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Full Length Research Paper

Morphovariability and agronomic characteristics of soybean accessions from the Democratic Republic of Congo (DR-Congo) gene pool

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Soybean [(*Glycine max* (L.) Merr.] is the most important grain legumes in the world in terms of total production. But only a fraction of its accessions has been characterized based on origin, morphometric traits, agronomic performance and seed composition. This crop is now cultivated to a very limited extent in twenty one sub-Saharan African countries. The main objective of the present study is to characterize morphologically and agronomically the soybean accessions from the Democratic Republic of Congo (DR-Congo) gene pool. The results of the present study highlight the high level of variability in the soybean gene pool in the DR-Congo. In general 41% of soybean accessions from this collection have lanceolate leaves, 35.3% rhomboid-lanceolate, 14.7% oval, and 8.8% rhomboid. More than 65% of accessions have pod color that fit in within a variation of light brown. Almost 62% of accessions have seed with light beige color, 27% curry, and 12% pink beige. There were significant differences among accessions for all the quantitative traits analyzed. In the DR-Congo collection, all the accessions were less than 0.5 m tall with 75% shorter than 0.4 m. In general, plant height, stem diameter at first internodes and number of leaves per plant were significantly correlated to each other. Significant correlation was also observed between leaflet length and plant height. Grain yields were highly and significantly correlated to the number of pods and seeds per plant. Based on grain yield and disease resistance over the two years of trials at different locations, ten accessions have been identified as adapted to the local conditions of the main growing soybean region in the DR-Congo.

Key words: *Glycine max*, soybean collection, morphometric traits, Democratic Republic of Congo (DR-Congo), *in situ* conservation, agronomic performance.

INTRODUCTION

Soybean (*Glycine max*) was domesticated in China and spread around the world. The cultivated landraces were initially distributed throughout Asia and more recently extended to Europe and America (Tavaux-Pirra et al., 2009). The International Plant Genetic Resources Institute estimated that 129 institutions worldwide hold about 150,000 accessions of *G. max*. Ten (10) of the 129 institutions maintain half of the accessions (http://www.ipgri.cgiar.org; Chen, 2002). The most important of them include Institute of Crop Germplasm Resources, CAAS (China), United States Department of Agriculture (USDA) soybean germplasm collection, Institute of Agroecology and Biotechnology (Ukraine), N.I. Vavilov Research Institute of Plant Industry (Russia), Asian Vegetable Research and Development Center (AVRDC), Department of Genetic Resources and National Institute of Agrobiology Resources (Japan), Crop Experiment Station Upland Crops Research Division (Korea), and Australian Tropical Crops Genetic Research Center. The largest collection found in China maintains about 25,000 entries while the USDA collection

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Abbreviations: DR-Congo, Democratic Republic of Congo; **ITTA,** International Institute of tropical Agriculture; **LSD,** least significant differences; **USDA,** United States Department of Agriculture.

at the University of Illinois, the second largest holds 18,000. Only a small fraction of these soybean (*G. max*) entries have been characterized based on origin, morphometric traits, agronomic performance and seed composition (protein and oil) (http://www.ipgri.cgiar.org; Chen, 2002). Extensive research has been conducted on genetic diversity in annual wild soybean (*Glycine soja*) (Dong et al., 2000, 2001).

Some seventeen tropical soybean (*G. max*) varieties developed by the International Institute of Tropical Agriculture (ITTA) have been released by National Agricultural Research and Extension Systems (NARES) of several West and Central African countries (Nigeria, Benin, Ghana, DR-Congo, Togo), and Uganda. These varieties represent the main core of these African soybean collections (Ogoke et al., 2003; Mudibu et al., 2011).

Phenotypic evaluation of soybean germplasm is a fundamentally important step for the management of collections and determining genetic diversity. The knowledge of the genetic variation within accessions from germplasm collections is essential to the choice of strategy to incorporate useful diversity into the program, to facilitate the introgression of genes of interest into commercial cultivars, to understand the evolutionary relations among accessions, to better sample germplasm diversity, and to increase conservation efficiency (Fu, 2003). A more comprehensive assessment of genetic diversity would allow curators and users to manage and access ex situ collections more efficiently. Gemplasm evaluation includes descriptive, agronomic and composition data. Traits described by colors, shapes, appearances or forms are classified in the descriptive category. Agronomic data consist of scored or measured traits such as lodging, shattering, seed weight, plant height and maturity date. Seed composition data include seed protein and oil, palmitic, stearic, oleic, linoleic, and linolenic acids (Nelson et al., 1988). Many phenotypic characters of soybean are significantly influenced by environmental conditions under which the plants are grown. Protein, enzyme and DNA markers can be used to assess genetic diversity, but their application in gemplasm identification is limited and expensive (Li and Nelson, 2001; Chen, 2002; Mudibu et al., 2011). There are insufficient data on genetic diversity of soybean germplasm collections in African countries including DR-Congo.

The main objective of the present study is to characterize morphologically and agronomically the soybean accessions from the DR-Congo gene pool for conservation and breeding purpose.

MATERIALS AND METHODS

Field experiments were conducted over two years (2008 to 2010) at two sites in Eastern Kasai (Gandajika) in the DR. Congo (Figure 1). Site one was located at INERA Agricultural Research Station (23° 57'E, 06° 48'S and 754 m altitude) and site two in Mpiana (23° 56'E, 06° 36'S and 685 m altitude). The region falls within the Aw4 climate type according to Köppen classification characterized with four months of dry season (from mid-May to August) coupled with eight months of rain season, sometimes interrupted by a short dry season in January/February. Daily temperature averages 25°C and annual rainfall is close to 1500 mm. Typically, Gandajika soils consist of a collection of sandy on clay sediment more often based on a shallow lateritic old slab. The adsorption complex is fairly well saturated and there are still some weatherable minerals (Muyayabantu, 2010).

The plot at each site was ploughed and ridged at a spacing of 0.75 × 0.5 m. Gross plot size (experimental unit) was 5 m long and 1.5 m wide. Two seeds were were sown at every 10 cm to a depth of about 2 cm. Manual weeding was carried out as to keep the field clean. The experiment was a completely randomized block design (RCBD) with three replicates. The trials were conducted with no fertilizer or pesticide applications.

In total fouteen characters were selected for germplasm characterization. The descriptive data included leaf shape, pod color, and seed coat color. Munsell color order system was used for precise color validation for leaves, pods and seeds. Leaf shape was determined as per Carlson (1973).

Agronomic data include plant height at maturity, stem diameter at the first internodes, leaflet length and width, leaf surface area, pod length and width, number of leaves per plant, number of stem ramification per plant, weight per 100 seeds, number of pods per plant, number of seeds per plants, days to 50% flowering, and grain yield per ha. Plant height was measured as the length of the main stem from the soil surface to the terminal node at maturity.

Data were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 3 and R software. Main effects were separated by least significant differences (LSD) at P = 0.05 level. The relations among means were calculated using Pearson correlation test at P = 0.05 level.

RESULTS

Qualitative traits

Qualitative characteristics are described in Table 1. Leaves from all the accessions analyzed were green Reseda with the exception of leaves from TGX 999-49F and TGX 1485 – 1D Lub accessions that were green apple. In general 39.5% of soybean accessions from the DR-Congo collection have lanceolate leaves, 36.7% rhomboid-lanceolate, 13.2% oval, and 10.5% rhomboid. The frequencies for pod color were 47.4% light beige, 10.5% light brown, 10.5% ochre - yellow, 10.5% caramel, 7.9% havana, 7.9% pink beige, and 5.3% creamy pink. Almost 61% of accessions have seed with light beige color, 26% curry, and 13% pink beige. As expected, the correlations among qualitative traits (leaf shape and seed color) were negatives but not significant at P ≤ 0.05.

Number of pods and seeds per plant, grain yield per hectare, and weight of 100 seeds

Four main components of yields were analyzed in details. They include, number of pods per plant, number of seed per plant, grain yield per hectare, and weight of 100

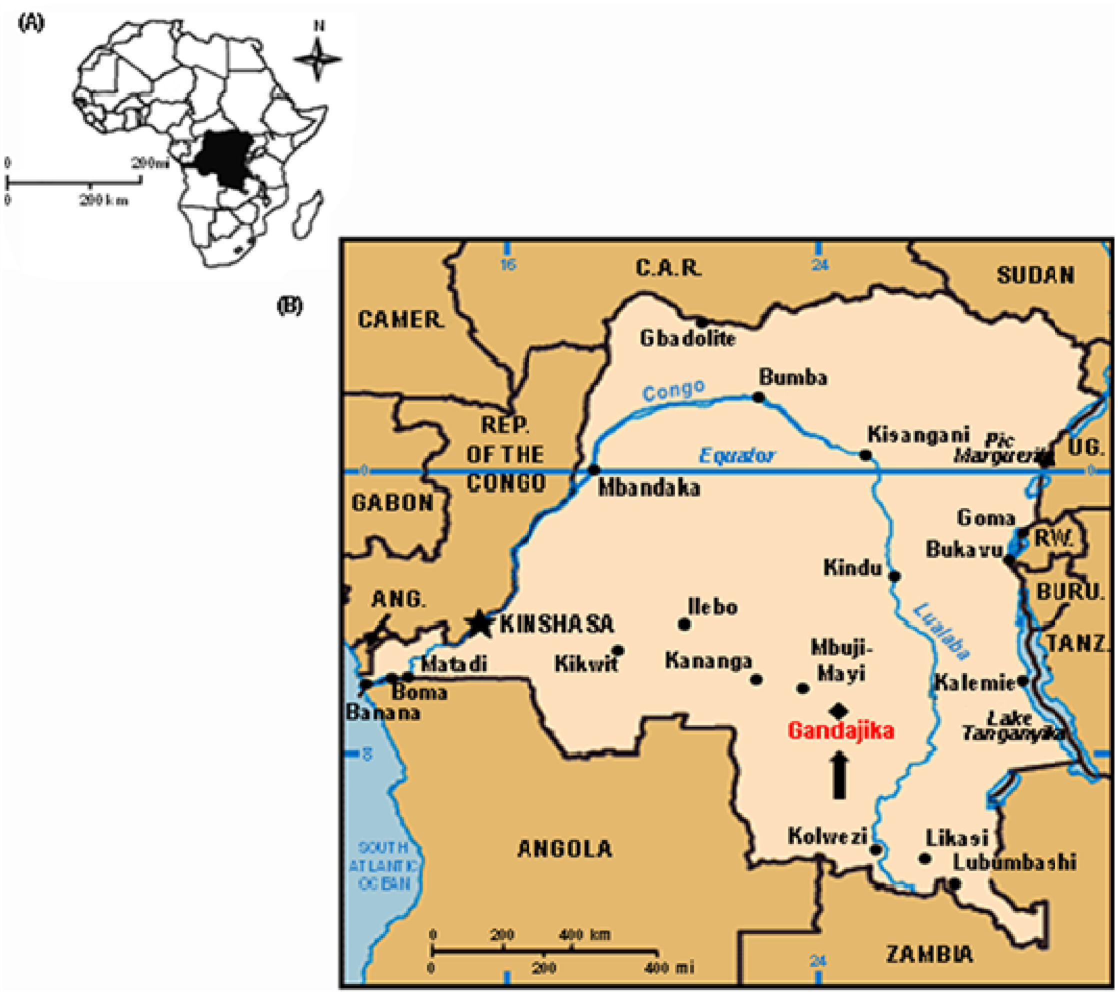

Figure 1. Location of experimental sites: (A) Democratic Republic of Congo (in black); (B) Details on the map of the Democratic Republic of Congo. The arrow indicates the trial location (Gandajika).

seeds (Table 2). Grain yield varied from 650 kg/ha for Zaire 196 to 2898 kg/ha for ORIBI. The number of pod per plant ranged from 30.8 for AFYA Kiyaka to 103.7 for TGX1888-29F. The accession TGX1740-7F had the smallest number of seeds per plant and TGX814-26D the largest number of seed. The weight of 100 seeds ranged from 7.9 g for Botula II to 14.7 g for SAPRO. The accession KenSoya II showed 50% of flowering after 33.8 days while the accession Zaire was the latest to flower with 50% of flowering after 53 days. Grain yields were highly and significantly correlated to the number of pods and seeds per plant (Table 4). There was no correlation between grain yield per hectare and weight of 100 seeds.

Pod length and width

The values for pod length and width are summarized in Table 3. As with the other parameters measured, there were significant differences among accessions for pod length and width. The two parameters were positively and significantly correlated. No correlation was found among these two yield components and grain yield per hectare, but a significant difference was observed between pod width and weight of 100 seeds (Table 4).

Plant height, stem diameter at first internode and number of leaves per plant

The mean values for plant height, stem diameter at first internodes and number of leaves per plant are presented in Table 3. Plant height varied from 15.8 cm (for ORIBI) to 49.2 cm (for TGX1740-7F). Stem diameter ranged from 4.8 mm (for TGX1904-2F) to 10.1 mm (for Bwamanda). The highest number of leaves per plant was observed on the IMPERIAL accession while the smallest number was found in Zaire 196. In general, these three parameters (plant height, stem diameter at first internodes and number of leaves per plant) were

Table 1. Sources, leaf shape, pod color and seed color of 40 soybean accessions from the DR-Congo gene pool.

Variety	Sources/Origin	Leaf shape	Pod color	Seed color
AFYA	INERA Gandajika, DR-Congo	Lanceolate	Light brown	Pink beige
AFYA Kiyaka	INERA Gandajika, DR-Congo	Rhomboid-lanceolate	Light beige	Light beige
BOTULA I	CREN-K/CGEA, DR-Congo	Rhomboid-lanceolate	Caramel	Light beige
BWAMANDA	Bwamanda, Equateur	Lanceolate	Light brown	Light beige
DAVIS	California, USA	Lanceolate	Pink beige	Curry
IMPERIAL	INERA, DR-Congo	Rhomboid-lanceolate	Light beige	Curry
KAMBULUKU	INERA Gandajika, DR-Congo	Lanceolate	Ochre yellow	Pink beige
KenSoyaI	Kenya	Rhomboid	Havana	Light beige
KenSoyaII	Kenya	Oval	Havana	Light beige
KITOKO	INERA, M’vuazi, DR-Congo	Rhomboid-lanceolate	Light beige	Light beige
MELOC	INERA Gandajika, DR-Congo	Rhomboid-lanceolate	Havana	Pink beige
NAMSOI 4m	INERA M’vuazi, DR-Congo	Lanceolate	Light beige	Curry
NI	INERA, Gandajika, DR-Congo	Lanceolate	Light beige	Light beige
No5	INERA Gandajika, DR-Congo	Rhomboid-lanceolate	Pink beige	Curry
ORIBI	INERA Mulungu, DR-Congo	Oval	Light beige	Light beige
PKO6	INERA Mulungu, DR-Congo	Oval	Light brown	Curry
SAPRO	INERA-Mulungu, DR-Congo	Rhomboid-lanceolate	Light beige	Curry
SB4	INERA M’vuazi, DR-Congo	Rhomboid	Ochre yellow	Curry
SB19	INERA Mulungu, DR-Congo	Rhomboid-lanceolate	Light beige	Light beige
SB24	INERA M’vuazi, DR-Congo	Oval	Caramel	Pink beige
SENASEM	INERA	Rhomoboid-lanceolate	Light beige	Light beige
TGM1196	INERA M’vuazi, DR-Congo	Lanceolate	Caramel	Curry
TGX -198F-17F	IITA, Nigeria	-	-	-
TGX814-26D	IITA, Nigeria	Rhomboid-lanceolate	Light brown	Light beige
TGX814-49D	IITA, Nigeria	Rhomboid-lanceolate	Light beige	Curry
TGX1485-1D Lub	ITTA, Nigeria	Rhomboid-lanceolate	Light beige	Light beige
TGX1740-7F	ITTA, Nigeria	Lanceolate	Light beige	Curry
TGX1879-9E	IITA, Nigeria	Lanceolate	Ochre yellow	Light beige
TGX1879-13E	ITTA, Nigeria	Oval	Ochre yellow	Light beige
TGX1879-9F	ITTA, Nigeria	Rhomboid-lanceolate	Light beige	Light beige
TGX1880-3E	ITTA, Nigeria	Lanceolate	Light beige	Light beige
TGX1888-29F	ITTA, Nigeria	Rhomboid-lanceolate	Light beige	Light beige
TGX1888-49F	ITTA, Nigeria	Lanceolate	Light beige	Light beige
TGX1895-33F	ITTA, Nigeria	Lanceolate	Creamy pink	Light beige
TGX1895-49F	ITTA, Nigeria	Lanceolate	Light beige	Pink beige
TGX1895 -50F	ITTA, Nigeria	-	-	-
TGX1904-2F	IITA, Nigeria	Rhomboid	Creamy pink	Light beige
TGX1908-6F	ITTA, Nigeria	Lanceolate	Light beige	Light beige
VUANGI	INERA M’vuazi, DR-Congo	Lanceolate	Pink beige	Light beige
Zaire 196	INERA Gandajika, DR-Congo	Rhomboid	Caramel	Light beige

significantly correlated to each other (Table 4).

Leaflet length and width, leaf surface area, and number of ramification per plant

Mean values for leaflet length vary from 5.7 mm for KenSoya I to 11.9 for the SB4 accessions. Significant differences ($P \geq 0.05$) were also observed among leaflet width, which ranged from 4.6 to 6.9 mm. The accession with the largest leaflet length (SB4) also had the biggest leaf surface area. Likewise the smallest leaf surface was observed in KenSoyaI that showed the shortest leaflet. Overall, the correlation between leaf surface and leaflet length was 0.92 and highly significant. The same trend was observed between leaf area and leaflet width where the correlation was 0.98 (Table 4). Significant correlation was observed between leaflet length and plant height.

Table 2. Grain yield, number of pods and seeds per plant, weight of 100 seeds and days to 50% flowering for 40 soybean accessions from the DR-Congo gene pool.

Accession	Grain yield/ha (kg)	Number of pods/plant (Mean number)	Number of seed/plant (Mean number)	Weight of 100 seed (Gram)	Number of day to 50% flowering (Mean number)
AFYA	2449.6	102.2	200.7	10.0	48.5
AFYA Kiyaka	904.7	30.8	90.5	10.1	52.8
BOTULA I	1741.3	63.8	107.0	12.6	38.0
BOTULA II	1149.7	56.5	83.3	7.9	38.0
BWAMANDA	1739.7	83.7	104.75	9.6	48.5
DAVIS	1147.0	35.0	43.0	11.5	35.5
IMPERIAL	2137.2	90.7	105.3	9.1	48.5
KAMBULUKU	1765.3	67.0	104.3	10.3	47.5
KenSoyaI	1128.7	32.8	39.8	13.2	35.5
KenSoyaII	1708.7	48.5	65.3	13.7	33.8
KITOKO	2036.0	75.0	99.8	8.8	51.0
MELOC	1319.3	44.7	71.2	10.8	52.0
NAMSOI 4m	1930.3	72.2	108.8	13.0	48.5
NI	1541.2	69.2	78.3	10.5	47.8
No5	2324.7	53.7	113.0	13.5	38.0
ORIBI	2898.0	79.7	174.7	14.6	38.0
PKO6	1196.0	36.3	51.7	14.6	35.5
SAPRO	1343.2	31.3	42.3	14.7	35.2
SB4	2054.2	64.8	102.3	11.3	37.0
SB19	1545.5	58.8	73.8	10.2	41.3
SB24	1233.8	33.3	59.0	12.4	37.0
SENASEM	2389.7	89.0	131.7	9.2	50.0
TGM1196	1900.3	67.5	107.7	12.3	46.5
TGX814-26D	2594.3	74.2	122.8	11.5	48.5
TGX814-49D	1776.8	84.3	85.7	9.5	46.5
TGX888-49F	1390.7	68.2	74.0	10.5	49.7
TGX1485-1D	1153.7	40.2	51.8	11.8	37.0
TGX1485-1D Lub	1319.8	56.7	60.2	10.0	38.0
TGX1740-7F	1004.2	73.5	31.2	14.1	40.0
TGX1879-9E	2060.0	96.5	145.8	10.0	47.5
TGX1879-13E	1732.2	78.5	113.2	7.9	49.0
TGX1879-9F	1095.2	36.2	51.5	9.4	49.0
TGX1880-3E	1770.3	60.2	85.7	10.2	37.0
TGX1888-29F	2641.2	103.7	132.5	12.8	50.0
TGX1895-33F	1989.8	85.8	121.8	9.1	50.0
TGX1895-49F	1933.3	66.7	77.2	11.0	51.0
TGX1904-2F	1278.3	53.5	81.7	11.7	37.0
TGX1908-6F	2854.5	105.0	113.0	12.7	49.0
VUANGI	1528.2	65.0	95.5	10.2	48.5
ZAÏRE196	650.0	58.8	40.8	9.8	53.0
Lsd ($p \geq 0.05$)	90.4	4.7	5.3	0.4	0.3

The number of ramifications per plant is also used as a taxonomic characteristic. In the present study, the mean number of ramifications per plant varies from 3.3 to 7.2 (Table 3).

DISCUSSION

Traditionally, genetic diversity in soybean has been based on the differences in morphological and agronomic

Table 3. Plant height, stem diameter, number of leaves per plant, leaflet width, leaf surface, number of ramification per plant, pod length and width in 40 soybean accessions from the DR-Congo gene pool.

Accession	Plant height (cm)	Stem diameter (mm)	Number of leaves/plant	Leaflet length (mm)	Leaflet width (mm)	Leaf surface (mm^2)	Number of ramification / plant	Pod length at 3 lodge stage (mm)	Pod width at 3 lodge stage (mm)
AFYA	40.7	8.3	35.5	9.8	5.7	58.6	6.3	4.2	8.6
AFYA Kiyaka	33.5	6.8	32.0	9.1	5.5	53.5	5.3	3.7	9.1
BOTULA I	36.5	7.0	20.8	7.9	5.1	45.3	4.2	4.3	9.2
BOTULA II	41.2	6.1	32.0	9.5	5.6	56.7	6.3	4.0	8.3
BWAMANDA	42.7	10.1	38.5	10.3	6.5	73.8	5.5	4.2	8.3
DAVIS	16.7	6.8	19.5	6.4	4.8	34.7	4.3	4.5	9.5
IMPERIAL	46.2	8.9	43.7	11.3	8.1	95.4	6.2	4.8	9.2
KAMBULUKU	32.0	6.4	23.0	8.5	5.4	49.4	7.2	4.5	9.2
KenSoyaI	14.8	4.4	14.7	5.7	4.0	29.2	3.5	4.6	10.5
KenSoyaII	31.0	7.1	21.2	8.6	5.8	52.8	3.3	4.6	10.5
KITOKO	37.2	8.9	33.7	9.2	5.6	54.6	4.8	4.4	8.6
MELOC	36.0	11.1	38.2	10.1	6.5	68.5	5.0	4.3	8.6
NAMSOI 4m	40	7.4	21.7	10.6	6.0	69.7	3.7	4.9	8.7
NI	39.2	7.9	29.3	10.1	6.0	65.7	4.3	4.0	8.5
No5	43.5	9.7	29.5	10.3	6.5	70.3	4.7	4.6	9.3
ORIBI	15.8	6.0	17.7	7.0	5.3	42.9	7.2	4.9	10.8
PKO6	19.0	5.6	20.7	7.6	5.1	41.7	3.0	4.3	9.7
SAPRO	23.8	6.6	16.3	8.5	6.0	57.8	4.3	4.8	9.3
SB4	21.2	7.5	28.0	11.9	8.5	108.8	4.2	4.8	9.4
SB19	35.5	7.0	28.5	8.7	5.3	48.8	4.2	4.2	8.6
SB24	16.3	7.2	18.0	6.4	4.6	32.0	3.3	4.1	9.4
SENASEM	34.5	7.1	31.8	8.6	5.0	44.9	4.3	4.0	8.5
TGM1196	52.3	9.2	26.8	10.6	6.9	77.2	5.0	4.7	9.5
TGX814-26D	31.3	8.6	30.8	8.6	5.2	47.0	4.5	4.2	8.2
TGX814-49D	36.8	6.8	34.7	8.8	5.3	49.1	4.8	4.0	8.5
TGX888-49F	34.2	6.3	21.0	8.4	5.1	46.1	4.7	4.2	8.6
TGX1485-1D	19.8	5.9	17.7	7.1	4.7	35.4	5.0	4.5	9.3
TGX1485-1D Lub	45.3	7.9	41.5	9.8	5.5	55.8	6.0	5.1	9.3
TGX1740-7F	49.2	6.4	28.7	8.5	5.4	49.8	3.8	4.3	8.5
TGX1879-9E	35.5	8.0	28.5	9.9	5.5	59.2	5.0	4.0	8.4
TGX1879-13E	35.7	8.9	44.2	10.3	6.2	67.6	4.0	4.0	8.4
TGX1879-9F	31.2	9.2	21.2	9.2	5.4	51.6	5.5	4.1	8.4
TGX1880-3E	24.2	8.1	34.3	9.3	5.7	55.8	3.3	4.1	7.6
TGX1888-29F	23.0	5.3	23.5	8.1	4.9	42.9	7.2	3.8	8.1
TGX1895-33F	43.2	7.9	27.2	9.5	5.9	60.8	7.5	4.2	8.7
TGX1895-49F	32.2	7.0	25.2	8.4	5.0	44.6	3.7	4.1	8.1
TGX1904-2F	16.2	4.8	16.3	9.3	6.2	66.4	3.5	4.4	8.9
TGX1908-6F	41.2	7.8	31.2	10.8	6.5	72.9	5.3	4.4	8.3
VUANGI	38.2	7.0	35.3	9.1	5.4	52.0	4.3	4.0	8.9
ZAÏRE196	30.8	6.3	16.0	8.7	5.8	52.8	6.3	3.9	7.9
LSD ($p \geq 0.05$)	2.1	0.5	1.6	0.4	0.3	0.9	0.8	0.2	0.4

traits and pedigree information. This evaluation is important for breeding programs but particular soybean varieties are adapted to specific agro-ecological regions and the phenotypes are highly influenced by environmental factors (Li and Nelson, 2001). Molecular markers have been preferred to assess genetic variability of soybean collections. Information on genetic variability of soybean accessions from Africa is limited. The soybean collection from the DR-Congo was first characterized using molecular markers by Mudibu et al.

Table 4. Pearson's correlations among morphological and agronomic traits in 40 soybean accessions from the DR-Congo gene pool.

Accession	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
V1	1.00														
V2	0.75	1.00													
V3	0.83	0.74	1.00												
V4	0.08	-0.27	-0.17	1.00											
V5	0.16	0.46	0.23	-0.36	1.00										
V6	0.29	0.44	0.35	-0.37	0.65	1.00									
V7	0.24	0.26	0.22	-0.15	0.39	0.86	1.00								
V8	0.25	0.20	0.26	-0.35	0.57	0.63	0.52	1.00							
V9	0.26	0.45	0.33	-0.60	0.64	0.63	0.43	0.64	1.00						
V10	0.20	-0.10	-0.01	0.45	-0.03	0.12	0.36	0.04	-0.13	1.00					
V11	-0.04	-0.41	-0.09	0.56	-0.36	-0.38	-0.07	-0.29	-0.40	0.61	1.00				
V12	0.27	0.33	0.27	-0.20	0.45	0.92	0.98	0.53	0.48	0.31	-0.14	1.00			
V13	0.22	0.51	0.35	-0.54	0.48	0.40	0.13	0.40	0.41	-0.47	-0.59	0.19	1.00		
V14	-0.05	-0.25	-0.15	-0.02	-0.16	-0.06	0.03	0.05	0.03	0.06	0.09	-0.02	-0.04	1.00	
V15	-0.12	-0.20	-0.23	0.32	0.05	0.09	0.30	-0.01	-0.08	0.40	0.21	0.24	-0.33	-0.04	1.00

V1, Grain weight per Ha; V2, number of pods per plant; V3, number of seeds per plant; V4, weight for 100 seeds; V5, plant height; V6, leaflet length; V7, leaflet width; V8, stem diameter at first internodes; V9, number of leaves per plant; V10, pod length; V11, pod width; V12, leaf surface; V13, days to 50% flowering; V14, leaf shape; V15, seed color.

(2011). Genetic relationships among accessions were established and the data confirmed that the genetic base of soybean cultivars in the DR-Congo collection is very narrow. For conservation and breeding purpose, morphological and agronomic characterization of existing accession in the DR-Congo is required to supplement molecular data.

Although qualitative traits such as seed or pod color are not correlated to quantitative traits such as yield components. They represent important taxonomic characteristics for germplasm evaluation. Shahi and Pandey (1981) reported a significant correlation between seed color and seed permeability. Rotzler et al. (2009) observed that soybean variety with lanceolate leaf form have smaller leaf surface, but a higher grain yield compared to varieties with oval leaves have larger leaf areas. Reduced leaf surface with lanceolate form was associated with a better light entrance that allows old basal leaves to extend their photosynthetic activities. This has a positive impact on grain yield. In fact in the present study, most entries with high grain yields were characterized by lanceolate or rhomboid-lanceolate leaf shape.

Leaf is a very important plant organ for photosynthesis. The numbers of leaves per plant and leaf surface are important characteristics for germplasm characterization. In the present study, the mean number of leaves per plant ranged from 16 to 44. Puech et al. (1974) assessed several genotypes in France and reported that the maximum number of leaves per plant was 14. Such difference can be ascribed to genetic differences between the two sets of soybean accessions used in the present study compared to Puech et al. (1974) genetic materials. Among the other parameters analyzed, the number of leaves per plant was negatively correlated with the weight of 100 seeds. The correlation value estimated (- 0.60) was significant. Genotypes with a high number of leaves per plant produced the lowest weight for 100 seeds. This can be ascribed to the fact that upper leaves cover lower and basal leaves, which affect the amount of photosynthetic products.

Pod color occurs in various shades of black, brown and tan. Approximately 80% of accessions in USDA collections are brown. In the present study 60 to 70% of accessions have pod color that fit in within a variation of light brown. There are two gene pairs that control three majors pod colors (Bernard 1967). L_1 causes black pod, and l_1 produce either brown, with L_2, or tan with l_2. Seed color on the other hand has a more complicated genetic model.

Significant differences among accessions were observed for all the quantitative traits analyzed. The results of the present study highlight the level of variability in the soybean gene pool in the DR-Congo. Based on previous molecular studies, every accession is unique and no redundancy was identified among the materials studied (Mudibu et al., 2011). Plant height at maturity is an important characteristic in soybean germplasm and cultivar evaluation. Most current commercial soybean cultivars are less than 1 m tall. Within the USDA soybean collection, the plant height varies from 0.2 m for PI 423870 to 3 m for PI 175188 (Chen, 2002). Patil et al. (1976) reported mean plant height varying from 14 to 80 cm among several soybean varieties evaluated in India. Wenger (1976) evaluating different soybean accessions in Liberia observed mean plant height varying from 55 cm to 95 cm. Puech et al. (1974) in France and Kabalan (1998) in Lebanon demonstrate soybean grown under irrigation reach significantly higher height compared to non-irrigated. In the DR-Congo collection, all the accessions were less than 0.5 m tall with 75% shorter than 0.4 m. The overall height distribution closely resembles a normal distribution that is consistent with quantitative traits. In fact, several quantitative trait loci (QTL) for plant height at maturity have been identified in soybean (Lee et al., 1996a, Mansur et al., 1996). Lee et al. (1996b) found eleven independent restriction fragment length polymorphism (RFLP) markers associated with plant height

The correlations among yield components were consistent with data reported by Puech et al. (1974) in France, Wenger (1976) in Liberia, and Kabalan (1998) in Libanon. Many accessions from the DR-Congo gene pool perform well in all the two sites in Gandajika. In fact, the evaluation sites provided favorable conditions for soybean crop. Grain yield is one of the most important selection criteria used by breeders. It is influenced by different yield components that include number of pods and seeds per plant, and weight of 100 seeds (Rotzler et al., 2009). In the present study, the correlation between grain yield and number of pods and seeds per plant were significantly high (0.75 and 0.83, respectively). A positive and significant correlation between weight of 100 seeds and pod width was observed. But, the correlations between weight of 100 seeds and other parameters measured were all negative and not significant. Antalikova et al. (2008) described negative correlations between plant height and grain yield. The present study revealed no significant correlation between the two traits.

Like in all plant species, grain yield is controlled by many genes and is strongly affected by environmental conditions. Rainfall, temperatures and photoperiods during the growing season are determinant environmental factors affecting grain yield (Patil et al., 1976; Sachansky, 1976). This later author reported significant variations in grain yield for the same genotype grown under different rainfall and temperature in Tanzania. Likewise, Patil et al. (1976) growing nine soybean genotypes in India under different photoperiod conditions reported significant differences in grain yield. Rainfall during growing periods in the present study was estimated at 1000 mm and the average temperature was 24°C. This represents optimum conditions for soybean growth.

Days to maturity and to 50% flowering represent also soybean characteristics controlled by many genes. There have been seven loci (E1 to E7) reported for controlling maturity in soybean (Bernard, 1971; Cober and Voldeng, 2001) and most soybean varieties are classified as early or late maturing. Soybean plants flower early when daylight period is short. The photoperiods and reactions to different temperatures are key factors used to determine the agroecological regions for growing soybean varieties (Wang et al., 2008). Shortening of grain filling period caused by high temperatures was among the main causes of significant yield reduction (Allen, 1994). Data from the present study indicate genetic variability for days to flowering among the accessions analyzed. Based on grain yield over the two years of trials at different locations, ten accessions have been identified as adapted to the local conditions of the main growing soybean regions in the DR-Congo. They include AFYA, No. 5, IMPERIAL, SB4, SENASEM, ORIBI, TGX 1908-6F, TGX 1879-9E, TGX 814-26D, and TGX 1888-29F.

The information presented herein will be useful to curators and breeders for a better management of soybean collection, *in situ* conservation, cataloging and development of specific breeding strategies.

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