremely useful industrial oilseed species, which could assist in its development, sustainable utilization, conservation and future domestication for the benefit of not only the local communities that depend directly on it for food, feed and medicine, but also the country at large.

1. Introduction

Vitellaria paradaxa Gaertn[1] (Sapotaceae) is a tree, which usually attains a height of up to 10-25 m (von Maydell, 1986) and is the source of a vegetable fat, which is second in importance only to palm oil in West Africa. A wide variety of useful products are made from this tree. But, by far, the most important is the oil derived from the kernels traditionally extracted by women through a laborious and time-consuming process (Hall et al., 1996[2]). The common names used for *Vitellaria paradaxa* are '**Shea Butter Tree**' (English) and '**Karite**' (French).

The tree occurs in a belt stretching across Africa, from Senegal to the Sudan/Ethiopian border (Fig. 1). Two subspecies, namely *V. paradoxa* C. F. Gaertner subsp. *paradoxa* (hereafter abbreviated as VPP) and *V. paradoxa* C. F. Gaertner subsp. *nilotica* (Kotschy) A. N. Henry (hereafter abbreviated as VPN) have been recognized. VPP is present in the western parts of Sub-Saharan Africa, i.e. in Benin, Burkina Faso, Cameroun, Central African Republic, Chad, Côte d'Ivoir, Guinea Bissau, Mali, Nigeria, Senegal, and Togo while VPN occpies the eastern parts of Africa, i.e. Ethiopia, Sudan, Uganda and Zaire.

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[1] Synonyms: *Butyrospermum niloticum* Kotschy, *B. parkii* (G. Don) Kotschy var. *niloticum* (Kotschy) Pierre ex Engler (Cufodontis, 1953-1972; von Breitenbach, 1963; Hall et al., 1996); *Butyrospermum paradoxum* subsp. *parkii* (G. Don) Hepper, *Bassia parkii* Don (von Maydell, 1986); *Butyrospermum parkii* (G. Don) Kotschy subsp. *niloticum* (Kotschy) J. Hemsley, *Butyrospermum paradoxum* (C.F. Gaertner) Hepper subsp. *niloticum* (Kotschy) Hepper (Hall et al., 1996).

[2] Unless specified, most of the information included in this paper is adopted directly from the works of Hall et al. (1996) and published works cited therein, with acknowledgement and many thanks to the authors.

The focus of this paper will be on VPN, unless specified, which is also commonly known by the names'**Wado**' (Anywaa, in Gambella National Regional State, southwestern Ethiopia) (Tesfaye Awas, 1997), '**Lulu**' and '**Shedderek-Ark**' (Arabic) (von Breitenbach, 1963). In Ethiopia, VPN is restricted in its natural occurrence to only the Gambella National Regional State (GNRS), where it is being used by the Neur ethnic groups as a source of food, feed and traditional medicine. However, although VPN occurs in the southwestern parts of Ethiopia, and has great actual and potential socio-economic and ecological benefits, it has received almost no attention from researchers, development and conservation workers in the past. This is clearly reflected in the complete absence or scantiness of documented information about indigenous knowledge or research results on VPN in Ethiopia. More alarming is the fact that, similar to other tree or forest resources in the country, the densities of populations of VPN are reported to have declined continuously over the years in their natural habitats associated with anthropogenic and natural factors, especially annually recurring fire. This is happening before even we have a chance to study and document about them. Unless urgent actions are taken by concerned bodies, the species could be threatened from local extermination, which might represent significant economic and ecological losses both to the local communities and country as a whole.

Figure 1. Geographical distribution of *Vitellaria paradoxa* in Sub-Saharan Africa (Source: Hall et al., 1996)

In this review paper, we have attempted to provide a summary of the available relevant information about the botany, geographical distribution, ecology and uses of *Vitellaria paradoxa* in general and VPN in Ethiopia in particular with the major objective of sensitizing concerned bodies about the occurrenece of this species in Ethiopia with great actual and potential socio-economic and ecological importance. It is hoped that this, in turn, could stimulate the interest of concerned bodies so that the species would receive the attention it deserves in terms of research, development, sustainable utilization, conservation and, ultimately, domestication.

2. Geographical Distribution and Ecology

The two subbspecies of *Vitellaria* occur in 18 countries (Fig. 1). They prefer dry and sandy clay soils with a good humus cover, tolerate stony sites and lateritic subsoil although reacting with lower yields, avoid swampy sites and flood plains inundated for any length of time, moist heavy loam soils or watercourses and prefer moderately fresh subsoil rich in humus (von Maydell, 1986). The extensive root system is essential to surviving the seasonal droughts of savanna climates.

The eastern subspecies, i.e. VPN, has been recorded in Ethiopia, Sudan, Uganda and Zaire. It occurs in areas underlain by old crystaline rocks, and grows preferably on lateritic slopes in humid lowland woodland and *Albizia* - thicket, and is mostly gregarious (von Breitenbach, 1963). There is a difference between the two subspecies in terms of altitude with VPN occurring at higher altitudes (650 - 1600 m) than subsp. *paradoxa* (100 - 1300 m). VPN occurs in the mountains of Uganda and Zaire, i.e. at 1200-1600 m, although in the Sudan there are populations at only 500 m. In Ethiopia it grows between 1200 and 1700 m (von Breitenbach, 1963). VPN is associated with mean annual rainfall of 900-1400 mm, estimated mean annual potential evapotranspiration of 1500 - 2000 mm, 3 - 5 dry months and 4 - 7 months with a soil moisture deficit. The highest mean annual temperature for VPN does not exceed 28° C and the mean annual temperatures do not fall below 22° C. Nevertheless, for highest occurrences, some 200 m above the level of the reference climatic station, mean annual temperature is likely to be only about 20° C.

Cultivation, fire, domestic livestock and exploitaion of the wood all affect populations of *Vitellaria*. The first two effects are particularly significant while the last is increasing rapidly in significance.

The relationship of *Vitellaria* with fire is reflected in a wide range of published comments based on casual observations. The use of fire as a hunting, land preparation and sward rejuvenating tool in woodlands and wooded grasslands has both positive and negative effects on *Vitellaia*. Positivie effects arise because, as large individuals, both subspecies are adapted to withstand quite sever fires, which adversely affect associated species and improve conditions for subsequent seed germination. Adaptation, however, extends beyond the fire tolerance ensured by the thick bark to seedling morphology and development, including a robust, reserve-rich rootstock. Nevertheless, a broader view indicated that despite tolerance of fires, even large trees benefit from its exclusion provided competition from other plants is also eliminated or kept low.

3. Contents and Food Values of the Fruit

As implied by names given to the tree in various languages, the primary traditional role of *Vitellaria* is derived from the oil present in the kernels. This oil has played an important part in local economies in west and central Sub-Saharan Africa for centuries. Today, *Vitellaria* produces the second most important oil crop in Africa, after oil palm, but as it grows in areas unsuitable for oil palm, it takes on primary importance in West Africa. Shea butter is a vital source of energy for those who cannot afford other fats although its energy values given by different authors are rather low, ranging from 2.3 - 2.6 MJ 100 g^{-1}. The solidified shea oil is called ‘butter’. It is constituted primarily of heavier carbon molecules and is more or less solid at room temperature. It has been suggested that the staric acid content has a beneficial effect on total cholesterol, **LDL cholesterol and factor VII Coagulant** activity in humans. The kernel itself is rich in vitamin A.

The pulp, which surrounds the nut, is eaten fresh during the collection period, and its taste can be sweet or bitter and astringent, in which case it may be inedible. The fruit pulp is a particularly rich source of ascorbic acid, i.e. 196.1 (mg 100 g^{-1}) compared with 50 (mg 100 g^{-1}) for oranges (Table 1). The iron and calcium content compares favorably with raspberries: 1.93 mg 100 g^{-1} compared with 0.92 mg 100 g^{-1}. It is also reported that B vitamins are also present. The sugar content varies from 3-6%, equally distributed between glucose, fructose and sucrose. Whilst the total carbohydrate content is not as great as in, for example, mango or banana, the importance of the pulp in the pre-harvest ‘lean season’ has been noted across the species range. The fruit is a food source for wilds animals and is also eaten by domestic animals such as pigs and sheep. Since the unripe fruit contains latex, the fruit can only be eaten raw if slightly overripe or after light cooking. The riper the fruit, the lower is the quantity of unsaponifiable matter.

Freshly picked fruits contain kernels with moisture content of 40-60% while different values of moisture contents of dried kernels have been reported by different authors (Table 1). The quality of shea kernels is determined by the level of free acidity, i.e. the lower it is, the better the butter produced. Free acids are produced by the breakdown of fats, a process which occurs in the presence of water and catalytic agents such as lipolytic enzymes (inherent in the kernel or produced by bacteria or fungi) and certain chemical compounds. Inadequate storage is the primary reason for the loss of kernel quality, and drying is essential to avoid spoilage.

Table 1. Mineral elements, ascorbic acid levels and fruit sugars in the fruit pulp and nutritional values of dried *Vitellaria* kernels.

Item	Value
A. Mineral Elements (mg 100 g^{-1})	
Magnisium	26.30
Calcium	36.40
Zinc	0.47
Molubidenum **(Mn)**	0.24
Copper	0.11
Iron	1.93
Posphorus	18.00

B. Ascorbic Acid (mg 100 g^{-1})	
Ripe fruit	196.10
Unripe fruit	33.00
C. Fruit Sugars (g 100 g^{-1})	
Glucose	1.1 - 2.0
Fructose	1.1 - 1.9
Sucrose	0.7 - 1.7
D. Nutritional Item*	
Fat (%)	31.3-62.0, 34.0-60.3, 40.0-57.0, 42.0-57.0, 45-60.0, 48.8, 52.6, 53.4-55.5
Protein (%)	8.4-8.8, 8.0-9.0, 6.8, 9.0, 7.4, 7.3, 8.4-8.9
Carbohydrate (%)	31.0-37.0, 26.0, 38.2
Unsaponiable fat (as percentage of total fat content)	4.6-11.0, 3.0-6.0, 4.0-10.0, 2.5-12.0, 4.0-10.0
Calcium (%)	0.10, 0.11
Phosphorus (%)	0.04, 0.04
Iron (%)	0.003
Thiamine (mg 100 g^{-1})	0.0006
Moisture content (%)	6.8 - 8.0, 5.0 - 8.0, 6.9, 5.7

Source: modified from Hall et al. (1996); * Values reported by different authors

4. Processing of Shea Butter

The traditional, labor-intensive processing of shea fruit for the extraction of shea butter is a task performed solely by woman. Regional variations exist in the traditional methods of oil extraction, even within the same ethnic groups, but there are several basic steps involved. The steps involved in the processing of shea butter include collection of nuts, depulping, drying of nuts (Fig. 2), dehusking, drying and smoking of kernels, pounding and grinding, mixing with water, treading, kneading and churning, floating, washing and refining and solidifying and moulding for the details. Among the several ways of producing shea-butter, the following is a procedure used by the Mossi of Burkina Faso (von Maydell, 1986). The ripe fruit is collected under the trees during the rainy season, stored in deep pits, covered with earth and kept moist, causing it to ferment, which facilitates the removal of the fruit pulp. After cleaning, the seeds (nuts) are boiled and dried for easier separation of the hard brown pericarp from the inner kernel or almond. This separation is achieved by pounding and crushing while lighter shell particles are removed by shaking and winnowing. Moisture is reduced to approximately 10% by air-drying to avoid germination or decomposition of the seeds. Now, the kernels can be stored for months without spoiling. Finally the butter is molded into characteristic shapes and packed in leaves for preservation, ease of storage and transport. Shea butter is often sold as loaves (Fig. 2), in shapes characteristic of particular villages, weighing usually 2.2 - 2.7 kg. The deeper the colour, the stonger the odor and taste of shea butter. This has been linked to the presence of decomposed proteins, which occur in proportion to the degree of fermentation of the nuts and as a result of over-roasting.

The time taken for processing shea butter, not including collection or drying, depends on experience and the method used. It commonly takes 5-6 hours, but may take less than four hours or more than nine hours. It has also been estimated that 8.5 - 10.0 kg of fuelwood is needed to produce one kilogram of shea butter. Typical efficiency rates for traditional techniques of shea butter processing expressed as the weight of butter produced per kg of kernels processed range between 10 and 34%. The skill and experience of the buttermakers and their particular processing techniques have a considerable influence on the efficiency of oil extraction in relation to oil content. The highest extraction rates of up to 83% have been obtained by Dagomba women in northern Ghana, who are considered to have most developed their traditional technology in terms of speed and efficiency, but the more usual extraction rates vary from 30-70%. The colour of shea butter varies, depending on the processing technique, in particular on the different temperatures to which the kernels are heated during the different processes. This enables butters from various ethnic groups to be readily distinguished. The keeping properties of shea butter are good following careful preparation. In parts of Benin, it is common for women to store butter pats for two years.

The traditional oil extraction technique of shea butter is time consuming, physically exhausting and requires large quantities of fuelwood and water resources that are often scarce in the regions where the butter is produced. In general, it is also inefficient in tems of the amount of available fat, which is extracted. Attempts have been made to incorporate appropriate technology into a number of the processing stages, both to improve efficiency and or reduce the amount and drudgery of the labour as well as impact on the environment. The Dagomba women of Ghana were among the first to initiate mechanization of the process. They adapted a corn mill to grinding roasted shea nuts. Other inventions include: a kneading machine, grinders, a hydraulic hand-press, solar dryers and a heater and mixer. Manual labour, animal traction and motors have been employed to power these devices. Some of these interventions have achieved extraction efficiency rates of up to 85% with about 60% as the minimum. Eventually a more appropriate kneader was developed in consolation with the women themselves, which although its extraction rest was slightly lower than the manual process, reduced the work time by two- thirds.

5. Uses

The uses of *Vitellaria* could be categorized as traditional and industrial.

5.1. Traditional Uses of *Vitellaria*

The *Vitellaria* tree is sacred to many ethnic groups and plays an important role in religious ceremonies. Together with the fir tree, it is said to have been blessed by God during the Great Flood, when Noah's Ark came to rest between the two trees and was thus saved from capsizing. Almost all parts of the tree, namely flowers and fruits, foliage, roots, bark, wood and latex are used. Even, one of its parasitic mistletoes and one of the leaf eating caterpillars are used locally.

5.1.1. Flowers and Fruits

The flowers are prepared into food items and eaten by some ethnic groups. The fruit pulp is a valuable food source but may also be taken for its slightly laxative properties. The nuts are eaten raw by children. Shea nut cake is also used for cattle feed although in small amounts as it has been shown to have some toxic properties. The residual meal is also applied to the exterior walls of mud huts, doors, windows and traditional beehives, in a similar way to shea butter, to act as a waterproof layer. The sticky black residue, which remains after the clarification of the butter, is used for filling, cracks in hut walls and as a substitute for kerosene when lighting firewood. The husks make good mulch and fertilizer, but are also used as fuel on three-stone fires.

5.1.2. Foliage, Root, Bark and Latex

Decoctions of yound leaves are used as a vapour bath against headaches (migraine). Medicine to treat stomachache in children can be produced from the leaves. The leaves in water give a forthy opalescent liquid, with which the patient's head is bathed. Leaf decoction is also used as an eye bath. The leaves are a source of saponin, which lathers in water and can be used for washing. Roots and root bark are ground to a paste and taken orally to cure jaundice and used for the treatment of diarrohea and stomach ache. Mixed with tobacco, the roots are used as poison by the Jukun of northern Nigeria. Chronic sores in horses are treated with boiled and pounded root bark. Infusions of bark have been shown to have selective anti-microbial properties. Macreated with the bark of kapok tree and salt, bark infusions have been used to treat cattle with worms. Infusions have been used in the treatment of leprosy, for gastric problems and against diarrhoea or dysentery. A bark infusion is used as eyewash to neutralize the venom of the spitting cobra and also as a foot bath to help extract Jiggers. Bark extracts are also taken as a drink or bath because of their curative effect. The latex is heated and mixed with palm oil to make glue. It is chewed as a gum and made into balls for children to play with.

5.1.3. Wood

The wood has a range of uses, which reflect its hardness, durability and resistance to termites. These include domestic utensils, mortars, Fuel, firewood, charcoal , stakes, construction, medium and heavy duty flooring, furniture, seats, joinery, sleepers, tools & hoe handles, shingles, house posts and frames, platters. Use for domestic utensils is consistently reported. The wood ash is used for dyeing. However, as wood usage tends to compete with demand for the fruit, wood only tends to be used when the tree has passed the fruit-bearing stage, when unproductive trees are eliminated or branches are lopped to promote fruiting, and in areas where the fruits are not valued. A long-term graveyard test in Uganda showed that twenty untreated samples all survived for 12 years, and the overall loss through degradation was only 7 %. In Uganda, poles that had not been stripped of bark were found to have a reduced number of insect borers compared with debaked poles, after three months.

5.1.4. Other Traditional Uses

Vitellaria serves as a source of fat for soap making, particularly for ethnic groups who do not have access to other vegetable fats. The production of soap provides a useful means of disposing of rancid butter, and the sale of soap insures a valuable and reliable source of income to women's household budgets. One of *Vitellaria*'s most common parasitic plants, *Tapinanthus globiferus* (A. Rich.) Danser, is reported to have many medicinal purposes. The importance of *Vitellaria* for apiculture has been noted for the savanna zone of Nigeria as well as central and northern Togo and Benin. Traditional bee hives are often placed singly, or in groups, in the branches of the trees since the flowers furnishe bees with a great quantity of nectar and pollen.

As a cosmetic, it is used as a moisturizer and for dressing hair and for protection against the weather and sun. It is popularly used of dislocation, swelling and bruising. It is widely used to treat skin problems such as dryness, dermatitis, sunburn, burns, chilblains, ulcers and dermatoses, and to message pregnant women and small children. The high melting point (32 - 45^{o} C), close to body temperature, is an attribute, which makes it particularly suitable as a base for ointments and medicines. Shea butter is also used to treat horses internally and externally for girth galls and other sores. The healing properties of shea butter are believed to be partly attributable to the presence of allantoin, a substance known to stimulate the growth of healthy tissue in ulcerous wounds. Poor quality butter is applied to doors, windows, earthen walls, and even beehives as a waterproofing agent. Traditionally, shea butter, especially of poor quality or when rancid, was commonly used as an illuminant, in lamps or as candle. Refuse water from the production of shea butter is believed to keep termites away from places where it is deposed of. In Burkina Faso, shea butter is mixed with cowpeas in traditional storage containers to protect the crop from insect damage.

5.2. Industrial Uses

In the early days, shea oil was mainly used in edible fats and margarine but later began to attract interest from the soap and perfume industry. Since the mid 1970s, the market for shea products has expanded rapidly, particularly in the cosmetics (Fig. 2) and confectionery industry. Its appeal to manufacturers lies in its price and properties, but also in the fact that it provides an exotic label for their products, which meets the demand for natural products by modern customers. Shea butter is produced on an industrial basis in Benin, Burkina Faso, Mali and Togo but exported in any great quantity only from Benin, where there is the capacity to use deep tank storage for bulk shipping of 500 - 100 tons lots. The relative expense and scarcity of suitable containers represents a major block to export of processed shea butter form Africa. For this reason, and also for reasons of quality control, it is kernels that tend to be exported. Shea butter has a number of industrial roles, but the majority of kernels (approximately 95%) provide an important raw material for cocoa butter replaces (CBRs), used for manufacturing chocolate and other confectionery. Minor uses include cosmetics and pharmaceutics. The export market for CBRs is shared by Unilever (UK), Arhus (Denmark), Fuji Itoh and Kaneka-Mitsubishi (Japan) and Karlsham (Sweden).

Figure 2. Nuts of *Vitellaria paradoxa* being dried in a clay kiln and traditional *Vitellaria* butter pats at a market in Benin; industrially produced shea butter beauty products in Burkina Faso (left) and United Kingdom (right).

6. Marketing and Future Demand

Within Africa Shea-butter products are traded in the form of sun-dried nuts, oil in cans, indurated fat (Shea-butter), margarine in tins or as a pounded mass (kadanya). It would seem that export demand is relatively stable and can easily be met by the present supply. Producers of CBEs have the ability to store processed oil and are therefore able, to some extent, to ride any annual fluctuations. Future demand will be strongly affected by the market for chocolae products. Unfortunately, for countries producing shea products, the prices offered are directly affected by those of cocoa butter. In years of poor cocoa harvest, a good price is offered for shea products but in good cocoa years the opposite is true.

7. *Vitellaria paradoxa* subsp. *nilotica* in Ethiopia

As indicated above, in the GNRS, VPN is known by the local name '**Wado**' (Anywaa) (Tesfaye Awas, 1997). Despite its great traditional and industrial importance, very little is known about this species in Ethiopia. Even the indigenous knowledge about the species has not been investigated and documented.

7.1. Botanical Description

Characteristically, the VPN is a medium-sized, 12-15 meters high, tree, which is deciduous in the dry seasons, and with poor stem form (Fig. 3). Its bole is stout and one to three meters long with a diameter of one meter. Its branches develop into a number of large, knotted, wide-spreading limbs that form a dense crown with the lower branches dropping to the ground. The branchlets are also stout. The bark has a dark grey to almost black colour and is deeply fissured and cross-cut to form very thick, four to six centimeters wide, square or rectangular scales (Fig. 4). This prominent scale-pattern extends to the smaller branches. The slash has crimson colour with exuding copious white latex (Figure 4). Leaves exhibit reddish colour when young and are clustered towards the top of the branchlets, being pubescent at first and glaborous or puberulous when matured (Fig. 4). They are repand and oblong to obovate-oblong in shape with rounded apex and base and measuring up to 25 cm in length and 10 cm wide. The leaves usually produce 20 - 30 pairs of conspicuous and parallel lateral nerves that spread almost at right angles. Lenght of the petiole measures four to ten centimeters. Flowers are eight to ten-merous and borne in dense clusters at the extreme tips of the branchlets above leaves of the previous years (Fig. 4). Sepals are produced in two sizes and measuring eight to twelve millimeters, having oblong-lanceaolate shape with the outer row softly rust-brown tomentose outside and the inner row pubescent and greenish, often with a pink tinge, in colour. The petals posses creamy-white colour (Fig. 4) and develop about as large as the calyx. The staminodes are petaloid, apiculate and toothed. The pistil develops a tomentose ovary and persistent style. Pedicles are ferruginous-tomentose and measure up to 2.5 cm. Size of the ellipsoide fruits ranges between five and six centimeter in length as well as four and five centimeters in diameter (Fig. 4). Each fruit contains one to three shining and dark brown seeds with large white scars running down at one side and measuring five centimeter in length and about three centimeters in diameter. The sapwood and heartwood are pink and deep rich red with a purple tinge in colour, respectively. The tree produces very hard and heavy (density = 1.28) wood, which is very resistant to termites. The wood is difficult to saw, tends to split, picks up under the plane and takes a high polish (von Breitenbach, 1963).

Figure 3. VPN growing in the GNRS during the dry (left) and rainy (right) seasons. Note the big grasses at the left and the developing grasses at the right sides, which serve as fuel for the annual fire.

7.2. Geographical Distribution

VPN occurs naturally exclusively in the Gambella National Regional State (GNRS), which is located in the south-western part of Ethiopia (von Breitenbach, 1963; Deribe Gurmu, 2002) at 6° 30' - 8° 30' N and 33 00' - 35° 45' E (Anonymous, 1988; Tesfaye Awas, 1997; Tesfaye Awas et al., 2001) (Fig. 1) and covering a total area of 3,203,280 ha (Anonymous, 2001; Deribe, 2002). The eastern part of GNRS comprises the main highland escarpment and foothills that lead into a wider river flood plain of the Baro and Akobo Rivers, interspersed with undulating ridges of low relief. The northern and eastern parts of GNRS have an elevation of about 2000, the central part is between 500 and 600 m and the elevation decreases gradually to an altitude of 300 m towards the border of the Sudan (Tesfaye Awas et al., 2001). The three areas that predominantly contain VPN in the GNRS are Abobo, Gog and Phugnido, which are on the average 98 km apart from each other. Abobo and Phugnido lie at the interfluves between the plains while Gog is found within the escarpment. Abobo is located between 7° 50’ N and 34° 25’ E (Anonymous, 1988) with a total area of about 329,700 ha at an altitude of 600 m. Gog is located between 7° 30’ N and 34° 30’ E with a total area of about 701,750 ha at an altitude of 500 m. Phugnido is located between 7° 33’ N and 34° 45’ E with a total area of about 385,800 ha at an altitude of 500 m.

Figure 4. Trunk of *Vitellaria paradoxa* showing deeply fissured bark and blaze, immature fruits borne in clusters at the extremities of branches, freshly cut stump showing white latex, leafless shoots bearing fascicles of melliferous, creamy flowers, plumule emerging from the pseudoradicle after cryptogeal germination, longitudinal transverse section of fruits, terminal clusters of leaves showing undulating margin and shoot with prominent leaf scars (Source: Hall et al., 1996).

7.3. Ecology

A summary of the available information on the ecology of the distribution areas of VPN in the GNRS, namely rainfall and temperature, soils and vegetation, is presented below.

7.3.1. Rainfall and Temperature

The rainfall generally increases with increase in altitude and ranges between 850 mm in the west to over 2000 mm at the highest parts of the escarpment (Anonymous, 2001; Deribe Gurmu, 2002), with May to September as the wettest period (Chaffey, 1979). The mean annual temperature is high with mean annual maximum of 35 - 38° C and mean annual minimum of 18 - 20° C (Friis, 1992).

7.3.2. Soils

Four major soil types have been recognized in the GNRS: (i) the fertile but poorly drained Vertisols, which are found at the low-lying alluvial plains and representing 47 % of the total land mass; (ii) the relatively well drained orthic Acrisols, which are found at the interfluves between the plains and representing 14 % of the total land mass; (iii) the fertile eutric fluvisols, which occasionally contain high water tables and found at the gently sloping foothills below the escarpments representing 27 % of the total land mass; and (iv) the deep and well drained dystric nitosols of moderate fertility, which are found at the escarpments and representing 12 % of the total land mass (Anonymous, 2001; Deribe Gurmu, 2002). VPN can establish itself on areas underlain by old crystalline rocks, and prefers orthic Acrisols with pH values of above 6.0. It can tolerate drought but not flooding (Friis & Vollesen, 1984; Deribe Gurmu, 2002). The best representation of the species is in the colluvial phase of the toposequence where on loamy sand or sand, trees of VPN are among the more frequent woody species.

7.3.3. Vegetation

About 1,850,700 ha (about 58 %) of the total land area of GNRS is covered by forests, woodlands and bushlands (Fig. 5). The woodlands and shrublands cover total areas of about 1,167,200 and 149,000 ha, respectively, while the natural high forests cover 534,500 ha

(Anonymous, 2001; Deribe Gurmu, 2002). In Abobo, Gog and Phugnido, the woodlands cover about 75,200, 381,800 and 38,000 ha, respectively.

Figure 5. The habitat and vegetation in which VPN grows in the GNRS.

Four components of vegetation have been recognized in the GNRS, namely *woodland and grassland, riverine forests, dry peripheral semi-Guineo-Congolian forests and transitional rainforets* (Tesfaye Awas, 1997). In his classification of floristic forest types in Ethiopia, Friis (1992) classified the forests, woodlands and shrublands occurring in the GNRS under the "*Dry peripheral semi-deciduous Guineo-Congolian forests*" (Fig. 1). These forests are restricted to the GNRS, and have only become known in recent years. The first inventory of a forest of this type was made by Chaffey (1979) and was also visited by several other botanists since then (Friis et al., 1982; Friis, 1986; Mesfin Tadesse, 1992; Ensermu Kelbessa et al., 1992; Friis, 1992; Tesfaye Awas, 1997). The following description of the forest vegetation in the GNRS has been taken from the work of Friis (1992).

The forest occurs mainly on rocky or sandy and well-drained soils, and is semi-deciduous, with a 15 - 20 m tall, more or less continuous canopy of *Baphia abyssinica* (endemic to southwestern Ethiopia and adjacent areas of the Sudan), mixed with less common species such as *Celtis toka, Diospyros abyssinica*, *Lecaniodiscus fraxinofolius*, *Malacantha alnifoiia*, *Trichilia prieureana*, *Zanha golungensis* and *Zanthoxylum leprieurii*. Some species emerge high above the main canopy: *Alstonia boonei, Aniiciris toxicaria, Celtis gomphophylla* and *Milicia excelsa*. Below the closed canopy is a more or less continuous stratum of small trees, especially *Acalypha neptunica, Erythroxylum fischeri, Tapura fischeri, Ziziphus pubscens* and *Xylopia parviflora.* The shrub layer is sometimes dense and includes: *Alchornea laxiflora, Argomuellera macrophylla, Mimulopsis solmsii, Oncoba spinosa, Oxyanlhus speciosus, Rinorea ilicifolia* and *Whitfteldia elongata*. Tail lianas are not prominent, but the lower strata of the forest are often densely mixed with woody climbers, some of which are thorny and make walking in the forest difficult. There is no record of any epiphytic species. The ground is mostly covered by thick litter, and there are apparently very few species of forest floor herbs, one being the widespread grass species, *Streptogyna crinita*.

Unfortunately, no mention has been made about VPN in the work of Friis (1992), presumably due to the limited exploration of the floral composition of the GNRS. As indicated above, Friis (1992) admitted that the vegetation resources of GNRS remained unexplored and, hence, became known and reported only in 1979. He also admitted that the two botanical explorations they made in 1982 and 1986 were restricted to the track between Abobo and Gog villages, 50 – 100 km south of the town Gambella (Friis, 1992, page 28). As a result, VPN was completely missed out in the book published by Friis (1992) and entitled "*Forests and Forest Trees of Northeast Tropical Africa*" despite the fact that Cufodontis (1953-1972, page 663) had enumerated the species as *Butrospermum niloticum*, also indicating its distribution in southwestern Ethiopia. Moreover, during our herbarium study, only five specimens were found deposited in the National Herbarium suggesting that the species has not been botanically well explored. This might partially explain why information about VPN is so scanty.

In a recent study, the vegetation of GNRS has been classified into seven major clusters or plant community types, namely *Commelina zambesica - Hygrophyila auriculata, Sorghum purpureo-sericeum - Pennisetum thunbergii, Loudetia arundinacea - Hyparrhenia pilgeriana, Combretum adenogonium - Anogeissus leiocarpa, Tamarindus indica - Anogeissus leiocarpa, Baphia abyssinica - Tapurea fischeri* and *Manlikara butigi - Cordia africana* community types (Tesfaye Awas, 1997; Tesfaye Awas et al., 2001). VPN was reported to occur in *Loudetia arundinacea - Hyparrhenia pilgeriana* community type (Tesfaye Awas, 1997).

7.4. Ethnobotany

Of the 18 ethnic groups represented in the GNRS, the Neur ethnic groups are semi-settled agro-pastoralists whose life style is predominantly associated with the collection, processing and use of forest products, e.g. wild fruits of trees such as VPN, and livestock rearing (Anonymous, 2001; Deribe Gurmu, 2002). They mostly depend on livestock than agricultural products. The Neur ethnic groups use VPN for different purposes. They use it as a source of food and feed, wood, cooking oil and traditional medicine as well as for lighting. The oil is applied as eye ointment and also used to make soap and cosmetics locally. Extracts from roots and the bark of roots and stems are used against various human and animal diseases. Decoction of leaves is used against headache and as eye ointment. The flowers are used to maximize honey production through the traditional apiculture practice. Ash from burning the wood is used as dyeing material. VPN is the only tree used by the Neur as source of edible fleshy fruits and oil/butter. The fruits are eaten directly and/or used to extract oil/butter (Tesfaye Awas, 1997; Deribe Gurmu, 2002). Similar to the different shea butter producing ethnic groups in Africa, the Nuer have their own unique way of shea butter production.

7.5. Traditional Processing of Shea Butter

Currently, seed collection is done only for domestic consumption as it is used as a source of food, feed and medicine by the local households. The women and children collect the fruits, mostly, from the ground following their dispersal by the trees and either by climbing the trees or throwing sticks to fruit producing branches. The fruits are, then, stored in sacks or in clay pots for about one or two days and used to process a thick white substance, which looks like butter or thick oil, known locally as '*Mare-weddo*' and used as cooking oil. In addition, thin, white and sweet oil, known locally as '*Acargnane*', which is used to prepare local bread, is produced from the pericarp of fruits. The powder prepared by pounding the pericarp of fruits is locally known as '*Adeg-atteir*' (Anonymous, 2001; Deribe Gurmu, 2002).

7.6. Market Prospects for Shea Butter from VPN

The demand in the international market for shea butter from VPN is very high. But, the overall shea butter produced from VPN in the Sub-Region encompassing Ethiopia, Sudan, Uganda and Zaire, has so far had negligible commercial impact internationally compared with VPP due to the decline in its populations associated with anthropogenic and natural factors, which are discussed below (Deribe Gurmu, 2002).

7.7. Status of Populations of *Vitellaria paradoxa* subsp. *nilotica*

There is very little information about the status of populations of VPN in the GNRS. However, the first hand visit by the authors of this paper to the three areas reported to contain populations of VPN revealed that the populations of VPN exhibit sparse distribution, often growing in pockets, in the vegetation described above. For instance, in Gog, considerable number of trees has been observed in small pockets at Chaydi, Bare-Gilo, Wellagn, Apuwa, Terkudii, Pentidii, Awaree, Digra, Aja, Gog-Dipach and Chach (Anonymous, 2001; Deribe Gurmu, 2002). Despite the sparse distribution of VPN, its populations are under pressure from anthropogenic and natural factors. The anthropogenic factors include deforestation, through the annual human-induced fires and damage associated with livestock during grazing. The natural factors include damage inflicted upon the trees by the natural bush fire (Fig. 6) recurring annually, death of trees due to ageing of the trees themselves and, probably, the consumption of fruits of VPN by wild animals, such as monkeys and rodents. These and other, as yet, unidentified potential factors could be the major factors responsible for the decline in the number of trees and hampered regeneration of VPN observed in the field (Fig. 7).

Figure 6. Occurrence of fire is an annual phenomenon in the habitat of VPN

7.8. Research on *Vitellaria paradoxa* subsp. *nilotica*

Much of the research work on *Vitellaria*, especially on VPP, concentrated in countries of western Africa. As reiterated above, similar to several other multipurpose tree species, there had been complete lack of research, development and conservation works on VPN in Ethiopia. Cognizant of the socio-economic and ecological importance as well as lack of research, development and conservation works in Ethiopia, the Forestry Research Directorate (FRD) in the Ethiopian Agricultural Research Organization (EARO) has initiated a PhD thesis research work entitled "*Phytogeography, Genetic Variation and Mating System of VPN in Ethiopia*" (Deribe Gurmu, 2002) in collaboration with University Putra in Malaysia (Fig. 8).

Figure 7. Seedlings of VPN during the dry (left) and rainy (right) seasons.

The overall objective of this study is to examine the population distribution, genetic variations both within and between provenances/populations and investigate some aspects of the mating system of VPN. The specific objectives of the study are to: (i) examine the phytogeographical distribution and status of the species; (ii) assess the genetic variation within and between provenances of the species by using both morphorogical characteristics/traits and isozyme analysis; and (iii) investigate some aspects of the mating system and, subsequently, draw the phylogentic relationships of the natural populations of the species (Deribe Gurmu, 2002). So far, the reconnaissance surveys and field data collection activities have been conducted. Results would be disseminated to relevant stakeholders through various means, including publications, as soon as the study is completed.

Figure 8. An example of the ongoing PhD research work on VPN in GNRS.

8. Conclusions

Vitellaria paradoxa subsp. *nilotica*, an indigenous species already recognized for its great socio-economic and ecological benefits, occurs exclusively in the GNRS, southwestern Ethiopia. Besides its traditional benfits to the local hosuseholds, specifically the Neur communities residing in GNRS as a source of food, feed and medicine, it has great potentials for various industrial uses, e.g. in the production of chocolates, cosmetics and pharmaceuticals. However, almost no attention was given to the species from concerned bodies, which is reflected in the complete lack or scantiness of documented information on either the indigenous/traditional knowledge or research results on the species. Obviously, similar to other multipurpose tree species, development and conservation works on this extremely important species do not exist.

These being the realities, the natural populations of VPN are being affected by both anthropogenic and natural factors, leading to its hampered regeneration and decline in the number of trees in the field. If impacts from these factors continue unabated, there could be a great danger of local extermination of the species. This, in turn, could result in undesirable impacts on the welfare of the local pastoral and agro-pastoral communities who depend on the species for food, feed and medicine. It could also mean great socio-economic and ecological loss to the country as a whole.

This calls for urgent attentions and interventions by all concerned bodies, be it Government, Non-Government and Private Organizations as well as professionals and their Societies/Associations, which is one of the major objectives of this article. Already, research work has been initiated by the FRD in EARO which is aimed at examining the population distribution, genetic variations both within and between provenances/populations and investigate some aspects of the mating system of VPN and, hence, generating valuable firsthand information on which future research, development and conservation works on VPN could base. More research works dealing with different aspects of this valuable, and other similar multipurpose species, are recommended.

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