Participatory breeding experience and implications for sweetpotato breeding in Uganda

R.O.M. Mwanga, C. Niringiye, A. Alajo, I. Mpembe, B. Kigozi[1], R. Kapinga, S. Tumwegamire, B. Lemaga[2], E. Marandu[3], and R. W. Gibson[4]

[1]National Agricultural Research Organization (NARO), National Crops Resources Research Institute (NaCRRI), Namulonge, P.O. Box 7084, Kampala, Uganda. [2]International Potato Center (CIP), Box 22274, Kampala, Uganda. [3]Root crops - department, ARDI Maruku, P.O Box 127, Bukoba, Tanzania. [4]Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK.
Email-mail address: r.mwanga@cgiar.org (and rmwanga7@gmail.com).

ABSTRACT

The National Sweetpotato Program (NSP) breeding cycle in Uganda takes 7-8 years to officially release a variety. In 2003 participatory plant breeding (PPB) was initiated in six farmer groups (3 each in Central Uganda and Northern Tanzania) with the objective of assessing the benefits of PPB, including the time it would take to deliver improved varieties to farmers, and to take advantages of PPB. Segregating populations were given to each group to select superior sweetpotato clones. In 2005 trials in Tanzania, and Kiboga in Uganda were disrupted by monkey damage and drought, respectively. In Uganda, however, seven promising PPB advanced selections were made by 2006 and were evaluated by the NSP on-farm and on station in 4 locations (four replications per site). From the PPB results clones NKA1081L, NKA259L and NKA103M were as good as or better in performance than the local checks. Release documents for NKA1081L have been prepared and other PPB materials will be evaluated further to generate data on stability for official release. Farmers started consuming and selling PPB sweetpotato clones in the third to fourth year, which would occur in year six to seven in conventional breeding. These PPB trials demonstrate the potential for rapid progress in sweetpotato breeding in targeted environments, and the high risks involved in loosing valuable genetic material due factors such as drought and destruction by animals.

Keywords: breeding efficiency, botanical seed, clonal evaluation, variety ranking.

Introducion

Participatory plant breeding (PPB) involves farmers selecting genotypes from segregating populations or generations. Successful examples of PPB have been reported in the literature. For example, Sthapit *et al.* (1996) conducted PPB with farmers in Nepal to select chilling tolerant rice from F5 bulk families. Joshi and Witcombe (1996) created a broad-based maize composite for PPB in India, and the first selection by farmers was in Gujarat in the 1995 rainy season. PPB improved selection efficiency in barley (Mangione et al., 2006).

PPB facilitates close interaction among farmers, researchers and other actors in crop genetic improvement, allowing researchers to respond more closely to the needs and preferences of resource-poor farmers and their market clients (Cleveland et al., 2000). PPB also results in better identification of criteria that are important to the local community, targeted local environmental conditions and varieties obtained from this process are developed more rapidly, are more diverse and have higher adoption rates (Witcombe et al., 2003). Farmer selection of finished or near-finished varieties is termed participatory varietal selection (PVS), while farmer selection of segregating materials with a high degree of genetic variability is known as PPB (Witcombe et al., 1996). Ceccarelli et al., (2000) also described testing and selecting in the different locations representative of the target-breeding environment as decentralized breeding. The National Sweetpotato Program (NSP) breeding cycle in Uganda takes seven to eight years to officially release a variety. In 2003, the NSP and the Natural Resources Institute together with Ugandan and Tanzanian farmer groups initiated PPB trials (Gibson et al., 2008) with the objectives of: 1) estimating the time it would take to deliver improved varieties to farmers, and 2) assessing any other advantages of PPB.

materials and methods

Seedling Nurseries. Sweetpotato participatory breeding trials in Uganda were started in May 2003. Sweetpotato botanical seed was scarified in concentrated sulfuric acid at the National Crops Resources Research Institute (NaCRRI), Namulonge, washed under running water, and pre-germinated overnight on moist filter paper in covered petri plates. The pre-germinated botanical seeds (segregating populations) were given to farmer groups in the districts of Luwero, Mpigi, and Kiboga in Central Uganda, and three groups in Kyaka, Nyungwe and Maruku in the Lake Zone of Northern Tanzania to select superior sweetpotato clones. The pre-germination of the seed in Northern Tanzania was done at Maruku Research Station. The pre-germinated seeds were planted in one meter wide raised field seedbeds at a spacing of 10 cm by 20 cm. The seedlings were watered as required to allow establishment. Each group received 2,000-6,000 pre-germinated sweetpotato seed of at least two families (New Kawogo and Bunduguza) depending on the availability of scientific staff, technicians, and willingness of the groups to handle segregating populations in the seedling nursery and subsequent large numbers of clones in the initial stages of the PPB trials. Each selected seedling furnished 5 vine cuttings that were planted at each of the six sites on ridges 1 m apart, and 30 cm between the plants. Subsequent clonal selections were planted on mounds or ridges in 2004 onward. By 2005 onward the remaining selected clones were planted in three replications, minimum (Tables 1 and 2). In Kiboga, our research team retrieved (rescued) eight remaining sweetpotato clones that the farmers had abandoned in 2006 in the PPB trial due to severe drought. The 8 clones were planted and multiplied at Namulonge, and were taken back to Kiboga for evaluation by the farmers in October 2006. All the sweetpotato clones in Tanzania were lost due to drought. monkeys and hippopotamus damage between 2005-2006.

Clonal Evaluation. In 2006/2007 we evaluated in PPB trials the selected SP advanced clones in three districts:

(a) Luwero- Nine farmers hosted the trials. Each farm consisted of a household that planted 1-3 ridges (50 plants per ridge), 1 m between ridges, 30 cm between plants on the ridge, with Dimbuka and NASPOT 1 as check varieties. At harvest, five months after planting, taste ranking was done by 12 farmers (8 females, 4 males), where, 1 = best (most preferred); 8 = least preferred based on pair-wise selection of the 8 varieties.

(b) Mpigi- Fifteen farmers (farms) hosted the PPB trial (13 females, 2 males) who planted 4 ridges (30 plants per ridge), 1 m between ridges, 30 cm between plants on ridge. Taste ranking was done by 15 farmers (12 females, 3 males): 1 = best (most preferred); 8 = least preferred as described above.

(c) Kiboga- One farmer hosted the PPB trial. A group of nine farmers (8 females, 1 male) planted the trial at one farm in three replications, on mounds (3 plants per mound), 1 m between centers of mound. There were seven clones rescued from drought and two local checks. All the rescued clones performed poorly compared to the control, and so were discarded. However, the promising seven clones from Luwero and Mpigi were planted in 2007 in Kiboga to continue the PPB trials.

PPB trial evaluation on-station. The promising advanced clones in the PPB trials in Luwero and Mpigi were evaluated on station at Namulonge, Kachwekano, Ngetta and Serere in 2006-2009. The routine procedure for the NSP for evaluating advanced sweetpotato clones was followed. There were 4 ridges, 5.4 m long, 1 m between ridges, one vine cutting per planting point on the ridge, 0.3 m between plants (18 plants/ridge) (plant density 33,333 plants/ha), in a randomized complete block design (RCBD) with 4 replications. All outside rows of the experimental plots had border plants to minimize experimental error due to competition by border plants in adjacent plots. SPVD and *Alternaria bataticola* blight were scored at 2 months after planting, while vine, and total root and biomass yield were computed from plot yields. Dry matter content (DMC) of storage roots was expressed as the average percentage of dry weight of fresh weight. DMC was determined after weighing two replications of 500 g samples of sliced roots and oven- drying to a constant weight at 65^{0}C.

Results

The number of promising sweetpotato clones in PPB trials declined sharply each selection cycle from over 2,000 clones in 2003 to less than 10 by 2006 (Tables 1 and 2). Selection rates varied from 0% where there were problems of drought (Kiboga in Uganda and Kanyigo in Tanzania), and monkeys and hippos (Kyaka in Tanzania) to 1.8% at Maruku (Tables 1 and 2).

Table 1. Selection of sweetpotato clones (C) from seedlings (S) by farmers in sweetpotato participatory breeding trials in Central Uganda and Northern Tanzania, 2003-2007, showing C rescued from drought (RFD), and destroyed by monkeys (M) at single site (SS) or replicataions

Year	Central Uganda (District/Site)			Northern Tanzania			Number of sites
	Mpigi	Luwero	Kiboga	Kyaka	Nyungwe	Maruku	(Replications)
	Kitutuntu	Manyama	Watuba				
2003	6,000 S	6,000 S	6,000 S	2,000	2,000	2,000	1
	553 C	2,382 C	902 C	0 (M)	0 (D)		1 (1)
	117 C	163 C	126 C	0 (M)	0 (D)		1 (1)
2004	25 C	68 C	67 C	0	0	398	1 (1)
	21 C	14 C	67 C	0	0		1 (1)
2005	11 C	13 C	40 C	0	0	36	1 (3)
2006A	3 C	4 C	8 C (RFD)	0	0	0	1 (4)
2006B	7 C	7 C	8 C (SS)	0	0	0	10-15 (10-15 farms)
2007	7 C	7 C	7 C	0	0	0	10-15 (10-15 farms)
Selection (%) 2005	0.18	0.22	0.67	0	0	1.8	

Sweetpotato clones considered superior by the farmers and originally selected in Luwero in the PPB trials end with L in their clone name, and those originally selected in Mpigi end with M. These superior clones were exchanged at the third clonal generation (March 2005) evaluation stage. Results of the promising advanced clones in on-farm trials in Luwero and Mpigi are shown in Table 2. Clones NKA102M, NKA103M, NKA1081L, and NKA318L were selected in both districts, NKA259L was selected in Luwero but not in Mpigi. BND145L was selected in Mpigi but dropped in Luwero. The reasons for ranking high and selecting the clones were: attractive skin color (purple/red) and flesh, plenty of vines, high yielding, large straight storage roots, continuous storage root setting or yield, less susceptible to weevils, drought tolerant, mealy, and not fibrous (NKA1081L, NKA318L, NKA259L). The local control (Dimbuka) was out yielded by all the promising PPB selections by 23-84%, and was ranked among the last in acceptability in Mpigi in 2005 (Table2), clearly presenting considerable advantage in the PPB selections. In Mpigi, where SPVD pressure is high, Dimbuka was less resistant to SPVD than the PPB clonal selections. There was no significant yield advantage over the local check (Dimbuka) or the released variety (NASPOT 1), but NKA103M, NKA316M, and NKA259L were ranked better than the two former varieties in Luwero in 2005 (Table 2). The reasons for ranking clones low were in different combinations: not sweet at all, very hard, low yielding, susceptible to drought, low vine yield, very susceptible to weevils and diseases (NKA41M, BND145L, Dimbuka).

Results of the same promising PPB clones evaluated on station in four locations are shown in Table 3. From the on-farm (Tables 1-2) and on-station (Table 3) trial results, clones NKA1081L, NKA259L and NKA103M were as good or better in performance in NSP conventional trials for the desired traits than the local checks in specific locations and in the four agroeclogies represented by the four stations. The desired traits included marketable and total root, and biomass yields, resistance to Alternaria blight, SPVD and weevil (Tables 2 and 3).

Table 2. Summary of performance of promising clones in sweeptato participatory breeding trials on-farm, 2005-2007 (sweetpotato virus disease (SPVD) and other scored traits, rating scale = 1-5 (1 = no apparent damage, 5 = severe damage; taste ranking, 1 = first choice (best), 10 = last choice)

District/ year	Code	Clone	Yield (t/ha)		Disease severity		Taste
			Root	Biomass	SPVD	Alternaria	test rank
Mpigi 2005	1	NKA259L	18.0	37.3	3.0	2.0	5
	2	NKA103M	16.8	60.1	2.3	1.7	2
	3	NKA102M	19.5	54.5	3.0	2.0	8
	4	NKA41M	17.4	58.1	3.0	3.0	1
	5	WAG34L	13.9	63.7	2.3	2.0	7
	6	NKA1081L	27.8	77.3	2.3	2.0	3
	7	BND145M	3.8	13.3	3.0	5.0	4
	8	NKA318L	30.1	53.6	2.3	2.3	3
	9	Dimbuka	4.9	46.4	3.7	2.0	7
	10	BND145L	18.1	45.8	2.3	2.7	6
	11	NKA51M	5.7	17.9	2.7	2.0	4
	Mean		16.0	48.0	2.7	2.4	NA
	LSD (0.05)		13.5	32.5	0.8	0.7	NA
	CV (%)		49.5	39.8	17.4	17.9	NA
Luwero 2005	1	NKA259L	17.2	31.9	1.7	1.3	3
	2	NKA1081L	12.2	30.2	1.3	1.3	6
	3	NKA147M	11.9	21.8	1.3	1.3	7
	4	NKA318L	16.1	28.9	1.7	1.7	2
	5	NKA103M	10.7	24.7	1.3	1.0	5
	6	NKA102M	9.4	28.6	1.3	1.3	1
	7	BND145L	17.6	33.8	1.3	1.3	9
	8	Dimbuka	17.9	44.5	1.7	1.3	8
	9	NASPOT 1	16.7	32.2	1.3	2.0	4
	Mean		14.4	30.7	1.4	1.6	NA
	LSD (0.05)		6.3	10.0	0.8	1.3	NA
	CV (%)		25.4	18.8	33.6	47.3	NA
Soroti 2007	1	NKA259L	2.7	6.6	1.2	1.0	10
	2	NKA103M	3.8	7.8	1.0	1.0	3
	3	NKA1081L	3.7	7.2	1.0	1.0	1
	4	NKA318 L	2.9	6.7	1.2	1.2	8
	5	NASPOT 1	4.0	7.5	1.0	1.0	4
	6	Dimbuka	3.2	6.9	1.0	1.0	7
	7	BND12K	2.5	8.3	1.0	1.0	5
	8	NKA14K	2.5	5.5	1.0	1.0	9
	9	BND21K	1.4	5.0	1.0	1.2	2
	10	BND18K	2.5	6.9	1.0	1.0	6
	Mean		3.1	6.8	1.1	1.0	NA
	$LCD_{0.05}$		1.2	2.4	0.3	0.3	NA
	CV (%)		29.6	27.0	22.7	19.5	NA

Table 3. Performance of 10 sweetpotato clones selected in participatory breeding trials in four locations on station - Namulonge, Kachwekano, Ngetta and Serere, planted between June and October 2006 and harvested 5 – 5.5 months after planting (sweetpotato virus disease (SPVD) and other scored traits, rating scale = 1-5 (1 = no apparent damage, 5 = severe damage)

Code	Name of clone	Marketable root yield (t/ha)	Total root yield (t/ha)	Dry matter %	Vine yield (t/ha)	Biomass yield (t/ha)	SPVD	Altermaria	Weevil damage
1	NKA259L	34.7	36.2	33.6	23.5	59.7	1.8	1.6	2.3
2	NKA103M	32.4	32.9	32.8	22.0	54.9	1.5	1.2	2.3
3	NKA102M	28.7	30.1	32.3	22.2	52.2	1.6	1.8	2.3
4	NASPOT 1	38.0	39.2	32.8	31.7	70.9	1.5	2.1	2.1
5	Local check	16.1	17.1	33.3	46.8	63.9	1.5	1.6	1.9
6	NKA1081L	37.0	38.1	31.9	30.1	68.2	1.4	1.3	2.1
7	NKA318L	29.3	31.1	32.3	20.0	51.1	1.6	1.2	2.3
8	Dimbuka	25.8	27.3	32.6	25.2	52.2	1.6	1.4	2.3
9	BND145L	27.4	29.5	32.5	33.0	62.5	1.4	1.3	2.3
10	New Kawogo	24.6	25.6	30.9	30.8	56.5	1.8	1.9	2.2
Mean		29.4	30.7	32.5	28.5	59.2	1.6	1.5	2.2
$LSD_{0.05}$		6.8	7.7	NA	8.0	12.5	0.2	0.3	0.2
CV (%)		32.9	30.1	NA	39.9	30.1	21.8	28.9	15.0

Discussion

From the on-farm (Tables 1-2) and on-station (Table 3) trial results, clones NKA1081L, NKA259L and NKA103M were as good as or better in performance for the desired traits than the local checks in specific locations and in the four agroeclogies represented by the four stations. The taste ranking varied with location and community, suggesting that the clones could have specific adaptation. Among the PPB selections NKA1081L has been selected for official variety release based on its superior performance (Tables 2-3) (Mwanga et al. 2009). These PPB trials demonstrate the potential for significant rapid progress in sweetpotato breeding especially in specific target environments. In the third year (2005) of clonal selection, participating farmers had started consuming sweetpotato from the promising PPB materials in their homes. In the fourth year (2006) PPB participating farmers started selling NKA318L and NKA259L in their local markets in Zirobwe, Luwero District. This is a big plus for the PPB approach in ensuring cultivars cultivars identified are well adapted to specific conditions and are highly client-oriented. These results are in agreement with Gabriel et al. (2000), Thiele et al (2001), Witcombe et al. (2003), Ssemakula et al. (2003), Belay et al (2008), and Gibson et al. (2008). Sweetpotato consumption and exchange by participating farmers (PVS) in the so called conventional breeding would normally start only in year six or seven (Mwanga et al. 2001, 2003).

These PPB trials also demonstrate the high risks involved in loosing valuable genetic material due to such factors as drought, destruction by wild animals such as monkeys and hippos and domestic animals such as cattle and goats, thefts by neighbors, farmers abandoning PPB trials due to fatigue because of the long periods (several years) involved to be committed to conducting the trials, death of the most active participating farmer(s) in the group, inadequate budget support, and the type of starting (base) breeding populations. In all our participatory on-farm selection trials (not PPB) NSP always selects about 15 farmers to host the trials in each location in a district. In almost all cases we experience various combinations of the above-mentioned problems, and end up excluding 30-40% of selected farms from the analysis. In the PPB trials, it is important to keep apart a portion of the populations under evaluation to resort to should such problems crop up. In the on-going PPB trials, we started with very good, carefully selected populations, otherwise all the populations would have been wiped out in the first two to three seasons of planting because we were working in agroecologies where SPVD pressure was high.

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