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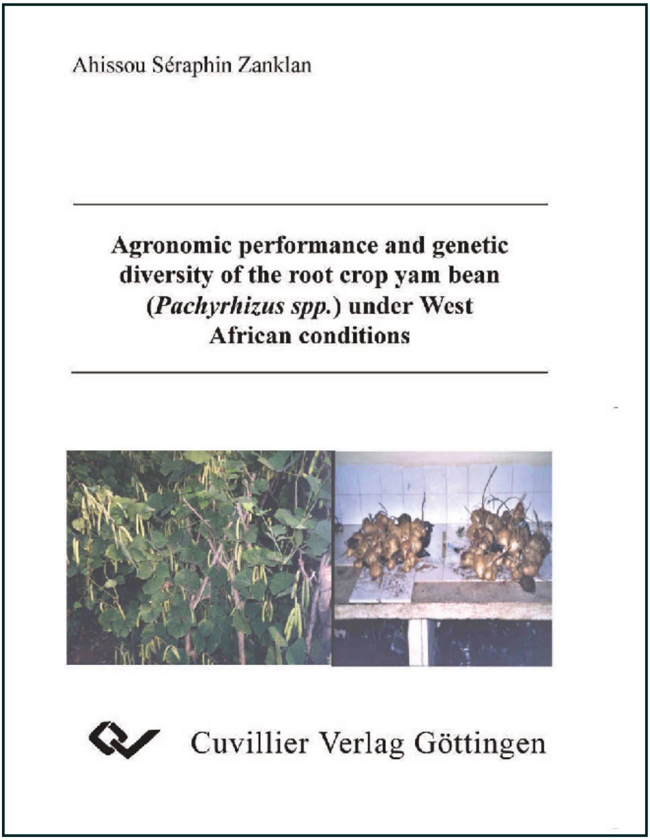
Agronomic performance and genetic diversity of the root crop yam bean(Pachyrhizus spp.) under West African conditions



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1. Introduction and literature review

1.1 Background and objectives

Many thousand plant species have been used for several purposes by human. About 100 have been developed into important crops (Hill et al., 1998) and only few of these crops have been intensively and widely used in the world´s agriculture. This has lead to the shrinking or erosion of agricultural biodiversity and at the same time to an increasing level of vulnerability of food suply. These concerns have generated growing interest in the research on “underutilized“ crops.

Root and tubers are second in importance for human nutrition after cereals. Conventional root crops such as cassava, sweet potatoes, yam and taro are seriously deficient in protein and when used as the main source of nourishment, the local population, especially weaning children, often suffers from protein deficiences. Already in 1979 the FAO (1979) pointed out that due to the unawareness of legume root crops extension agents recommend farmers to cultivate conventional root crops which often imperil good protein food sources.

The yam bean (*Pachyrhizus spp*) is one of the legume root crops. Unlike its close relatives the soybean and the *Phaseolus* beans, the yam bean is exclusively used for its tuberous roots (Sørensen, 1996; Sørensen et al., 1997). The name yam bean is used to designate the species within the genus *Pachyrhizus*, in particular the three cultivated species; *P. erosus*, from the semiarid tropics of Central America; *P. tuberosus* from the tropical lowlands of both slopes of the Andean mountain range (Sørensen, 1996) and *P. ahipa* from Andean highland (Sørensen et al., 1996). Moreover, *P. erosus* is cultivated in many South East Asian countries.

The yam bean is attractive for agronomy and plant breeding. As a root crop it might provide high yields as well as high yield stability (Grüneberg, pers. comm.) and as a legume it will produce protein rich food and improve sustainability in cropping systems (NRC, 1979). However, the plant has been known until recently as a vegetable crop only because the tuberous roots are usually consumed raw due to their high moisture content. Sørensen et al. (1997) observed a new yam bean type within *P. tuberosus* which is consumed like manioc and this so-called Chuin type from Peru has a high dry matter content (Grüneberg et al., 1998). This has lead to the conclusion that the yam bean might be developed into a widely adapted protein rich staple legume root crop. Grüneberg et al. (2003) reported that *P. ahipa* can be hybridized with the *P. tuberosus* Chuin type resulting in fertile and vigorous hybrids. The starch may be of good quality in regard to the digestibility and consists essentially of amylopectine (Bergthaller et al., 2001). The seeds of the yam bean are not used due to the high rotenone content (about 1% seed weight), even so the seeds are an interesting source of high palmitic acid oil (Santos et al., 1996, Grüneberg et al., 1999). According to Santos et al. (1996) a rotenone reduction from 1% to 0.06% is achieved by heating and solvent extraction.

In West African countries as in many other world regions there is the need to increase the production of high quality food and the sustainability of cropping systems. A broadly adapted high dry matter yam bean which can be used like cassava could be a crop which might help to fulfill these needs, especially in Sub-Saharan Africa where in some areas root crops are a major source of nourishment. So far investigations on the yam bean germplasm as well as on the possibility to incorporate high dry matter from the Chuin type into the remaining yam bean genepool is limited. There are numberous reports and poster presentations on the yam bean (Sørensen,1996; Sørensen et al., 1996, Sørensen et al., 1997; Nielsen et al, 1999; Nielsen et al., 2000), but many of these investigations have focused only on few accessions or were not carried out at several locations. It is still necessary to evaluate a broad range of yam bean accessions under field conditions in order to obtain more detailed information about the climatic zones where yam beans can be grown, the agronomic potential of accessions as well as the genetic diversity within the yam bean genepool. Informations on genetic distances within and between the species may assist to get a better understanding of the phylogenetic relationships between yam bean species and the amount of diversity within each yam bean species. This information is helpful to make decision concerning parental material for further breeding programs.

Breeding research over the past decade has developed techniques which assist the breeder to take the most promising material into his multi-locaton field trials. Traditionally genetic diversity has been estimated mainly for morphological traits. This is still the most widely used method to group genebank material. However, the measurement of many morphological traits is laborious and time consuming.

Near Infrared Reflectance Spectroscopy (NIRS) can offer an interesting alternative to estimate genetic diversity. It is cheap, rapid and does not require to germinate seeds. So far, NIRS is mainly used as alternative to wet chemistry procedures for determining concentrations of major classes of chemical compounds in organic materials. The methods utilizes reflectance signals resulting from bending and stretching vibrations in molecular bonds between carbon, nitrogen, hydrogen, and oxygen.

This study consists of three parts:

1. Estimation of the population mean and variation of agronomical traits in the yam bean (*Pachyrhizus spp.*) germplasm in field experiments at two locations in Benin (West Africa). The three cultivated species *P. erosus*, *P. ahipa* and *P. tuberosus* (including Chuin types with high dry matter content) are compared.

2. Estimation of the genetic diversity in the yam bean germplasm between and within the three species. Data from the same field experiments at two locations in Benin are analysed by multivariate methods.

3. Investigations to use NIRS for estimation of genetic diversity by comparing clusters obtained from morpho-agronomic traits and NIRS measurements of whole seeds.

1.2 The genus *Pachyrhizus*

1.2.1 Botanical description, taxonomy and ecogeographical requirements

The name *Pachyrhizus* comes from the Greek *Pachys* = thick(ened) and *rhiza* = root. The genus is taxonomically classified in the family *Fabaceae*, subfamily *Faboidae*, tribus *Phaseoleae* and subtribe *Diocleinae* in close relationship to the subtribe *Glycininae* and *Phaseolinae* (Lackey, 1977; Ingham 1990, Sørensen, 1988, 1996). One of the first botanical references to the yam bean was made by Plukenet in 1696, who described a plant from Mexico as *Phaseolus nevisensis* (Belford, 2000). The present generic name *Pachyrhizus* was originally used by L.C.M. Richard. *Pachyrhizus* is delimited by the short hairs on the adaxial side of the ovary extending almost to the stigma, forming a „beard“ along the incurved style and by the median to subterminal globular process on the adaxial side of the stigma (Sørensen, 1996).

The genus contains five species: The Mexican yam bean (*P. erosus*), the Andean yam bean (*P. ahipa*) and the Amazonian yam bean (*P. tuberosus*) are cultivated, whereas *P. panamensis* and *P. ferrugineus* are only found wild. Most likely *P. panamensis* is the common ancestor of *P. ahipa* and *P. tuberosus* and *P. ferrugineus* the ancestor of *P. erosus*. A key to the species is given in Table 1.1.