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Characterization of dekoko *(Pisum sativum var. abyssinicum)* accessions by qualitative traits in the highlands of Southern Tigray, Ethiopia

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Cultivated *Pisum* is dominated with *Pisum sativum* subgroup, but *P. sativum var. abyssinicum* (Dekoko) is a unique subgroup developed and cultivated in Ethiopia. The objectives of the study were the characterization of the accessions using three qualitative traits and understanding the genetic diversity of the crop. Twenty-four (24) accession/local collections of Dekoko collected from South Tigray and North Wello by Alamata Agricultural Research Centre were planted in three replications of the Randomized Complete Block Design (RCBD) at Mekhan farmers' Training Centre in Endamekhoni in 2010. Characterization of the accessions by three qualitative traits viz., flower color, seed size and seed shape had revealed the existence of high genetic diversity of the population (H'=0.84, 0.95, 0.98, respectively, with mean H'=0.92) implying that the crop can be improved through breeding. The distribution of the various categories of the three qualitative traits (flower color, seed shape and seed size) was independent of region and altitude. Clustering of the accessions by qualitative traits produced seven distinct clusters which did not classify the accessions according to regions or Weredas, but according to three altitude classes.

Key words: Characterization, Dekoko, *Pisum sativum* var. *abyssinicum*, accession/collection.

INTRODUCTION

The origin of field pea is controversial. Ethiopia is undoubtedly the centre of diversity for this crop since wild and primitive forms are known to exist in the high elevations of the country. Ethiopia is one of the major Vavilovian centers of diversity for several grain legume crops including lupine, field pea and wild ancestors of cow pea Ali et al. (2003).

Cultivated *Pisum* is dominated by *P. sativum*, but *P. sativum* species *abyssinicum* (or simply *P. abyssinicum*) is a unique species independently developed and cultivated in Ethiopia. The existing germplasm in the country shows tolerance/resistance to disease (IBC, 2007; Sentayehu, 2009; Jing et al., 2010). *P. sativum* is widespread across the Middle East and has affinity with the wild *P. elatius* while *P. abyssinicum* is restricted to highland regions of Ethiopia (South Tigray and North Wello) and Southern Yemen and shows a greater affinity to *P. fulvum* (Yemane and Skjelvåg, 2002; Jing et al., 2010). However, *P. fulvum* is found around the eastern edge (Syria, Lebanon, Israel, Palestine and Jordan) and not common in Ethiopia (Maxted and Ambrose, 2001).

P. sativum abyssinicum is locally known as Dekoko (minute seeded) in Tigrigna and Yagere Ater (pea of my country) or Tinishu Ater (the smallest pea) in Amharic.

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Dekoko is capable of producing seed yield of up to 1.95 t/ha under phosphorus fertilization and is known for its high market price (more than double of the price of faba bean and field pea) and for its food preference Yemane and Skjelvåg (2002). Farmers and consumers call it as the "Dero-Wot of the poor" (chicken stew of the poor) probably to express its high nutritional value. Most often, the dry seeds of Dekoko are decorticated and split ('split peas') before boiling. Sometimes they are boiled without decortications and consumed as soup (personal observation). In Ethiopia, the annual consumption per person of field pea including Dekoko seeds is estimated at 6-7 kg (Messiaen et al., 2006; Sentayehu, 2009).

The genetic diversity of a species is the outcome of cumulative mutation, recombination and selection on individuals by the environment and selection by man for traits desirable for cultivation or consumption (Ali et al., 2007). The largest collection of *P. sativum* germplasm in Africa is located at the Institute of Biodiversity Conservation, Addis Ababa, Ethiopia, with over 1600 accessions (Messiaen et al., 2006).

A large genetic diversity has been found in *P. sativum* collections from both Africa (Ethiopia) and Asia. High to medium field pea genetic diversity in Ethiopia was observed in collections from Shoa, Gojam, Gondar, Wello, and Tigray while low to trace genetic diversity was observed in collections from Arsi, Gamo-gofa, Wellega, Illubabur and Kafa (Ali et al., 2003).

Morphological characterization or description of germplasm is the first step in the description and classification of the germplasm (Smith and Smith, 1989). An understanding of morphological characters facilitates the identification, selection of desirable traits, designing new populations, in transferring their desirable genes into widely grown food legumes through biotechnological means, resistance to biotic and abiotic stresses that are known to individual accessions that increase the importance of the germplasm (Santall et al., 2001; Tar'an et al., 2005; Jorge, 2006).

In Ethiopia, more than 15 cultivars of field pea, with better yield potential, seed size, seed color and disease resistance than the farmers' varieties, have been released for different agro-ecological conditions (MoARD, 2008). Some of these varieties were obtained from local collections while others were obtained through hybridization of landraces with introduced germplasm. Land races are the genetic wealth that a crop acquires over many years of its existence and have considerable breeding values as they contain valuable adaptive genes to different circumstances (Messiaen et al., 2006; Ali et al., 2003).

Even though Dekoko (*P. sativum var. abyssinicum*) is important both for the local farmers and consumers, the existing germplasm was not characterized morphologically and/or at genetic level; neither was there any improvement work on this crop so far. The current study was, therefore, conducted with the objectives of characterizing Dekoko accessions collected from northern Ethiopia (South Tigray and North Wello regions) using qualitative traits and understanding the genetic diversity of the crop.

MATERIALS AND METHODS

Accessions evaluated

The research was conducted in Southern zone of Tigray regional state, Wereda Endamekhoni at tabia Mekhan farmers' training center which is one of the mandate areas of Alamata Agricultural Research Center (AlARC). It is located at a latitude of 120 78'N and longitude of 390 53'E Endamekhoni (BoANR, 2002).

Twenty four (24) accessions collected from two regions; South-Tigray and North-Wello were tested at Mekhan farmers training center (FTC) at an elevation of 2100 m above sea level. The accessions were collected in 2008 by AlARC from weredas: Alamata, Ofla, Endamekhoni, Alaje, and Hintalo-Wejerat in South Tigray, and Kobo, Guba-lafto, Srinka and Habru in North-Wello regions. Table 1 explains the sources and altitude of the accessions with their major agro-ecological condition.

Experimental design and trial management

The trial was conducted using Randomized Complete Block Design with three replications and the plot size for each accession was 1.5 m^2 with inter- and intra-row spacing of 25 and 5 cm, respectively. Accessions were sown in six rows each 1 m long. Phosphorus and Nitrogen fertilizers with normal recommendation rates to other pulse crops (46 kg P_2O_5 and 18 kg N ha-1, that is 100 Kg DAP (Di-Ammonium Phosphate ha-1) and seed rate of 150 kg ha-1 were applied.

Analysis of qualitative data

Frequency distribution of the various categories of qualitative traits was studied. Deviation of the frequency distribution from the theoretical distribution was tested by χ^2. Proc Freq of SAS SAS (1994) was used for the χ^2 test.

The Shannon- Weaver diversity index

The Shannon-Weaver diversity index (H') was computed using the phenotypic frequencies to assess the overall phenotypic diversity for each character by the classification variable. The Shannon-Weaver diversity index as described by Hutchenson (1970) was used to calculate phenotypic diversity for j^{th} trait with n sub classes:

$$h_j = \sum_{i=1}^{n} pi \ln pi$$

Where, pi is the relative frequency in the ith category of the jth trait. To keep Shannon-Weaver diversity index between 0 and 1, the formula suggested by Hennink and Zeven (1991) was used:

$$H' = \frac{-\sum Pi \ln Pi}{\ln n}$$

Where, pi is the relative frequency in the ith category of the jth trait. *H'* of 0 indicates that the trait is monomorphic, that is all individuals belong to one and the same category (clan), where as H' of 1 indicates maximum diversity i.e., individuals are equally dispersed among the *n* class.

Table 1. Accessions of Dekoko Included in the Study and Their Sources with their altitude.

Accession name	Source of accessions			
	Region	Wereda	Major agro-ecology	Altitude of wereda (masl)
T-001/08 Of	Tigray	Ofla	High land	2457
T-002/08 Of	Tigray	Ofla	High land	2457
T-003/08 Of	Tigray	Ofla	High land	2457
TK-004/08 Al	Tigray	Alamata	Low land	1178-3148
TK-005/08 Al	Tigray	Alamata	Low land	1178-3148
TK-006/08 Al	Tigray	Alamata	Low land	1178-3148
TK-008/08 Al	Tigray	Alamata	Low land	1178-3148
T-023/08 Mw	Tigray	Endamekhoni	High land	2100
T-022/08 E/A	Tigray	Emba-Alaje	High land	2116
T-024/08 E/A	Tigray	Emba-Alaje	High land	2116
T-021/08 H/W	Tigray	Hintalo-Wejerat	Mid –altitude	1400-3050
T-007/08 Ko	Amhara	Kobo	Low land	1100-3000
T-009/08 Ko	Amhara	Kobo	Low land	1100-3000
T-010/08 Ko	Amhara	Kobo	Low land	1100-3000
T-017/08 Ko	Amhara	Kobo	Low land	1100-3000
T-018/08 Ko	Amhara	Kobo	Low land	1100-3000
T-019/08 Ko	Amhara	Kobo	Low land	1100-3000
T-020/08 Ko	Amhara	Kobo	Low land	1100-3000
T-012/08 G/L	Amhara	Guba-lafto	High land	2061
TA-013/08 Sr	Amhara	Srinka	Mid –altitude	1868
TA-014/08 Sr	Amhara	Srinka	Mid –altitude	1868
TA-015/08 Sr	Amhara	Srinka	Mid –altitude	1868
T-011/08 Hb	Amhara	Habru	Low land	700-1900
T-016/08 Hb	Amhara	Habru	Low land	700-1900

RESULTS

Qualitative traits

Cluster analysis using qualitative traits

Dekoko accessions were clustered into seven distinct groups based on three qualitative traits. Dendrograms summarizing the genetic similarity among 24 Dekoko accessions based on their qualitative traits is given in Figure1. The characters used for clustering are flower color, seed size and seed shape. The seven clusters (I–VII) are also depicted on the Dendrograms. The number of accessions in each cluster varied from 7 in cluster II to 1 in cluster V, VI and VII (Table 2).

DISCUSSION

The seven clusters correspond to 7 of the 12 possible combinations of the 3 seed colors, 2 seed shapes and 2 seed sizes. The first cluster contains 6 accessions with red flowers and wrinkled large seeds. Accessions from five Weredas (Ofla, Alamata, Hintalo-Wejerat, Kobo and Srinka) are grouped into this cluster. A similar trend is observed in other clusters. Accessions from different weredas of the two regions are grouped into the same cluster and accessions from a single wereda are scattered among different clusters. For example accessions collected from Alamata wereda of Tigray are found in clusters 1, 2, 5 and 6 and accessions of Kobo wereda are distributed in clusters 1, 2 and 3. There were no accessions with the following combinations of the three qualitative traits: accessions with pink flowers and smooth large seeds, with red flowers and wrinkled small seeds, with red flowers and smooth large seeds, with white flowers and wrinkled small seeds and those with white flowers and smooth large seeds. Whether farmers have deliberately selected against these genotypes or whether this happened by mere chance or other factors needs further investigation. The only two accessions with white flowers (accession 7 from Alamata and accession 23 from Habru) formed solitary clusters VI and VII with only one member. There is some tendency of the accessions to be grouped according to altitude. Although cluster I contains accessions from all three altitudes, in Cluster II, four of the seven accessions are from high lands. Cluster III is composed of two accessions from lowlands and one from highland while cluster IV contains accessions from mid- and low-lands. Comparison of the seven clusters by quantitative data showed that accessions in cluster I and

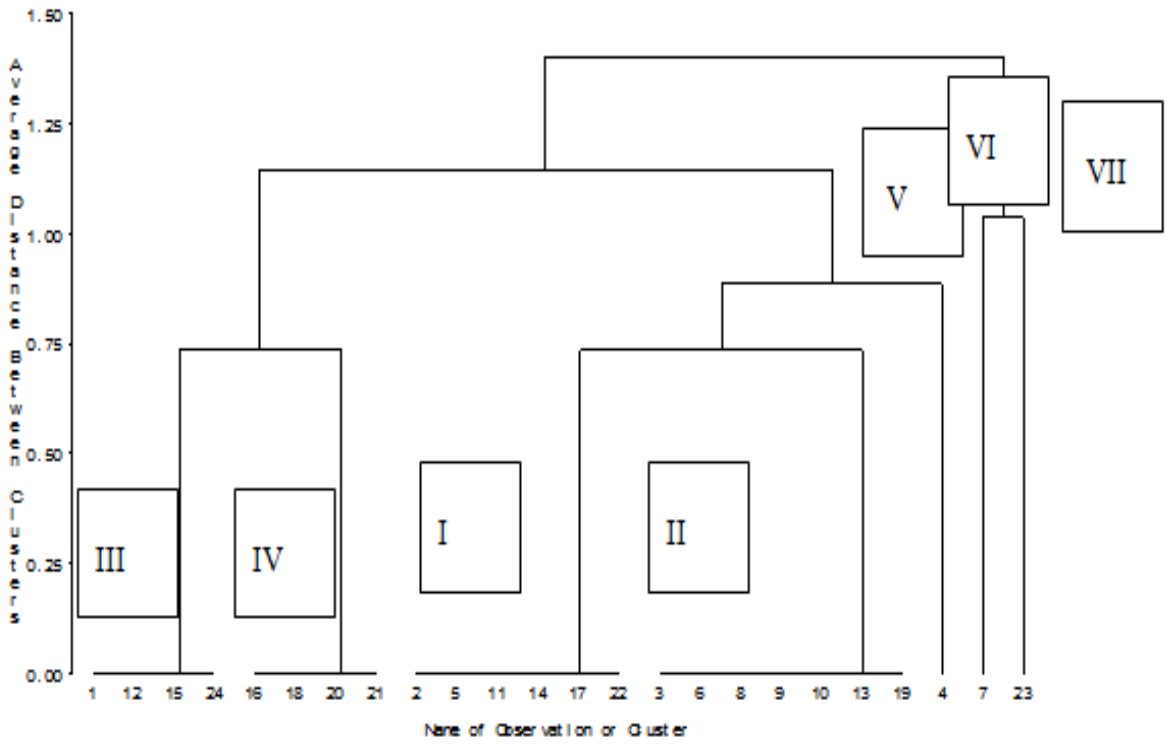

Figure 1. Dendrograms showing the distribution of 24 Dekoko accessions into 7 clusters.

Table 2. Classification of 24 Dekoko accessions into clusters by leaf color, seed shape &size

Cluster	S/N	Traits	Weredas (sources of accessions)
I	2, 5, 11, 14, 17,22	Red flower, Wrinkled and Large Seed	Ofla, Alamata, Hintalo-Wejerat, Kobo, Srinka
II	3, 6, 8, 9, 10, 13,19	Pink flower, Wrinkled and Large Seed	Ofla, Alamata, Endamekhoni, E/Alaje, Kobo, Guba-lafto
III	1, 12, 15, 24	Red Flower, Smooth and Small Seed	Ofla, Kobo, Habru
IV	16, 18, 20, 21	Pink Flower, Smooth and Small Seed	Kobo, Srinka
V	4	Pink flower, Wrinkled and Small seed	Alamata
VI	7	White flower, Wrinkled and Large seed	Alamata
VII	23	White flower, Smooth and Small Seed	Habru

VI emerged later (10.1 and 10.7 days, respectively, while the third latest emerging cluster was cluster 4 (9.4 days). Clusters V and VII emerged faster (8.7 days). Cluster VI was late in flowering (45.3 days), while clusters II and V were the earliest flowering (41 and 42 days, respectively). Clusters VII and II had the highest number of seeds per plant (5.3 and 5.1 seeds, respectively), while cluster VI had the lowest number of seeds per plant (4.1). Clusters V, II and I had high protein content (37.0, 30.4 and 30.1%, respectively), while clusters IV, VII and VI had low protein content (25.4, 26.3 and 27.3%, respectively).

Frequency distribution based on qualitative traits

Flower color varied from accession to accession with the dominant color being pink (50%) followed by red (41.67 %). White color was with least percentage (8.33%) which was expressed only in few accessions. Seed shape was dominantly wrinkled (62.5%) while seeds with smooth surface were 37.5%. Similarly, seed size was dominated by larger-sized seeds (58.33%) while smaller seeds constituted 41.67%. These two characteristics of Dekoko may, therefore, be used to characterize seeds into Kik ('split pea') and Shiro ('ground pea') type. Accordingly, at least 58% of the accessions are Kik ('split peas') type. Summary on the qualitative traits is given in Table 3.

The distribution of the various categories of the three qualitative traits (flower color, seed shape and seed size) was independent of region and altitude except that in Tigray region more large-seeded accessions than small-seeded ones (81.8 vs. 18.2%) are grown while in Amhara region (North Wello) more small seeded varieties are grown

Table 3. Frequency Distribution and Shanon-Weaver Diversity Index (H') of the Qualitative Traits of Dekoko Grown at Mekhan, Endamekhoni, in 2010.

Qualitative trait	Index and description adopted	Frequency (%)	H'
Flower color	Pink	50.00	0.84
	Red	41.67	
	White	8.33	
Seed shape	Smooth	37.5	0.95
	Wrinkled	62.5	
Seed size	Large	58.33	0.98
	Small	41.67	
Overall mean			0.92

grown (38.5 vs. 61.5%) (P = 0.03). More wrinkled seeded Dekoko varieties than smooth-seeded ones are grown in Tigray (90.1 vs. 9.1%), while in Amhara this ratio was 38.5 vs. 61.5% (P = 0.01). There was a strong association between seed size and seed shape ($p < 0.001$); all except one accession with big seeds had wrinkled seed surface, i.e., and all accessions with small seeds had seeds with smooth surface. These traits might be linked tightly; that is big seed size might be tightly linked with wrinkled seed shape while small seed size might be tightly linked with smooth seed surface. We have found out that Accessions from high lands had the highest protein content (31.3 vs. 25.58% and 24.33% of the mid altitudes and low lands, respectively). Seed yield was highest (0.70 t/ha) from collections of the lowlands followed by accessions from mid-altitudes (0.68 t/ha) and 0.66 t/ha for the high land accessions. This is reasonable that all the accessions were grown in more suitable environments (high lands) and as a result, the accessions collected from low lands might have expressed their potential for seed yield at the expense of protein. White flowered accessions flowered late (44.2 days) and accessions with pink flowers were the earliest to flower (42 days), while red-flowered accessions were intermediate in flowering (43days). Seed size had no effect on many of the quantitative traits except that 29 accessions with smaller seeds produced the highest leaf area index (2.14) as compared to 2.04 of accessions with bigger seeds.

The Shannon-Weaver Diversity Index (H')

In this study, Shannon-weaver diversity index was considered to measure the diversity of Dekoko accessions based on the frequency distributions of three qualitative traits. The result of 'H' values for the phenotypic characters showed high levels of diversity among 24 Dekoko accessions that ranged from 0.83 in flower color to 0.98 in seed size (Table 3). Furthermore, the overall mean of 'H' value of 0.92 confirms the existence of high level of phenotypic diversity among Dekoko accessions. Low 'H' value indicates low level of diversity and uneven distribution of accessions Hennink and Zevan (1991) while high "H" indicates high level of diversity with even distribution of accessions in the various categories. Except in flower color where the white color is rare, but the red and pink are almost equally abundant, farmers did not discriminate among genotypes according to seed size and seed shape, distribution of small and big and smooth and wrinkled seeds being even.

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