International Scholars Journals

African Journal of Plant Breeding ISSN: 2375-074X Vol. 8 (8), pp. 001-010, August, 2021. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Participatory Selection and Evaluation of Soybean (*Glycine max*) Varieties for Savannah Regions of the DR-Congo

Justin Mudibu[1,2], Kankolongo Mbuya[1,3], Adrien Kalonji-Mbuyi[2,4], Kabwe Nkongolo[5,*]

[1]Faculty of Agronomy, "Université National Pégadogique de Kinshasa (UPN)";
[2]Regional Nuclear Energy Center, Kinshasa (CRENK), RD-Congo,
[3]National Institute for Research and Agronomic Studies (INERA), B.P. 2037, Kinshasa 1, RD – Congo;
[4]Faculty of Agronomy, University of Kinshasa, B.P 117, Kinshasa 11, RD–Congo;
[5]Department of Biological Sciences, Laurentian University, Sudbury, Ontario, Canada, P3E 3C6.

Accepted 28 June, 2021

Abstract

Pulses and legumes in general are important staple crops for smallholders in sub-Saharan Africa that contribute to improvement of Africa's nutrient-poor soils. In the DR-Congo, the soybean genepool includes local and genetically improved varieties from international institutions such as the International Institute of Tropical Agriculture (IITA) or other countries. However, the acceptance rate of these varieties is very low. The main objective of this study was to identify and select elite soybean varieties grown in the DR-Congo using Participatory Varietal Selection (SVP) led by the breeder. In total, five field trials involving 22 soybean varieties were conducted in a savannah region of Eastern Kasai (DR-Congo) with or without nitrogenous-phosphorus – potassium (NPK) fertilization. A total of 61 males and females farmers from surrounding villages were involved in the variety evaluation. Selection was based primarily on agronomic characteristics such as yield components, duration to maturity, organoleptic qualities, and seed size and color. Significant differences among varieties for most of the traits studied were observed. Overall, three varieties were selected based on farmer's ranking. They include TGX1895-49F, TGX SENASEM, and TGX1879-9 E. These soybean varieties were released and promoted in the community.

Keywords: Soybean; *Glycine max*; participatory varietal selection; DR-Congo; farmer's knowledge.

INTRODUCTION

Pulses and legumes in general are important staple crops for smallholders in sub-Saharan Africa that contribute to improvement of Africa's nutrient-poor soils (Snapp et al., 2018). In the DR-Congo, they are usually grown in traditional production systems and are an important source of income for farm households. At the national level, they are the third most important food crop after cassava and maize. They are important in terms of nutrition and sustainability of production systems. From an industrial point of view, seed legumes are a safe and sustainable outlet for the development of an agro-industry in a country with an agricultural vocation like the DR-Congo.

Soybean (*Glycine max* (Merr.)), an annual legume seed, is a plant grown mainly because of its seeds rich in protein and fat. Its oil is one of the most traded vegetable oils in the world and its extraction can lead to the development of a flourishing agro-industry (Murithi et al.

*Corresponding author email: knkongolo@laurentian.ca

2016; Khojely, 2019). By-products of soybeans can contribute to an economic growth through a development of small scale transformation plants.

From an agronomic point of view, legumes are the best choice for crop rotation in cereal or cotton-based production systems. They help control weeds such as *Striga sp* and improve soil structure through their symbiotic nitrogen fixation capacity. A soybean crop can provide up to 150 to 180 kg of nitrogen per hectare through symbiotic activity (Carlson, 1973; Misiko et al., 2008).

Soybean varieties react differently to edapho-climatic conditions (Mudibu et al., 2011). Cultivars with excellent performances in areas where they have been selected can perform poorly under different growing conditions. Hence, resistance to diseases and pests, and adaptation to environmental conditions should be the main guiding selection criteria (Murithi *et al*., 2016).

Most genetically improved varieties are developed in agricultural research stations based on criteria defined by the breeder such as yields, resistance to diseases, and time to maturity, regardless of the actual needs of the users (Fadda et al., 2020). The adoption of varieties requires the contribution and participation of farmers at all levels of genetic improvement to increase the chances of long-term use (Morris *et al.*, 2004; Misiko *et al.*, 2008; Mbuya *et al.*, 2010; ; Ajanga *et al.*, 2011; Ceccarelli *et al*. 2006, 2020; Misisan *et al.*, 2020; Woku *et al.*, 2020). This participatory approach also incorporates women's knowledge because they often have cooking-related requirements that men do not always consider (Almekinders 2001, Mbuya *et al.*, 2010; Tufan et al., 2018; Ceccarelli et al., 2020).

The main objective of this study was to identify the best varieties responding to farmers needs among soybean varieties available in the Congolese gene pool using the Participatory Varietal Selection (PVS) approach.

MATERIALS AND METHODS

Site description

The trials were conducted during two major rainy seasons in 2016 and 2017 at three sites in Gandajika territory in Eastern Kasai. Site1 was located at the INERA experimental field (6°48'34 '' South, 23°57'05), site 2 at Mpiana farmer's field (6°36'39' 'South latitude, 23°56' longitude East and 685 m altitude), and site 3 at Mpasu farmer's field (6°48'10' 'South latitude; 24°00'09`` East longitude and 718 m altitude) (Fig. 1). Its humid tropical climate of the AW4 type according to the Koppen classification is characterized by two dry seasons with precipitation of the driest month of less than 60 mm. The annual rainfall is estimated at 1,425 mm, the relative humidity is 72.6%, the annual temperature is 23.3°C, and the sunshine duration is 2,400 hours / year (FAO, 1999; Lufuluabo et al., 2011).

Field trials

During the first round of evaluation, 22 soybean varieties were planted at two sites, site 1 (INERA) and site 2 (Mpiana). These materials were provided by the National Institute of Studies and Agronomic Research (INERA) and the Ministry of Agriculture. Local varieties were obtained from farmers.

The field trials were laid out in a randomized complete block design (RCBD) with three replicates. Seeding was done in lines at 60 cm apart; within each line, 3 seeds were planted every 10 cm at about 2 cm deep as described in Mudibu *et al.*, (2011). No phytosanitary treatments were performed to protect crops against pests and diseases. At each site, field evaluation of varieties were conducted in two trials, one without fertilizer application and the other with application of NPK fertilizer at a rate of 45 kg / ha. At the end of the first cycle of selection, the elites' varieties identified by the farmers and the breeder were planted at the three sites (Sites 1, 2, and 3) for a final field evaluation using criteria that include seed yield, resistance to diseases, insects, and *Alectra*.

Participatory Varietal Selection

Participatory Varietal Selection (PVS) led by the breeder was used to select the best soybean varieties grown in Gandajika in Eastern Kasai in the DR-Congo. Participants (34 males and 27 females) from surrounding villages were nominated by the local farmers' associations and management structures' and others who had expressed a desire to participate in these activities. They were selected after an investigation. Participation also took into account the representativeness of the gender, age, income level, and areas planted for soybean cultivation. Thirty-six farmers from Kalunga, Mpembanzeu, Mpasu, Kaniaka, Kaniana, Mulamba1, N`sana and Gandajika townships assessed the performance of varieties at the site 1 (INERA). Twenty-five farmers from Mpiana, Mbasangana. Mpiana Mutombo, and Mande were selected at site 2 (Mpiana).

Soybean varieties that were the subject of participatory selection (PVS) are described in Table 1. The selection was based on criteria set by the farmers and the breeder that included yield with or without fertilizer, drought resistance, resistance to excess rainfall of over 200 mm per month, earliness, pod filling, disease resistance, size and color of seeds, resistance to lodging, leaf drop before harvest and good vegetative development. Specifically, the morphometric parameters include plant height, the diameter at the collar, and the number of leaves, the duration of the sowing - flowering period of 50% of the

a)

b)

Figure 1. Site location a) DR-Congo (in black); b) Map (in white) of DR- Congo. The arrow indicates the targeted location (Gandajika) where the varieties evaluation was conducted.

plants. The yield parameters measured include seed weight / ha, number of pods and seeds / plant, and weight of 100 seeds.

The pathological parameters included the incidence of bacterial pustules and fungal diseases (brown spot diseases) as well as their severity. The level of insect damage on the leaves was also measured. Diseases incidence was estimated by the percentage of infected plants. The severity of the disease was based on the rating scale of 1 to 9 where 1 represents 3% of leaflet covered spots. Ratings 2, 3, 4, 5, 6, 7, 8, and 9 represent 6%, 12%, 25%, 50%, 75%, 87%, 94%, and 100% covered

Table 1. Soybean varieties used in the present study and their provenance.

N°	Names	Provenance
1	TGX888-49F	INERA Gandajika, DR-Congo
2	DAVIS	INERA M'vuazi, DR-Congo
3	TGX1740-7F	LUBUMBASHI, DR-Congo
4	SB19	INERA M'vuazi, DR-Congo
5	TGX1895-49F	INERA Gandajika, DR-Congo
6	KITOKO	INERA M'vuazi, DR-Congo
7	NI	INERA Gandajika, DR-Congo
8	TGX1485-1D	INERA Gandajika, DR-Congo
9	TGX814-49D	INERA M'vuazi, DR-Congo
10	TGX SENASEM	SENASEM, DR-Congo
11	TGX1879-9^{E}	INERA Gandajika, DR-Congo
12	SAPRO	INERA Mulungu, DR-Congo
13	BOTULA II	CGEA/CREN-K, DR-Congo
14	BOTULA I	CGEA/CREN-K, DR-Congo
15	VUANGI	INERA M'vuazi, DR-Congo
16	AFYA	INERA Gandajika, DR-Congo
17	TGX BWAMANDA	CDI Bwamanda, DR-Congo
18	MELOC	INERA Gandajika, DR-Congo
19	TGX1904-2F	INERA Gandajika, DR-Congo
20	SB24	INERA, Gandajika, DR-Congo
21	PKO6	INERA Mulungu, DR-Congo
22	KAMBULUKU	FERMIER Gandajika, DR-Congo

leaflets, respectively. For leaf insect damage, the rating scale ranges from 1 to 5 where 1 indicates no damage to the leaflets, and 2 represents at most 10% of the leaflets that are half damaged. The rating of 3 indicates at least 10% and at most 50% of leaflets damaged in half while the score of 4 corresponds to at least 50% and not more than 90% of leaflets damaged by half. The most severe rating of 5 was attributed when more than 90% of leaflets are damaged by half.

The presence of *Alectra* was measured by counting the number of shoots as soon as they appeared in the plots. After counting, the shoots of *Alectra vogelii* were dug up and thrown out of the test plots.

Field visits with the farmers took place twice, at 15 days after emergence for the first visit and 50 days after sowing for the second visit, which coincided with flowering, pod formation or filling according to varieties. After harvest, the farmers evaluated yields, color, and size of the seeds, organoleptic qualities and the cooking time of two prepared soy recipes (Maboulou and porridge) and selected the best five varieties.

At each meeting, the participants include three groups, the first consisting of only women, the second only men, and the third was a mix of men and women. For each selection criterion, the farmers used the scale of 1 to 5, as follows: excellent (5); very good (4), good (3), fair (2), and poor (1).

The observed parameters were analyzed using the R software. The means were compared using the ANOVA and the LSD test.

RESULTS

Overall, 22 soybean accessions were evaluated in two trials per site, one enriched with fertilizer and a second without fertilization. Significant differences for all measured parameters among soybean varieties were observed in all the trials. Mean values of observed yield data are described in Tables 2 and 3. For trials without fertilizer (Table 3), seed yield ranged from 796 Kg / ha to 2737 Kg / ha at site 1 (INERA) and between 709 Kg / ha and 2460 Kg / ha in site 2 (Mpiana). The number of pods / plant varied between 16 and 77 pods / plant at site 1 and from 41 to 94pods / plant in site 2. The number of seeds / plant varied between 43 and 158 seeds / plant at site 1 and between 35 and 94 seeds / plant in site 2. The weight of 100 seeds ranged between 8 and 14 grams at site 1 and between 8 and 15 grams in site 2.

For the test with fertilizer (Table 4), seed yield varied between 861 kg / ha and 2871 kg / ha at site 1 and between 1419 Kg / ha and 2887 Kg / ha in site 2. The number of pods / plant varied between 20 pods / plant at site 1 and 49 pods / plant in site 2. The number of seeds / plant varied between 60 and 189 seeds / plant at site 1 and between 66 and 178 seeds / plant in site 2. The weight of 100 seeds varied between8grams and 15 grams at site 1 and 8grams and 16grams at site 2.

Additional agronomic characteristics that were used to rank varieties include the number of branches / plant, number of pods / plant, number of empty pods / plant, number of seeds / plant, weight of seeds per hectare, number of days for flowering and maturity of 50% of seedlings, the incidence of bacterial and fungal diseases and their severity as well as the severity of insect damage on the soybean leaves, and the number of *Alectra* shoots / plot. Other morphometric information used to select elite accessions includes plant height, and growth and development. They were assessed by

Table 2. Seed yield per ha, number of pods /plants, number of seeds per plant, and weight of 100 seeds in trial without fertilizations.

Varieties	Seed yield (Kg/ha)		Number of pods/plant		Number of seeds /plant		Weight of 100 seeds (gram)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
TGX888-49F	1347	1304	48	49,7	92,7	46,7	9,9	11,8
DAVIS	796	1538	16,3	51	61,3	91	10,7	12,3
TGX1740-7F	1046	994	44	73	65	39,3	13,77	14,5
SB19	1572	1446,3	55,3	72	63,3	64,3	10,2	10
TGX1895-49F	2737	1186,3	76,7	53	131	41,3	10	12,3
KITOKO	2171	1435	64,3	71,3	88	94,3	8,5	9,9
NI	1444	1429	52,7	67,3	61,7	51	10,5	10,5
TGX1485-1D	1062	1290	44,7	48,7	49,3	64,7	11,9	12
TGX814-49D	2008	1742,3	46,7	93,7	155,7	46,3	9,2	9,8
SENASEM	2640	2239	63,7	70	157,7	98	9,1	9,3
TGX1879-9E	1943	1999,3	76,7	65,3	99	64,3	9,8	10,2
SAPRO	981	1813,3	20	48	48,3	71,3	14,4	14,2
BOTULA II	1336	709,3	42,7	62,7	70,7	34,7	7,9	7,9
BOTULA I	1322	1869	40,7	64,3	95	48,3	12,3	12,4
VUANGI	1461	1829	39,3	85,3	109,3	54,7	10,1	10,3
AFYA	1938	2460	78	87,3	89,7	88	10	10
BWAMANDA	1774	1515,3	77,3	51	96,7	45,7	9,7	9,7
MELOC	1422	1076	33,3	61,7	105,3	51,3	9,9	11,3
TGX1904-2F	1237	1559	30,3	62	55,7	39,3	12	12
SB24	834	1589,3	23,7	40,7	42,7	66	12,2	12,4
PKO6	1136	1544	25	50,3	63	62,3	13,9	15,2
KAMBULUKU	1458	1883	52,3	85	93	78	10,3	10,2
LSD (0,05)	135	138,1	4,9	7,3	6,2	7,5	0,3	0,6
CV (%)	6,3	5,4	6,2	6,6	4,8	7,6	1,2	2,6

farmers at 55 days after sowing. Seed colour and taste of local dishes ("Maboulou" and porridge) were also considered in the final evaluation of varieties. Figure 2 shows results of males and female farmer's evaluation. An additional fifth trial was conducted at the three sites (Site 1: INERA; Site 2: Mpiana; Site 3: Mpasu), one year later.

Based on all the parameters used and the variety ranking, five elite accessions

Table 3. Seed yield per ha, number of pods /plants, number of seeds per plant, and weight of 100 seeds in trial with fertilizations.

Varieties	Seed yield (Kg/ha)		Number of pods /plant		Number of seed/plant		Seed weight of 100 seeds (gram)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
TGX888-49F	1589,7	1737	50,3	89	124	117	10,1	11,9
DAVIS	1053,3	1842,3	20,3	49,7	73,7	98,3	10,8	12,8
TGX1740-7F	1459,7	1824	54,3	95,3	71,3	66,3	13,9	14,6
SB19	1636,7	2116,3	61,3	90,3	92,7	116,7	10,2	10,3
TGX1895-49F	2870,7	1598	86,7	58	188,7	69	10,1	13
KITOKO	2243	1509	77,3	90,3	116	110,7	8,9	10
NI	1569	1578	59,3	71,3	72	78,3	10,5	10,4
TGX1485-1D	1166	1427	45	52	61,3	71	12,1	12,1
TGX814-49D	2128	2887	54,7	118	165,7	176,3	9,3	10,3
SENASEM	2681,7	2393,3	73	113	167,7	99	9,2	9,7
TGX1879-9E	2068	2032,3	79,3	120,3	157,7	73,3	9,9	10,1
SAPRO	1055	2695	25,3	57,7	60,3	117,7	14,4	14,6
BOTULA II	1225,7	1419	53	71,3	75,7	132,3	7,8	7,9
BOTULA I	1395	1962	44	78	104,3	80	11,3	12,6
VUANGI	1653,7	1957,3	44	95,7	159	93,3	10	10,4
AFYA	2383,3	2942	84,3	139	112	125,3	10,1	10,2
BWAMANDA	1782,7	1713,3	82,7	79	148,3	70	9,9	10,1
MELOC	1623	2054	38,3	94,3	168	133,3	9,9	11,6
TGX1904-2F	1324	1874	35	67,7	85,3	83,7	12,1	12,7
SB24	860,7	2170,3	28,7	49	53	96,7	12,2	12,6
PKO6	1262,7	2700	28,7	73,7	71,3	109	13,9	15,6
KAMBULUKU	1717	2325	56,7	110,7	147	178	10,6	10,3
LSD (0,05)	121,9	141,9	4,9	7,9	8,4	10,2	0,3	0,5
CV (%)	4	4,2	5,3	5,8	4,6	5,9	1,1	2

were selected by the farmers (Tables 2 to 5). They include, TGX1895-49F, SENASEM, TGX814-49D, TGX1879-9 E, and AFYA for site 1 (INERA) and, AFYA, SENASEM, SAPRO, TGX1879-9 E and BOTULA I for site 2 (Mpiana). Botula and Sapro selected at site 2 were further eliminated based on poor organoleptic characteristics. Overall, TGX1895-49F, TGX SENASEM and TGX1879-9Ewere the best-rated varieties by farmers.

TGX1895-49F were highly ranked by farmers with regard to the taste of local dishes (Maboulou and porridge). It was also highly rated for the color of its seeds. This variety showed a low incidence of bacterial and fungal diseases and was less affected by bacteria, fungi and Alectra. The weight of its seeds per hectare was also high. This is probably related to its genetic potential, which gives it the longest duration between sowing and maturity of the crop thus favoring the sufficient accumulation of dry matter.

TGX SENASEM produced the most seed / plant at both sites (INERA, Mpiana) at the initial testing. The number of empty pods / seedlings, the incidence of bacterial pustules and the severity of insect damage to the leaves were among the lowest of the varieties selected in the second stage.

TGX1879-9 E has the same level of seed yield per hectare at both sites (INERA and Mpiana). In the second round of testing, it produced more pods and seeds per plant at both sites, more branching numbers per plant and a lower number of *Alectra* / plot stands.

All the three varieties (TGX1895-49F, TGX SENASEM, and TGX1879-9E) were highly ranked by farmers for organoleptic characteristics and palatability. They were released and promoted in the community.

Table 4. Number of seed / plant, number of pods / plant, and number of days to maturity of 50% of plants.

	Number of seeds /plant			Seed yield kg/ ha			Number of days to maturity of 50 % of plants		
Varieties	Site 1	Site 3	Site 2	Site 1	Site 3	Site 2	Site 1	Site 3	Site 2
AFYA	69	53	56	1620	722	1320	100	101	91
SENASEM	84	49	47	1754	900	1451	104	105	92
TGX 1895 – 49 F	85	54	59	1768	1341	1360	105	104	92
TGX 814 – 49 D	96	50	56	1319	1261	1330	101	103	91
TGX 1879 – 9 E	89	54	75	1757	723	1393	100	102	91
LSD	7,4	3,2	4,5	222,6	168,6	135,6	1,6	1,1	1,2
C.V	6,3	7,3	4,5	8,5	11,5	7	0,9	0,6	0,9

Site 1 : INERA ; Site 2 : Mpiana ; Site 3 : Mpasu.

Table 5. Farmer ranking of the five soybean elite varieties based on seed colour and taste of local dishes (Maboulou and porridege).

	Seed colour						Taste (local dish –Maboulou)						Taste (local dish - porridge)					
	Site 1			Site 2			Site 1			Site 2			Site 1			Site 2		
Variétés	F	mixt	M	F	mixt	M	F	mixt	M	F	Mixt	M	F	Mixt	M	F	Mixt	M
TGX1895-49F	4	4	4	4	2	4	4	5	3	4	5	4	5	5	4	4	4	4
TGX814-49D	3	3	4	3	4	3	5	4	4	5	4	4	4	4	5	4	4	5
SENASEM	4	3	2	3	3	3	3	2	2	2	3	2	2	2	1	2	1	2
TGX1879-9E	5	4	4	3	2	3	4	3	3	4	3	4	4	3	3	4	4	4
AFYA	4	4	3	4	3	3	2	3	3	2	4	2	2	3	3	2	3	2

Rating scores : 1 : Poor ; 2 : Fair ; 3 : Good ; 4 : Very good ; 5 : Excellent
F : Females ; M : males ; Mixt males and females.

DISCUSSION

The low soybean yield in Sub Saharan Africa (SSA) can be attributed to the use of poor-performing varieties and to a low input of fertilizers and rhizobial inoculants in soils with no history of soybean production (Khojely et al., 2018). Only few countries contribute to the total soybean production in SSA.In fact, South Africa and Nigeria contribute to more than half of the soybean production in SSA. In recent years, a combined effort in soybean research and promotion by international and national research institutions, including IITA, national soybean improvement programs, universities, and the private sector has resulted in increase of soybean production in some countries. They include Benin, Uganda, and Malawi producing between 130,000 to 160,000 Tones / year; Ethiopia and Zimbabwe between 70,000 to 85,000 T / year, Zambia, Cameroon, Rwanda, DR-Congo, and Burkina Faso with 20,000 to 26,000 T per year (FAOSTAT, 2019).

In the DR-Congo, the soybean genepool includes local and introduced varieties from the ITTA program or other countries. However, the acceptance rate of these varieties is very low. Participatory variety selection was applied in the main soybean production region of the DR-Congo to select soybean varieties that perform well in farmer's field with or without fertilizers to increase farmer adoption of diverse soybean varieties. This work was initiated within the context of food security and income improvement for rural farmers.

The present study showed that NPK fertilizer application at 150 kg /ha increased the yield and this increase varied with the site. The highest seed yield increase due to the inorganic fertilization was observed in site 2. In general, seeds weight is negatively correlated with the number of seeds per pod in many crops. In soybean, seed weight increased under nitrogen fertilization as indicated by Akbari et al. (2001). Yacoub et al., 2012 showed that fertilizer treatments with 361 Kg / ha of NPK had no significant difference on number of pods/plant, weight of seeds per plant, 100 seeds weight, number of pod / plant, number of seeds /plants. This confirms that responses to fertilizers depend on the varieties used and the growing conditions. With respect to nitrogen, soybean varieties

Figure 2. Male and female farmers participation to the variety selection process. a) male and female farmers evaluating soybean varieties in fields ; b) Male farmers assessing morphological characteristics of soybean varieties ; c) Female farmers ratingsoybean seed colour ; and d) female farmers tasting local dishes (Maboulou).

may exhibit different responses based on their symbiotic binding capacity.

TGX1895-49F, SENASEM, and TGX1879- 9 E distinguished themselves in the second phase of the trials among the five varieties selected in the first evaluation stage. TGX1895-49F was among the best-rated by farmers with regard to the taste of local dishes (Maboulou and porridge). It was also highly rated for the color of its seeds. The weight of its seeds per hectare was the highest in site 1 (INERA) and site 3 (Mpasu). This is probably related to its genetic potential, resulting to the longest duration between sowing and maturity thus favoring the sufficient accumulation of elaborated dry matter.

The results revealed that farmers in the targeted region favor productivity for varieties selection; they also prefer varieties with large seeds. This can be explained by the fact that soybean is more profitable compared to other food crops in most regions of the DR-Congo, and that soybean buyers are attracted by the size of the seeds. In contrast, Nkongolo et al. (2008, 2009), in their study on participatory varietal selection of sorghum accessions in Malawi, found that farmers prefer productive varieties and they also take into account other traits such as seed color, precocity, and other qualities that condition the processing of harvest products. Mbuya et al*.* (2010) reported that farmers selected maize varieties based not only on productivity and early maturity, but also on resistance to late blight, a disease that causes huge losses to the culture of corn in this environment.

The results of this study indicate that it is possible to organize a plant improvement program with a view to selecting varieties that meet the concerns of farmers and consumers through the participatory approach and confirms the interest of this fruitful collective dynamic through crossbreeding visions that potentially carries social and economic issues.

The evidence strongly indicates that the introduction of a participatory approach to agricultural research has allowed selection of varieties with a very high adoption rate. The underlying rationale and empirical evidence presented here argue strongly for a wider implementation of this participatory approach in other crops. A similar selection scheme that was applied to maize, sorghum, cowpea, and beans in the DR-Congo and Malawi was equally successful (Nkongolo et al., 2008 and 2009; Mbuya et al., 2010; Matondo et al., 2018). By comparison with many other participatory methods the approach also represents a cost-effective use of scientists' time: the role is that of building up a portfolio of varietal material broadly compatible with what farmers are known to prefer and then allowing farmers to makethe selection under their own conditions (Morris and Bellon, 2004; Nkongolo *et al.*, 2008 and 2009; Humphries *et al.*, 2015; Fadda et al. 2020).A most important variable is the range of diversity that farmers can be offered. The morevariability there is for quality traits, and the better the adaptation of the cultivars to the local environments, the more likely that several varieties will be selected and adopted for many years (Ceccarelli, 2003, 2020; Galluzzi et al., 2014; Mengistu et al., 2019).

The present study showed that farmers' evaluation of several varieties supported by breeders input for experimental design and data analyses were useful in selecting the best elite varieties that have been adopted by the farmers and the rural community at large. Their adoption rate remains high five years after release. The present PVS of soybean varieties from the DR Congo gene pool clearly confirms a number of reports that collaborative selection with farmers is extremely useful for decentralizing breeding programs.

ACKNOWLEDEMENTS

This research was conducted through a partnership between Laurentian University (Ontario, Canada), University of Kinshasa (DR-Congo), and Caritas Congo. The authors are grateful to the Canadian International Development agency (CIDA) for financial support and the Association of Universities and Colleges of Canada (AUCC) for managing the partnership program. We would like to express our sincere thanks to Caritas –Congo, Caritas, Mbuji Mayi, and INERA Gandajika for all the logistical arrangements.

REFERENCES

Ajanga, S. and J. Shuma.2011.Participatory farmer evaluation of stem borer tolerant

Akbari G.A., D.S. Scarisbrick, and W.T. Peat.2001. Soybean (*Glycine max* L. merrill) yield and yield components response to nitrogen supply and wither changes in South-East of England. Journal of Agriculture and Rural Development 3 (1): 15-32.

Almekinders C.J.M. and A. Elings.2001. Collaboration of farmers and breeders: Participatory crop improvement in perspective, Euphytica, 122: 425 – 438.

Carlson J.B., (1973). Morphology. In Soybean: Improvement, Production, and Uses. (Eds) Caldwell B.E, R. W. Howell, R. W. Judd, and H. W. Johnson n°16, Agronomy, American Society of Agronomy. Madison, Wisconsin pp 17-95.

Ceccarelli, (2006). Decentralized – Participatory Plant Breeding: lessons from the South – Perspectives in the North. Pp. 8-15. Desclaux, D. and M. Hédont (Eds), 2006. Proceedings of the ECO-PB Workshop on Participatory Plant Breeding: Relevance for Organic Agriculture, held in Domaine de la Besse (Camon, Ariège), France, 11-13 June 2006. ITAB, Paris, France, 112 pages

Ceccarelli, S.and S. Grando (2020). Participatory plant breeding: Who did it, who does it and where? Experimental Agriculture. 56 : 1-11. DOI: 10.1017/S0014479719000127.

Fadda C, D. K. Mengistu, Y. G. Kidane, M. Dell'Acqua, M. E. Pè and J. Van Etten (2020). Integrating Conventional and Participatory Crop Improvement for Smallholder Agriculture Using the Seeds for Needs Approach: A Review. Frontiers in Plant Sciences 11:559515. doi: 10.3389/fpls.2020.559515

FAOSTAT (2019). FAO statistical data base for food. Food and Agriculture Organization of the United Nations, Rome, Italy . Retrieved 06 November 2019.

Galluzzi, G., R. Estrada, V. Apaza, M. Gamarra, A. Pérez, G. Gamarra, A. Altamirano, G., Cáceres, V. Gonza, R. Sevilla, I. López Noriega, and M. Jäger. (2014). Participatory breeding in the Peruvian highlands: Opportunities and challenges for promoting conservation and sustainable use of underutilized crops. Renewable Agriculture and Food Systems 30, 408–417.CrossRefGoogle Scholar

Gyawali S, S. Sunwar, M. Subedi, M. Tripathi,K.D. Joshi, and J. R. Witcombe (2007). Collaborative breeding with farmers can be effective. Field Crop Research (101): 88-95.

Humphries, S., J. C. Rosas, M. Gómez (2015). Synergies at the interface of farmer–scientist partnerships: agricultural innovation through participatory research and plant breeding in Honduras. Agricultureand Food Security 4:27 DOI 10.1186/s40066-015-0046-0 https://doi.org/10.1186/s40066-015-0046-0.

Khojely, D. M., Ibrahim, S. E., Sapey, and T. Han (2018). History, current status, and prospects of soybeanproduction and research in sub-Saharan Africa. Crop Journal 6 : 226–235.

Lufuluabo, M., R. Kizungu, andK. K. Nkongolo (2016). Maize Production under Climate Change in a Savannah Region in DR-Congo. Journal of Experimental Agriculture International, 14(4), 1-10. https://doi.org/10.9734/JEAI/2016/29056.

maize varieties in three maize growing ecologies of Kenya.African Journal of Agricultural Research 5 (13): 3021-3028.

Matondo N.K., D. Mumba, D. K. Tshilenge, and K.K. Nkongolo (2018). "Sélection participative de haricot commun (*Phaseolus vulgaris* l.) basée sur des caractères morpho métriques et agronomiques", International Journal of Development Research, 8, (01), 18566-18579.

Mbuya K., K.K. Nkongolo, A. Kalonji – Mbuyi, and R. Kizungu (2010). Participatory selection and characterization of quality protein maize (QPM) varieties in savanna agro – ecological region of DR – Congo. Journalof Plant Breedingand Crop Sciences 2 (11): 325 – 332.

Mengistu, D., A. Kiros, J. Mohammed, Y. Tsehaye, and C. Fadda (2019). Exploitation of diversity within farmers' durum wheat varieties enhanced the chance of selecting productive, stable and adaptable new varieties to the local climatic conditions. Plant Genetic Resources: Characterization and Utilization, 17(5), 401-411. doi:10.1017/S1479262119000194

Misiko M., P. Tittonell, J.J. Ramisch, P. Richards, and K. E. Giller (2008). Integrating new soybean varieties for soil fertility management in smallholder systems through participatory research: Lessons from western Kenya, Agricultural System 97 (1- 2): 1-12.

Morris, M.L. and M.R. Bellon (2004). Participatory plant breeding research: Opportunities and challenges for the international crop improvement system. Euphytica 136: 21–35. https://doi.org/10.1023/B:EUPH.0000019509.37769.b1

Mudibu J., K.K. C. Nkongolo, and A. Kalonji-Mbuyi. 2011. Morphovariability and agronomic characteristics of soybean accessions from the DR-Congo gene pool. Journal of Plant Breeding and Crop Sciences 3(9): 260-268.

Murithi, H.M., F. Beed, P. Tukamuhabwa, B. P. H. J. Thommaban, and M. H. A. J. Joosten. 2016. Soybean production in eastern and southern Africa andthreat of yield loss due to soybean rust caused by Phakopsora pachyrhizi.. Plant Pathology 65: 176–188

Nkongolo K.K., K.K. L. Chintu, Malusi M., and Z. Vokhiwa. 2008. Participatory variety selection and characterization of sorghum (*Sorghum bicolour* (L.) Moench) elite accessions from Malawian gene pool using farmer and breeder knowledge. .African Journal of Agricultural Research 3 (4) :273 – 283.

Nkongolo, K.K., J. Bokosi, M. Malusi1, Z. Vokhiwa, and M. Mphepo. 2009. Agronomic, culinary, and genetic characterization of selected cowpea elite lines using farmers' and breeder's knowledge:A case study from Malawi. African Journal of Plant Sciences 3 (7): 147-156.

Snapp, S., M. Rahmanian, and C. Batello.2018. Pulse crops for sustainable farms in sub-Saharan Africa, edited by T. Calles. Rome, FAO. 60 pp.

Tufan, H.A., S. Grando and C. Meola (eds).2018. State of the Knowledge for Gender in Breeding: Case Studies for Practitioners. Lima (Peru): CGIAR Gender and Breeding Initiative. Working Paper. No. 3. Available at www.rtb.cgiar.org/gender-breeding-initiative Accessed 6 March 2020 Google Scholar

Witcombe J.R., A. Joshi, K.D. Joshi,and B. R. Sthait. 1996. Farmer participatory crop Improvement I: Varietal selection and breeding methods and their impact on Biodiversity. Experimental Agriculture 32: 445-460.

Worku, M. H. De Groote, B. Munyua, andD. Makumbi (2020). On-farm performance and farmers'participatory assessment of new stress-tolerant maize hybrids in Eastern Africa. Field Crops Research 246://doi.org/10.1016/j.fcr.2019.107693.

Yagoub, S.O., W. M. A. Ahmed, and A. A. Mariod (2012). Effect of Urea, NPK and Compost on Growth and Yield of Soybean (*Glycine max* L.), in Semi-Arid Region of Sudan. ISNR Agronomy, 2012: 1–6. doi:10.5402/2012/678124.