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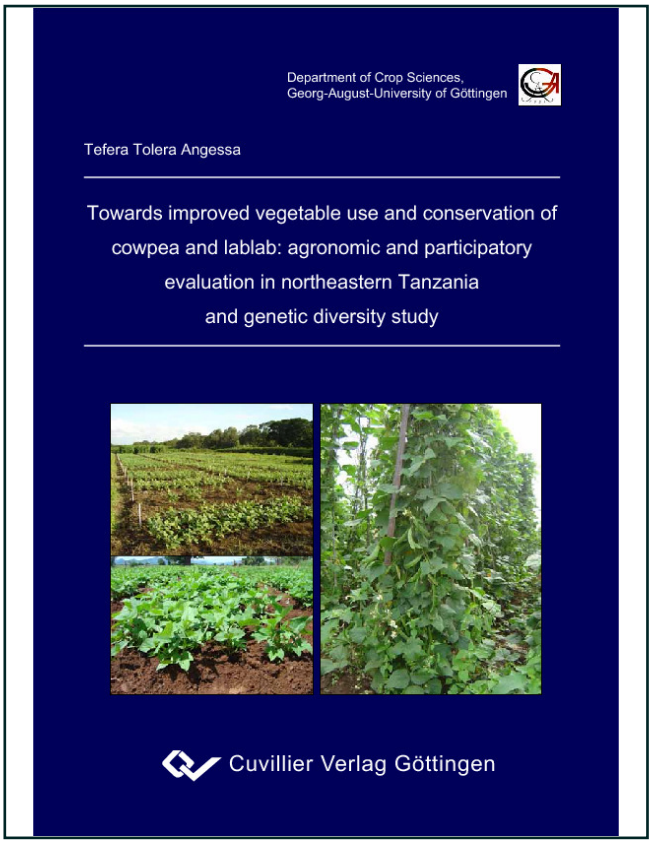
Towards improved vegetable use and conservation of cowpea and lablab: atronomic and participatory evaluation in northeastern Tanzanaia and genetic diversity study



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Chapter 1. General introduction

1.1 Background

1.1.1 Challenges for improving nutrition in Africa

The world population is increasing at high rate, while a large proportion is malnourished, hence, not only of poor health and low productivity but also with subsequent problems of cognitive development of children. Sub-Sahara African countries are most prominent in those that face a strongly increasing human population with which food production could not keep pace. In eastern and southern Africa, about 20-25% of the population is under-nourished due to poor energy and protein intake. In addition, 40% of the women in childbearing age have anemia, while a similar proportion of under-five children lack enough nutrients for normal physical development. It has been predicted that 132 million children worldwide will be malnourished with anticipated increased prevalence in Africa (IFPRI, 2001).

Wheat, rice and maize, which belong to the Poaceae family, account for more than 50% of human food globally (FAO, 1996). Also crops such as common bean (*Phaseolus vulgaris*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea*), belonging to the Fabaceae family, play a significant role in food provision. But, these crops that received major public and private attention in research and development cannot fill the comprehensive food needs particularly in sub-Sahara Africa.

Many locally and regionally important food crops exist and can help to solve the problem of malnutrition, food shortage and chronic starvation (Maundu et al., 1999). Among African legumes with broad economic importance, cowpea (*Vigna unguiculata* (L.) Walp.) is widely cultivated in eastern and southern Africa (Fery, 2002), while lablab (*Lablab pupureus* (L.) Sweet) production is patchy. Legume and other leafy indigenous vegetables are nutritious (Table 1.1), drought-tolerant, suitable for local production systems, require little management, and have social and cultural values. Various products (young shoots, young leaves, young pods, immature seeds, mature seeds and sprouts) of different legume species and cultivars are consumed in diverse ways. Despite their significant role in food

provision, many of these locally and regionally important crops are neglected in research and development (Padulosi et al., 2002).

The food habit in eastern and southern Africa is mainly starch-dominated. Nutritionally, legumes and cereals complement each other (Kitch et al., 1998) because of the low composition of the amino-acids methionine and cystine in the former and the low content of lysine in the latter. Despite their high nutritional quality, their utilization as vegetable since ages by local societies, and their co-evolution as locally important crops together with complex farming systems, little research has been conducted and, hence, poor achievements have been made for African legumes as vegetables. As a result, available diversity should be researched and promoted in order to develop improved cultivars, though breeding for advanced genotypes has an adverse effect on the genetic diversity. Therefore, appropriate conservation mechanisms need also be established in order to conserve the germplasm and important traits to meet the need of future generation.

1.1.2 The crops

Cowpea. Cowpea is originated from and domesticated in Africa (Zeven and de Wet, 1982). Centers of diversity have been identified in both Africa and Asia (Fig. 1.1). However, the exact region of domestication is still under speculation. Coulibaly et al. (2002) suggested the center of domestication of cowpea could be western Africa due to the (1) highest level of morphological diversity for cultivated cowpea, (2) existence of weedy intermediates between wild and cultivated cowpeas, (3) oldest archeological evidence for cowpea in Ghana, and (4) identification of a wild and a cultivated accession with an identical chloroplast DNA in Nigeria. The second region of domestication postulated is in northeastern Africa due to the (1) absence of true ecologically wild cowpea in West Africa, (2) high level of morphological diversity of wild cowpea in the region from Ethiopia to South Africa, and (3) results from ethnobotanic, linguistic, and isozyme studies.

Cowpea (2n=22) is highly self-pollinated in most environments, the result of a cleistogamous flower structure and simultaneous pollen shed and stigma receptivity (Ehlers and Hall, 1997). Despite introgression events and the

extensive variation in morphological and phenological traits among cultivated cowpea accessions, genetic variability in the cultivated gene pool appears to be limited (Ehlers and Hall, 1997; Li et al., 2001; Coulibaly et al., 2002). In general, four cultivar groups (cg.) of cowpea are recognized (Baudoin and Maréchal, 1985): (1) cg. unguiculata, which is the common form; (2) cg. biflora or catjang, characterized by small erect pods; (3) cg. sesquipedalis or yard-long bean, characterized by its very long pods and consumed as a green snap bean; and (4) cg. textilis, found in West Africa and used for fibers which were obtained from its long peduncles.

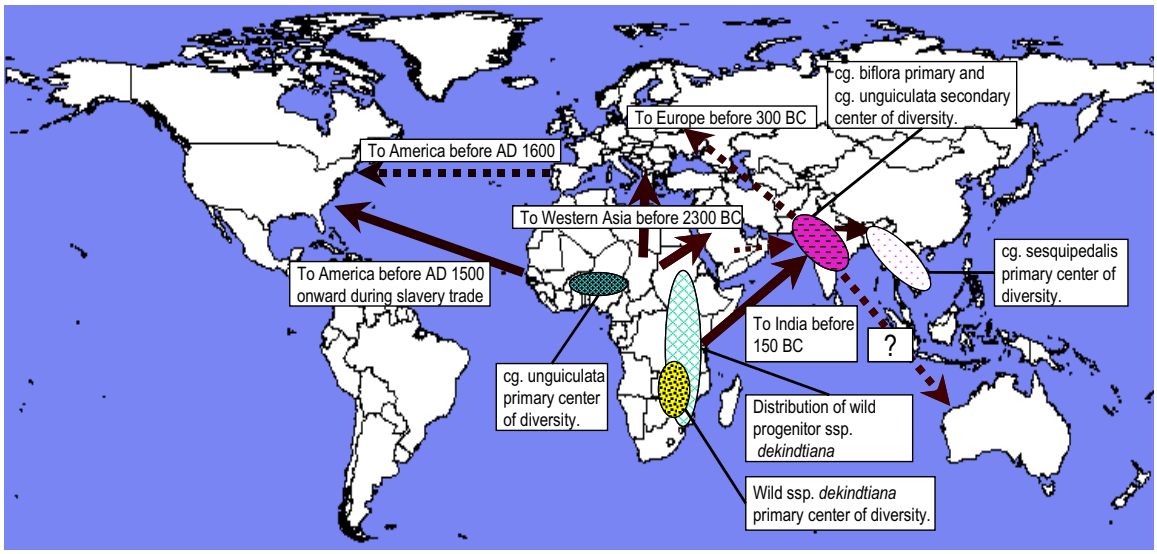

Fig. 1.1 Cowpea center of origin and probable dispersal modified from Ng and Maréchal (1985) (solid arrows, dispersal from center of origin; dashed arrows, dispersal from the secondary center of diversity).

Cowpea is widely distributed throughout the tropics and subtropics. It is an important pulse crop in farming systems in many regions of Africa (Ehlers and Hall, 1997). It is well adapted to semiarid conditions but has low tolerance to frost (Kay, 1979; Ehlers and Hall, 1997). The optimum temperature range to grow and develop is 20-35 °C, with a temperature of less than 15 °C hampering germination, while temperatures exceeding 35 °C lead to flowers and pods drop (Kay, 1979). Most genotypes respond to photoperiod but some are insensitive to a wide range of day length. Depending on genotype, environment and the interaction of both, cowpeas can flower in a range of 30 to 240 days (Wien, 1975

in: Hendricksen and Minson, 1985). Pod development is rapid and lasts about 19 days (Pandey and Westphal, 1992). Moisture stress between the age of emergence and flower initiation reduces yield, while excessive rainfall and atmospheric humidity induce high incidences of fungal diseases (Wien, 1975 in: Hendricksen and Minson, 1985). Cowpea is adapted to a wide range of soils.

Table 1.1 Nutritional composition in 100 g edible samples of some legumes as compared to common bean and other leafy vegetables of Africa adapted from Kay (1979), Tindall (1983) and Nielsen et al. (1997) (N.A., Not available).

Component	Cowpea		Lablab		Bambara groundnut		Common bean		Amaranth	Night shade
	Dried seed	Leaf	Seed	Fresh pod	Fresh seed	Dried seed	Seed	Fresh pod	Leaf	Leaf
Carbohydrate (g)	61.0	8.0	62.0	10.0	30.0	61.0	60.0	7.0	N.A.	N.A.
Fiber (g)	5.4	2.0	8.6	2.0	3.0	4.8	4.4	1.8	N.A.	N.A.
Fat (g)	1.4	0.3	1.0	0.1	3.1	6.2	1.5	0.2	N.A.	N.A.
Protein (g)	22.5	4.2-4.7	22.8	4.5	7.8	18.8	21.7	2.5	5.2	4.6
Water (%)	10.5	88.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	84.8	85.0
Calcium (mg)	104.0	110.0-256.0	90.0	50.0	14.0	62.0	120.0	43.0	340.0	215.0
Iron (mg)	N.A.	4.7-5.7	9.0	10.0	1.2	12.2	8.2	1.4	4.1	4.2
Phosphorus (mg)	416.0	63.0	328.0	N.A.	258.0	276.0	323.0	48.0	N.A.	N.A.
Ascorbic acid (mg)	2.0	35.0-56.0	trace	1.0	N.A.	trace	1.0	27.0	120.0	30.0
β-carotene (mg)	70.0	2.4-8.0	N.A.	N.A.	N.A.	10.0	10.0	750.0	7.7	1.7
Niacin (mg)	4.0	2.1	2.3	N.A.	N.A.	1.8	2.4	0.5	N.A.	N.A.
Riboflavin (mg)	0.9	0.4	0.1	N.A.	N.A.	0.1	0.2	0.1	N.A.	N.A.
Thiamin (mg)	0.1	0.2	0.5	N.A.	N.A.	0.5	0.4	0.8	N.A.	N.A.

Cowpea has both food and non-food economic values. It is an inexpensive source of protein and different nutritional components (Tables 1.1, 1.2, 1.3). Farmers in eastern, southern and other regions of Africa have long been consuming cowpea as leafy vegetable (Barrett, 1990; Fery, 2002; Keller et al., 2006). The relatively high contents of various nutritional components in cowpea leaf shows its potential use as a vegetable. A study conducted by Phillips et al. (2003) in Anambra State of Nigeria demonstrated that an increase in cowpea consumption might improve 50% malnourishment of children, though cowpeas were already prevalent in the local diet.

Table 1.2 Nutritional composition in 100 g edible portion of raw and processed cowpea leaf and seed adapted from Nielsen et al. (1997) (N.A., Not available).

Component	Leaf			Seed	
	Raw	Dried	Cooked	Raw	Cooked
Carbohydrate (g)	8.3	54.6	N.A.	61.7	13.8
Energy (Cal)	44.0	277.0	N.A.	343.0	138.0
Fat (g)	0.3	3.2	0.3	1.5	0.3
Protein (g)	4.7	22.6	3.2	22.8	5.1
Water (%)	85.0	10.6	8.9	10.5	80.0
Calcium (mg)	256.0	1556.0	132.0	74.0	17.0
Iron (mg)	5.7	12.0	4.7	5.8	1.3
Phosphorus (mg)	63.0	348.0	41.0	426.0	95.0
Ascorbic acid (mg)	56.0	86.0	6.0	N.A.	N.A.
β-carotene (mg)	2.4	27.0	6.5	0.02	0.01
Niacin (mg)	2.1	N.A.	N.A.	2.2	0.4
Riboflavin (mg)	0.4	N.A.	N.A.	0.2	0.04
Thiamin (mg)	0.2	N.A.	N.A.	1.1	0.36

Table 1.3 Essential amino acid content of cowpea (Nielsen et al., 1997) and lablab (Hendricksen and Minson, 1985) (N.A., not available).

Amino acid	Cowpea (mg/ 16g N))			Lablab (mg/ g N)			Requirements of	
	Fresh leaves	Solar-dried leaves	Mature seed	Mature seed in pod	Green seed	Mature seed	2-5 year	adult
Cystine	N.A	1.6	N.A.	56	44	39 -103	2.5	1.7
Methionine	5.0	2.6	1.5-2.3	56	56	32 - 105		
Histidine	4.1	1.8	2.9-4.7	194	262	143 - 162	2.8	1.6
Isoleucine	6.6	6.6	4.2-4.8	450	425	266 - 401	2.8	1.3
Leucine	13.4	11.8	7.6-8.5	631	650	467 - 695	6.6	1.9
Lysine	9.5	5.6	6.6-8.1	475	431	313 - 465	5.8	1.6
Phenylalanine	6.1	7.8	5.5-6.2	369	138	246 - 400	6.3	1.7
Tyrosine	4.5	4.9	2.2-3.6	63	113	143 - 313		
Threosine	6.6	6.6	3.6-4.5	194	262	168 - 313	3.4	0.9
Tryptophan	N.A.	N.A.	N.A.	N.A.	N.A.	50 - 60	1.1	0.5
Valine	6.1	9.5	4.9-5.7	313	463	316 - 393	3.5	1.3

Unlike other African indigenous legumes, cowpea has received international attention. The most extensive germplasm collection of 16,000 accessions is kept *ex situ* at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, (http://www.iita.org). This congregate of genetic resources has been used in various breeding programs to overcome several production constraints that reduce the yield potential of cowpea. IITA has been attempting to improve a number of traits, like yield level, resistance against diseases, nematodes, insect

pests, and the parasitic weed striga (*Striga gesnerioides*); it has also aimed at developing food-feed cowpea for dual use (Tarawali et al., 2002). Improving for leafy vegetable purpose, however, has neither been within the IITA's breeding goals nor within those of most National Agricultural and Research Extension Systems of African countries.

Lablab. The origin of lablab is speculated to be from Asia (Purseglove, 1968; Westphal, 1974; Kay, 1979; Shivashankar and Kulkarni, 1992), where large variability has been developed. Others claim lablab to be of African origin, where the only true wild materials have been collected so far (Verdcourt, 1970; Zeven and de Wet, 1982; Shivashankar and Kulkarni, 1992) (Fig. 1.2). Based on molecular evidence, Maass et al. (2005) did not find any evidence for Asia being the center of origin for this legume crop.

Many botanical names exist for what seem to be different forms of lablab (2n=22, 24) (NAS, 1979). Brenan (1954; in Verdcourt, 1980) showed that the type was a specimen of *Vigna unguiculata*. It was known as *Dolichos lablab* (L.) Sweet scientifically after Linnaeus but Verdcourt (1980) assigned it to the monotypic genus *Lablab*. The disagreement in naming of lablab may indicate lack of thorough study on the one hand. It also proves the thought of Kay (1979) that there might be no such variation occurring in other legumes as in lablab. In general, *Lablab purpureus* is the accepted botanical name of lablab (Verdcourt, 1980).

Verdcourt (1970) distinguished *Lablab purpureus* into three subspecies based mainly on the characteristics of pods and seeds: (1) ssp. *uncinatus* is the wild ancestral form distributed mainly in East Africa with pod size of about 40 x 15 mm, (2) ssp. *purpureus* includes a cultivated form with larger pods, 100 x 40 mm, and (3) ssp. *bengalensis* has characteristically longer pods than other subspecies, up to 140 x 10-25 mm. Due to considerable variation within these subspecies and possible crossing, it may be doubtful to distinguish them prperly.

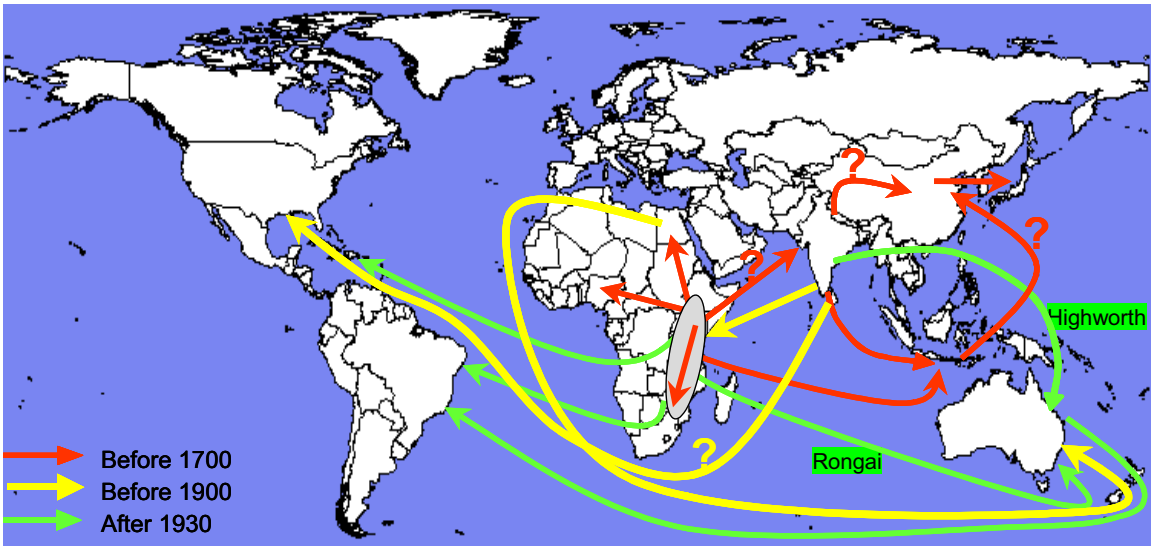

Fig. 1.2 Lablab center of origin and probable dispersal based on Maass (2005) and modified according to Hoshikawa (1981) and Maiden (1897; in Hendricksen and Minson, 1985).

Cultivated lablab is grouped into three cultivar groups (cg.) (Shivashankar and Kulkarni, 1992), namely: (1) cg. Lablab, widely distributed, mature seeds with the long axis at right angle to the suture, pods dehiscent or indehiscent, seeds not longer than ⅓-¾ of the width of the mature pod; (2). cg. Ensiformis, distributed in East Africa and South Asia, mature seeds with long axis more or less oblique to the suture, nearly filling the mature pod, pods indehiscent, difficult to distinguish from cg. Lablab when young; (3) cg. Bengalensis, also distributed in East Africa and South Asia, mature seeds with long axis parallel to the suture, more or less filling the mature pod, gibbous dorsally and at base, pods dehiscent. In India lablab is traditionally classified into garden type (Typicus) and field type (Lignosus) (Purseglove, 1968). Garden types are twining but can also be determinate; late maturing; pods long, tapering and used mainly as green vegetable; long axis of seeds parallel to the suture and require a cool season. The field types are erect (bushy), mature earlier, pods short and abruptly truncated, the green pods cannot be used as green vegetable due to their fibrousness; they are exclusively grown in low rainfall areas.

Lablab has been widely distributed to many tropical and subtropical countries where it has become naturalized (Purseglove, 1968). A recent simulation study

by Hill et al. (2006) demonstrated that lablab could produce high biomass under a number of different environmental conditions. It grows with a wide range of rainfall from 200 mm (arid) to 2100 mm (humid regions), from low lands to highlands (2100 m altitude), with different soil characteristics pH 4.4-7.8 as well as on aluminous soils (NAS, 1979). Its outstanding ability to tolerate drought is attributed to its tap root and its up to 2 m deep rooting system, which uses residual moisture, for which also genotypic differences exist (Schaaffhausen, 1963; Murphy and Colucci, 1999). For instance, CPI106548 and CPI30212 (cv. Highworth) were demonstrated to be drought-tolerant compared to other lablab accessions (Hall and Naidu, 2004). However, lablab needs rainfall or irrigation during the first two or three months after sowing (Kunhikrishnan, 1943; in Schaaffhausen, 1963). Its long production season and provision of food, fodder and soil protection, when many other herbaceous plants have become desiccated (NAS, 1979), makes lablab a potential crop suitable to produce in drought-prone areas of sub-Sahara Africa. Lablab can be a short day, long day or day-neutral plant. It requires high temperature for good performance (18-30 °C), the lower limit being 3 °C (Shivashankar and Kulkarni, 1992) or even -2 °C (Kay, 1979).

Once flowers of lablab open, they never close in the afternoon or night until they fade away (Schaaffhausen, 1963). It is reported as a cross-pollinating crop (Purseglove 1968; Skerman 1977; Shivashankar and Kulkarni, 1992) but with considerable self-pollination (Adebisi and Bosch, 2004). Systematic study is needed to discern the pollination behavior of lablab.

Lablab has been a traditional crop in Africa but is fading away (Kay 1979; Ngailo et al., 2003) probably because common bean (*Phaseolus vulgaris*) has replaced production and uses of lablab. Recently, new initiatives by International Livestock Research Institute (ILRI) and Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) researched lablab extensively as a feed for livestock. Resulting from that research, wide phenotypic and genotypic variation has been documented by Mugwira and Haque (1993), Pengelly and Maass (2001), Maass et al. (2003, 2005) and Whitbread and Pengelly (2004).

Lablab is used as pulse and vegetable (Westphal, 1974; Shivashankar and Kulkarni, 1992; Adebisi and Bosch, 2004). However, some reports indicate the presence of cyanogenic glycosides in lablab seed (Smartt, 1990), though Piper and Morse (1915) found no compound of such type in lablab seeds of different color and their respective plants. Speculative reports on cyanogenic glycosides content of lablab may be due to simple judgment based on lablab seed color and/or wrong sampling of non-lablab plants because botanical classification was not settled properly. This requires thorough study of lablab germplasm for this anti-nutritional factor. In general, lablab has high contents of nutritional components (Tables 1.1 and 1.3). However, it is neglected as a vegetable as well as pulse crop in sub-Sahara Africa.

1.1.3 Approaches

Genotype by environment interaction. The onset of rainfall since 1968 in sub-Sahara Africa has been late by historical standards with traditional varieties beginning to flower far too late (Ehlers and Hall, 1997). Additionally, farming systems in the region are heterogeneous and complex due to economic, social and cultural reasons. Convincingly, many micro-environments can be formed under such circumstances, making crop improvement efforts complicated. These necessitate studying stability of cowpea and lablab accessions for traits of economic importance across environments.

The basic cause of yield instability across environments is the wide occurrence of genotype by environment interactions (Becker and Léon, 1988), which limits the accuracy of yield estimates and complicates the identification of specific genotypes for specific environments (Crossa et al., 1990).

Depending on the goal and the character under consideration, two different concepts of stability are known (Léon 1985; in Becker and Léon, 1988). These are the dynamic and static concepts, which were defined by Becker and Léon (1988) as follows. With the dynamic concept, the genotype has a predictable response to the environment change with no deviation from the response to the environment. The static concept defines the genotype to have an unchanged performance regardless of the change in the environment.