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Utilization of landraces for the genetic enhancement of pigeonpea in Eastern and Southern Africa

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Abstract

The eastern and southern Africa (ESA) region is considered as a centre of secondary diversity for pigeonpea. Accessions (297) of pigeonpea landraces were collected from major production areas in four countries in the region and evaluated for desirable agronomic traits, particularly resistance to fusarium wilt and market-preferred traits. Selected germplasm was utilized in the regional breeding program aimed at genetic enhancement of pigeonpea. Five improved long-duration (LD) cultivars that are highly resistant to fusarium wilt and have large (100-grain weight >15.0 g) grains were developed. Similarly, six early maturing medium-duration (MD) cultivars (averaging 2.5 t/ha) for production in the high latitude areas in the region and three MD cultivars that are able to ratoon, were developed. Seed of pre-released cultivars that are preferred by the farmers was distributed widely in the region in order to facilitate adoption. Consequently, the productivity of pigeonpea and food security in the region improved significantly.

Key words: Germplasm, landrace, pigeonpea, ratoon.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important grain legume grown in the tropics and subtropics. The region in eastern and southern Africa (ESA) which extends from Uganda through Kenya, Malawi and Tanzania to Mozambique is considered as a centre of secondary diversity where pigeonpea has been grown for at least 4000 years [13]. Prior to the introduction of pigeonpea to ESA from the Indian sub-continent in the mid-1990's, unimproved landraces of the species were grown by smallholder farmers. The cropping systems were based on intercropping pigeonpea largely with cereals such as corn (*Zea mays*) or sorghum (*Sorghum bicolor*). Apart from contributing to soil fertility through biological fixation of atmospheric nitrogen in the cropping systems, pigeonpea is a valuable source of affordable protein particularly in rural communities that largely depend on cereal based diets and face high risks of malnutrition in the region. The nutritious grain of this crop contains approximately 20% crude protein and a wide range of minerals [1].

The pigeonpea germplasm that was introduced to the ESA region was poorly adapted to the local cropping systems partly due to differences in agro-ecological conditions. For instance, short-duration cultivars required 80-100 d to mature. When planted at the on-set of the cropping season (towards the end of November) in the region, these pigeonpea types matured (in March) before the end of the wet season in May. In contrast, traditional and unimproved landraces were sensitive to photoperiod and required at least nine months in order to mature. This late maturity increased their susceptibility to terminal drought stress and frost. Low grain yield (0.4 t/ha) potential among these landraces was reported [7]. In addition, insect pests such as pod-sucking bugs (*Clavigralla* sp.), podfly (*Melanogromza*) and pod-borer (*Helicoverpa armigera*) frequently reduce grain yields. In many countries in the region, high (90%) incidences of fusarium wilt were reported [8]. The introduced germplasm showed limited resistance to the disease. In a study aimed at screening for resistance to wilt, an exotic cultivar 'ICP 9145' was reported to be resistant in Malawi but susceptible in Kenya [8]. In 2004, the wilt disease was present in Malawi. However, in 2005, the disease was observed in pigeonpea production areas in Mozambique indicating that the disease was widespread in the ESA region [4].

Spurred by the potential of pigeonpea in the region as well as the need to curb genetic erosion, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) designed a long-term genetic improvement program aimed at utilizing indigenous germplasm that was adapted to the region. This paper describes the procedures and phases of the pigeonpea improvement program used by ICRISAT starting from germplasm collection missions conducted in the region to germplasm evaluation, hybridization and selection of improved novel cultivars.

Materials and Methods

Germplasm collection and genetic purification: Accessions of pigeonpea landraces were collected from major production areas in four countries in the region (Fig. 1) encompassing various agro-ecologies including the highland areas of Namuli (2 419 m a.s.l.) and Chiperone (2 054 m a.s.l.) in Mozambique and the coastal zone (< 200 m a.s.l.) in Tanzania [10]. In each season, the missions

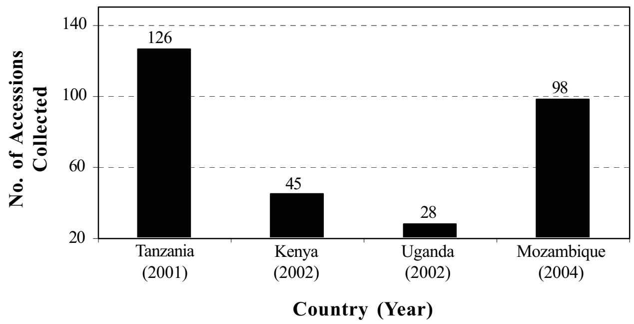

Figure 1. Pigeonpea accessions collected from four countries in eastern and southern Africa.

were planned to coincide with the harvesting time of the crop in the respective areas. The strategy was to collect, *in situ*, the superior landraces encompassing maximum diversity using several criteria as described previously [10]. In some cases, the variability in pod characteristics such as pod length (short, medium, long) or pod width (thin, medium, wide) and seed characteristics such as color (white, brown, red, black, purple, speckled), hilum size (small, medium, large) and shape (globular, oval, elongated, square) were considered in sampling the landraces. Pests were assessed in the field based largely on farmers' information. The assessment was made for pod borers (*Helicoverpa armigera*), pod suckers (*Clavigralla* sp.) and bruchids (*Callobruchus* spp.).

In order to make a preliminary evaluation of the agronomic traits, the seed of each accession was planted in single row observation plots at Kiboko Research Station (KRS) in Kenya. The seed was planted at 0.5 m apart within the row in order to allow optimum expression of the agronomic traits. Standard agronomic management recommendations for pigeonpea were followed during each season. During the evaluation, individual genotypes with unique desirable traits were identified. Because of the high (25%) level of out-crossing in pigeonpea, such genotypes were then purified by selfing for five to six successive generations under a controlled environment sheltered from insect pollinators.

Evaluation for biotic stresses: Two major biotic stresses of pigeonpea in the ESA region, namely fusarium wilt and insect pests, particularly pod borers, were evaluated. The reaction of the landraces to fusarium wilt was conducted on-station in wilt-sick plots where the disease pressure was considered to be high [2]. At physiological maturity, the percent incidence of fusarium wilt (%FW) was determined as described previously [6]. Individual genotypes that showed resistance to the disease were harvested separately and subsequently purified as described above. The promising genotypes were evaluated further for both resistance to the disease and desirable agronomic traits in the other countries in the region including Malawi and Tanzania. Similarly, the germplasm was evaluated for resistance to pests at Kampi ya Mawe Research Station (Kenya) where the natural infestation of pigeonpea by insect pests is generally high.

Development of early maturing cultivars: In 1994, crosses (and their reciprocals) were made between medium-duration (cultivar 'ICEAP 00068') x short-duration (cultivar 'ICPL 87091') types. Similarly, in 1995, crosses were made between long-duration (each of cultivars 'ICEAP 00020', 'ICEAP 00040' and 'ICP 13076') x short-duration (cultivar 'ICPL 87091'). The short-duration parent is insensitive to photoperiod and matures within 90 d (from sowing) in the ESA region. Cultivar 'ICEAP 00068' was selected for its large (100-grain weight ≥ 18 g) white grains and ratoonability [7]. Both 'ICEAP 00040' and 'ICEAP 00020' are resistant to fusarium wilt while 'ICP 13076' is moderately resistant to the disease.

The segregating plant populations were raised initially at KRS (2º20'S, Kenya) and subsequently at Chitedze Research Station (13º59'S, Malawi). This location at Chitedze represented the prospective production area requiring early maturing cultivars that flower and mature during May and early June in southern Africa. Single plant selections from these plant populations were evaluated for agronomic performance at the same location for two consecutive cropping seasons starting in 2005/2006.

Experimental design and data analysis: Each field trial for the evaluation of agronomic traits was arranged as a completely randomized design with three replications. Statistical analysis of data was performed using SAS (Statistical Analysis System) procedures [9] followed by Tukey mean comparison tests.

Results and Discussion

The highest (126) number of accessions was collected from Tanzania (Fig. 1). This germplasm included 31 and 30 accessions from the coastal (< 200 m a.s.l.) and highland (< 1 600 m a.s.l.) regions, respectively [10]. Only 28 accessions were collected from Uganda. In general, the seeds of these accessions were small (100-grain weight ≤ 10 g). In addition, the pods contained deep loculations as well as hard siliqua. These attributes appear to deter insect pests and probably present a good starting point for study efforts aimed at enhancing resistance to insect pests that attack pods in pigeonpea. However, in this germplasm, there was no strong evidence of field resistance to insect pests, especially the pod borer. There may be merit in conducting more detailed investigations of the relationship between these pod characteristics, secondary biochemical compounds in various plant organs and insect pest resistance. From a genetic improvement standpoint, the problem is compounded by the lack of sources of resistance to the insect pests in the pigeonpea gene pool. The few sources that are purported to be resistant, possess undesirable agronomic traits such as small, hard seed or unacceptable seed coat color. Consequently, the lack of natural sources of resistance to these insect pests poses challenges to the genetic improvement of pigeonpea particularly through conventional approaches. Nonetheless, renewed efforts at ICRISAT aimed at developing transgenic pigeonpea containing the *BT cry1Ab* gene could be a possible solution for the improvement of resistance to some of the insect pests [3, 12].

The germplasm collected from ESA showed varying levels of resistance to fusarium wilt. Cultivar 'ICEAP 00040' showed consistent resistance in several countries in the region (Table 1). Consequently, this cultivar was released for commercial production in many countries in the region including Tanzania and Malawi [11]. Similarly, a MD type (maturing in less than 160 d) cultivar, Tumia, that is able to produce a ratoon crop was developed and released for commercial production in ESA [5]. Both cultivars (ICEAP 00040 and ICEAP 00068) as well as the rest of the LD and MD possess large (100-grain weight ≥ 15.0 g), white grains that are preferred by the end-users (Table 2). In contrast to cultivar ICEAP 00040,

Table 1. Elite pigeonpea cultivars evaluated for resistance to fusarium wilt during 2001/02 in eastern and southern Africa.

Genotype	%Fusarium wilt		
	Kiboko (Kenya)	Ngabu (Malawi)	Ilonga (Tanzania)
ICEAP 00020	16.7 a	3.9 a	21.2 a
ICEAP 00040	13.3 a	4.6 a	19.2 a
ICEAP 00068	87.5 c	92.0 b	90.9 c
ICEAP 00053	52.7 b	1.7 a	-
ICPL 87051	24.1 b	-	-
Royes*	-	90.2 b	-
ICEAP 00057	-	-	4.7 a
Ex-Lugoba-1**	-	-	44.2 b

Means in the same column followed by the same letter are not significantly different at the 0.05 probability level by Tukey's test. *Check cultivar.**Traditional landrace from Tanzania [6].

Table 2. Elite pigeonpea germplasm developed from local landraces in eastern and southern Africa.

Code	Status in Country (Year)		Local Name	Key Notes
	Released	Pre-released		
Long-duration Types				
1. ICEAP 00040	Kenya (2000) Malawi (2003) Tanzania (2003)	Mozambique	Mbaazi Kachangu Mali	Resistant to fusarium wilt
2. ICEAP 00053		Kenya Tanzania		Compact, suitable for intercropping; highly tolerant to fusarium wilt.
3. ICEAP 00020		Kenya Malawi		Resistant to fusarium wilt
4. ICEAP 00576-1		Kenya		Resistant to fusarium wilt.
5. ICEAP 00936		Kenya		Resistant to fusarium wilt.
Medium-duration Types				
1. ICEAP 00068	Tanzania (2003)	Kenya	Tumia	Ability to ratoon.
2. ICEAP 00554		Kenya Malawi Tanzania		Highly tolerant to fusarium wilt; ability to ratoon.
3. ICEAP 00557		Kenya Malawi Tanzania		Highly tolerant to fusarium wilt; ability to ratoon.

Table 3. Agronomic traits of improved medium-duration pigeonpea cultivars evaluated during 2005/2006 cropping season at Chitedze Research Station (Malawi). (50%DF = number of days from planting to 50% flowering; 75%M = number of days from planting to 75% maturity).

Cultivar	50% DF (d)	75% M (d)	Grain color	100-grain weight (g)	Grain yield (t/ha)
ICEAP 01144/13	86 b	115 c	White	13.7 a	2.7 a
ICEAP 01160/15	112 a	167 a	White	14.4 a c	2.4 a
ICEAP 01480/32	102 ab	166 a	White	13.8 a	3.0 a
ICEAP 01162/21	102 ab	163 ab	White	14.9 a	2.6 a
ICEAP 01167/11	96 ab	166 a	White	15.5 a	2.2 a
ICEAP 01514/15	84 b	153 bc	White	14.4 a	2.9 a
Mean	97	161	-	14.4	2.7
Royes*	83 b	173 a	White	13.7 a	1.0 b
MtawaJuni**	119 a	172 a	Brown	16.8 a	1.1 b

Means in the same column followed by the same letter are not significantly different at the 0.05 probability level by Tukey's test. *Check cultivar. **Traditional landrace from Malawi.

cultivar ICEAP 00053 showed differential host response to fusarium wilt suggesting that probably, at least two different pathogenic races of the disease exist in the region. This genotype could be useful as a race differential to facilitate identification of races based on host x pathogen interactions.

The newly developed germplasm showed considerable improvement in terms of duration to maturity (Table 3). At least six cultivars that flowered and matured by May were developed at Chitedze research station. Cultivar ICEAP 01514/15 matured significantly ($P < 0.05$) earlier (153 d) than both the commercial cultivar Royes (173 d) and an unimproved local landrace Mtawajuni (172 d). The average grain size (as measured by 100-grain weight) among the enhanced elite cultivars ranged between 13.6 and 15.5 g compared with 13.0 g observed for the check cultivar. The grain color of all the newly developed elite germplasm was white which is preferred in the market. The highest grain yield (3.0 t/ha) was observed for the cultivar ICEAP 01480/32 compared with 1.0 t/ha attained by the check cultivar (Royes). This indicated a significant increase in the productivity of pigeonpea in the region.

These improved cultivars developed from the local landraces offer a range of desirable characteristics which include disease resistance, early maturity and ability to ratoon. Moreover, they are high yielding and possess grain qualities that are preferred in both the local and international markets. These traits enhance adoption of the cultivars by farmers in the region. In future, this elite germplasm will be useful in the various national breeding programs since it is of good genetic background which is well adapted to the local agro-ecological conditions in ESA. By combining this local and exotic germplasm, plant breeders will be able to retain the plasticity and potential for genetic change in future cultivars in order to enhance food security in the region.

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