1 General Introduction

1.1 Background

The agricultural sector in Sub-Saharan Africa (SSA) is mainly characterized by small-scale subsistence farming of low productivity. Half of all food-insecure people are farmers and, although they are the main food producers in the region, they have insufficient resources to meet their needs through production or in local markets (Cohen *et al.*, 2008). Within the region, East Africa has the lowest per capita incomes, per capita agricultural production, and per capita food production. At the same time, almost 80 percent of the population depends on agriculture for their livelihoods (Resnick, 2004).

Limited areas of arable land and unpredictable environmental conditions oblige farmers to produce a maximum of food with a minimum of waste of resources, i.e., energy within a short period. Therefore, early maturity was a very important trait of many vegetables considered by farmers in different districts of Tanzania (Keller, 2004). A common risk-reducing strategy of resource-poor small-scale farmers is increased diversification of their cropping patterns (Srivastava *et al.*, 1996; Below *et al.*, 2010). Thereby, legumes often play an important role. For example, in the Arumeru district of Tanzania, farmers do not practice crop rotation due to shortage of land, but intercrop legumes and cereals to maintain soil quality (Shetto and Owenya, 2007). Also farmers in Kenya, cultivating legumes intercropped with cereals, have land sizes not larger than 2 ha and do not apply fertilizer (Mburu *et al.*, 2008). Particularly in marginal areas, not only crops are diversified, but also their suitability to multiple utilization is of considerable importance to smallholders (Almekinders and Elings, 2001). In Eastern Africa, seed supply of subsistence crops such as legumes is primarily through the informal sector (Mitawa and Marandu, 1995; Mburu *et al.*, 2008). However, farmers' access to improved germplasm with a range of growth habits and maturity types to fit into different market and cropping niches is often insufficient (Snapp *et al.*, 2004; Mburu *et al.*, 2008).

To improve household food security of resource-poor groups in Eastern and Southern Africa, The World Vegetable Center's Regional Center for Africa (AVRDC-RCA) and partners initiated a six-year project "*Promotion of Neglected Indigenous*

Leafy and Legume Vegetable Crops for Nutritional Health in Eastern and Southern Africa (*ProNIVA*)" in 2003. Research activities within the project were focused on safeguarding biodiversity of indigenous vegetables (IVs), reducing malnutrition and poverty among small-scale farmers and consumers through promotion, production and consumption of IVs, and diversifying and stabilizing farmers' income and nutritional health through higher quality seed and improved cultivation practices of IV crops. Based on their local importance for farmers due to the good adaptability to environmental conditions and high nutritional value (Keller, 2004; Hallensleben, 2009), cowpea (*Vigna unguiculata* (L.) Walpers) was chosen as one of the indigenous preference legume vegetable crops for the ProNIVA project.

It is estimated that cowpea is grown by tens of millions of smallholders in Africa and more than 200 million people live of cowpea products (NRC, 2006). In East Africa, cowpea leaves are an important component of the daily diet in rural areas (Bittenbender *et al.*, 1984). Farmers who practice rain-fed small-scale crop cultivation are prone to seasonal malnutrition, also called pre-harvest malnutrition, especially if they rely only on single grain harvests during the year (Patel *et al.*, 2005; Wright *et al.*, 2007). In the Sahel zone, for instance, early cowpea varieties can be the first food available in the current growing season, thus, breaking the hungry period when grain stores from the previous year's harvest are likely to be low (Ehlers and Hall, 1997). Cowpea leaves are promising sources of proteins and β-carotenes for human diet (Nielsen *et al.*, 1994; Nielsen *et al.*, 1997) that are partly superior to other vegetables (Bittenbender *et al.*, 1984; Bubenheim *et al.*, 1990). Not only due to their nutritional quality but also because of their timely availability in farmers' fields before grain harvest, they become very important for the supply of nutrients in farm households (Bubenheim *et al.*, 1990).

After common beans (*Phaseolus vulgaris*) and groundnuts (*Arachis hypogaea*), cowpeas belong to the seven and twelve most frequently planted crops in Tanzania and Uganda, respectively, the other being only starchy staple crops (UBOS, 2002; NBS, 2006). In a survey carried out by Hallensleben (2009) in Arusha, Kilimanjaro, and Dodoma that are important cowpea regions of Tanzania, smallholders particularly appreciated the multipurpose character and low water demand of cowpea. However, interviewed farmers expressed their demand to access varieties with better yield performance of seed or both, seed and leaves. Further the study showed that especially farmers in Arusha and Kilimanjaro cultivated only one plant type, although they would need to increase the cowpea diversity in their plots. It was difficult for farmers to respond to price fluctuations in the markets, encounter interventions for abiotic factors such as water shortage, and to meet all requirements for the crop's multiple uses if they cultivated only one plant type. Since the 1980's, breeders have been focussing on improving different cowpea traits and started to increase yield performance of dual-purpose cowpeas (Singh *et al.*, 1997b). However, these plant types were chiefly not bred for leaf consumption by humans but for grain and animal fodder (Singh *et al.*, 1997a; Tarawali *et al.*, 1997).

1.2 Physiological aspects in cowpea

Cowpea is very well adapted to semi-arid conditions that prevail in many SSA-countries. It grows in a wide range of soils and is able to produce a substantial grain yield even under low rainfall conditions. For example, cases are reported where cowpea produced a considerable amount of grain in an environment with only 181 mm/year (Hall and Patel, 1985, cited by Ehlers and Hall, 1997). According to Graufurt *et al.* (1997), optimum temperatures for seedling emergence are 35°C, leaf appearance >28°C, first open flower between 27 and 29°C, and for first ripe pod >28°C. However, base temperatures for these characteristics range from 8°C to 16°C. The diploid crop (2n=2x=22) is highly self-pollinated in most environments (Ehlers and Hall, 1997). Usually, pollination occurs in cowpea flowers before they open. Cross-pollination is possible but occurs at rates between 1-10% (Fatokun and Ng, 2007) and 40% (Brink and Belay, 2006). It is assumed that the presence of an abundant number of pollinating insects (Fatokun and Ng, 2007) and increased air humidity (Brink and Belay, 2006) could lead to higher levels of outcrossing. Hence, seed exchange among farmers may be the main component of gene flow in cowpea landraces that contribute significantly to the level of genetic make-up and variability existing among and within cowpea accessions (Nkongolo, 2003).

1.3 Effect of defoliation on growth and yield performance of cowpea

Generally, low grain yields are reported from smallholder-produced cowpea all over the world (Singh *et al.*, 1997b), however, these ignore the additional biomass production through leaves. Smallholders cultivate cowpea as multi-purpose crop from which both leaves and seeds are harvested (Bittenbender *et al.*, 1984). However, depending on timing, frequency, and proportion leaf-harvesting practices, may reduce the seed yield by more than 60% (Nielsen *et al.*, 1994; Tefera, 2006; Saidi *et al.*, 2007). In the past, some studies have been carried out to determine the effect of defoliation on seed yield (Mehta, 1970; Nielsen *et al.*, 1994; Karikari and Molatakgosi, 1999; Saidi *et al.*, 2007). Some authors studied the defoliation effect on seed yield by removing different proportions of aerial biomass (Pandey, 1983; Rahman *et al.*, 2008). However, for human consumption only young leaves are picked repeatedly from the same plants, which may have a different effect on plant growth. Further, the impact of defoliation on seed yield seem not only to depend on the harvest method, but also to be genotypically determined (Karikari and Molatakgosi, 1999; Saidi *et al.*, 2007). Bittenbender *et al.* (1984) concluded that defoliation reduces seed yield less in indeterminate types than in determinate types. However, it has not yet been reported how repeated harvesting of young leaves affect both leaf and seed yield performances of different genotypes.

1.4 A review on yield stability

Yield parameters of a particular variety usually do not only depend on the genotype but also on its interaction with a given environment. By the analysis of variance, different sources of variation are considered. Depending on the extent of a field experiment, these are varieties (genotypes), location and years. While interaction takes place among all sources of variation, genotype by environment (GxE) interactions only occur between varieties and locations (*GL*) as well as varieties and years (*GY*). Only the interaction between varieties and location can be exploited by breeding varieties for specific localities, but only if the *GL* component is consistently greater than the other components of the GxE interaction (Witcombe, 1989).

However, a relatively larger GxE interaction is usually expressed as a higher variability in yield parameters, which complicates a selection of superior genotypes. Hence, researchers and/or breeders have to consider the adaptability, yield reliability and stability of a certain cultivar when they want to improve the sustainability of food supply. Although these three terms have a similar meaning when material for a large range of environments is selected, for location-specific selection approaches, researchers talk more about the stability and sustainability (Annicchiarico, 2002).