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Breeding for bean anthracnose resistance: Matching breeding interventions with people's livelihoods through participatory variety selection

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Abstract

The common dry bean is the main source of protein, food and income for the majority of rural smallholder farmers in Uganda especially the women and children, and any constraints hindering its production directly affects these vulnerable groups. Despite its importance, there has been an unmerited decline in bean production over the last few decades as a result of bean anthracnose disease. Breeding for genetic resistance to bean anthracnose and the use of participatory variety selection which aims primarily at accelerating the transfer of new lines to farmers' fields, are the most practical and economical options for controlling anthracnose and popularising the new varieties to smallholders farmers.The objectives of this study were to introgress anthracnose resistance into existing susceptible market class varieties, generate segregating populations, make selections and conduct farmer participatory evaluation trials to identify new bean lines having characteristics that are preferred by both farmers and the market for release as new varieties.A total of 365 new bean lines were generated and 54 of these were introduced to 10 farming communities in four different ecological zones for evaluation using the participatory variety selection approach. Farmers were able to select eight promising lines, which were ear-marked for new variety release. Out of the eight lines, two have already been released.It can thus be concluded that the participatory variety selection acts as an entry point into the farming communities where new varieties are introduced to farmers. Furthermore, participatory variety selection is reliant on farmer preferences and rural livelihood dynamics.

Key words: Bean anthracnose, bean lines, breeding, farmers, livelihoods, participatory variety selection,varieties

Introduction

The common bean (*Phaseolus vulgaris* L.) is a basic component of traditional diets in Uganda and is recognised as a good source of calories and the most important source of protein for most people. The production of beans in every district (Opio *et al*., 2001) shows not only the dependence on beans as a major food security crop, but also the importance of the crop in the farmers' household economy. Beans are used as either food or sold for cash (domestically or exported). Ninety percent of dry bean production in Uganda is mainly by smallholder resource poor farmers (UBOS, 2010).

Although dry bean production has increased in Uganda, the increase has been as a result of increased acreage rather than increased yield per acre. This has mainly been attributed to a range of both biotic and abiotic stresses. The most important being diseases like bean anthracnose, root rots and angularleaf spot and more recently drought. One way of overcoming these constraints, is the development of novel varieties. Despite the enormous time and resources committed to develop new varieties, varietal adoption by smallholder and resource poor farmers is low. This has been attributed in part to low farmer involvement in the selection and release process for new varieties. There is a growing acceptance that the starting point in improving traditional smallholder agriculture needs to be knowledge, problems analysis and priorities of farmers and farm families (Eklund, 1990, Gridley, 2001). Instead of viewing the research station and the extension system as the main locus for action, this new approach emphasizes the farm household and its experimentation capacity. This method is called the Farmer First Approach (Chambers *et al*., 1989). In parallel, the key to the adoption of new bean varieties in Uganda lies in the involvement of farmers through the whole process, from germplasm collection to participatory variety selection (PVS) and variety release. This encourages integration of indigenous knowledge of farmers with modern science to clearly identify crop characteristics that may be suitable for farmers' use.

Ugandan farmers are very particular about the characteristics of bean varieties they can adopt, and this may vary from one agroecology to another.The low bean yields currently experienced in Uganda are partly due to lack of suitable varieties and low adoption rates among smallholder farmers. It is believed that varietal adoption would be enhanced if farmers were involved in their production and selection before release (Gridley, 2001). According to Baidu-Forson (1997), PVS has the potential to develop crop varieties that are better adapted to farmers' requirements. It is thus envisaged that the involvement of farmers in the variety selection process enhancesadoption and usage of these new varieties. It is also assumed that thisincreased adoption of suitable varieties within the different communities would result into higher beans production which will directly translate into higher incomes, increased food security and ultimately improved livelihoods.The objectives of our study were to: 1) Determine farmers' preferred traits in new bean cultivars and 2) Develop bean lines with suitable home consumption and market qualities.

Materials and methods

Origin of new bean lines

The new lines introduced to the farming communities were derived from crosses made between three anthracnose susceptible Ugandan market class bean varieties (K20, K132 and Kanyebwa) and five anthracnose resistant varieties (G2333, AB136, NAT002, NAT003 and NAT067) (Nkalubo *et al*., 2009). The progenies from these crosses were taken through both a backcross and pedigree selection procedure and a total of 365 anthracnose resistant nurseries/lines were obtained. From this nursery, 54 elite lines were introduced to farmers for PVS trials (Fig. 1). The elite lines comprised of all the four bean growth habits (type I determinate bush; type II indeterminate bush; type III indeterminate prostrate vine; and type IV indeterminate climber).

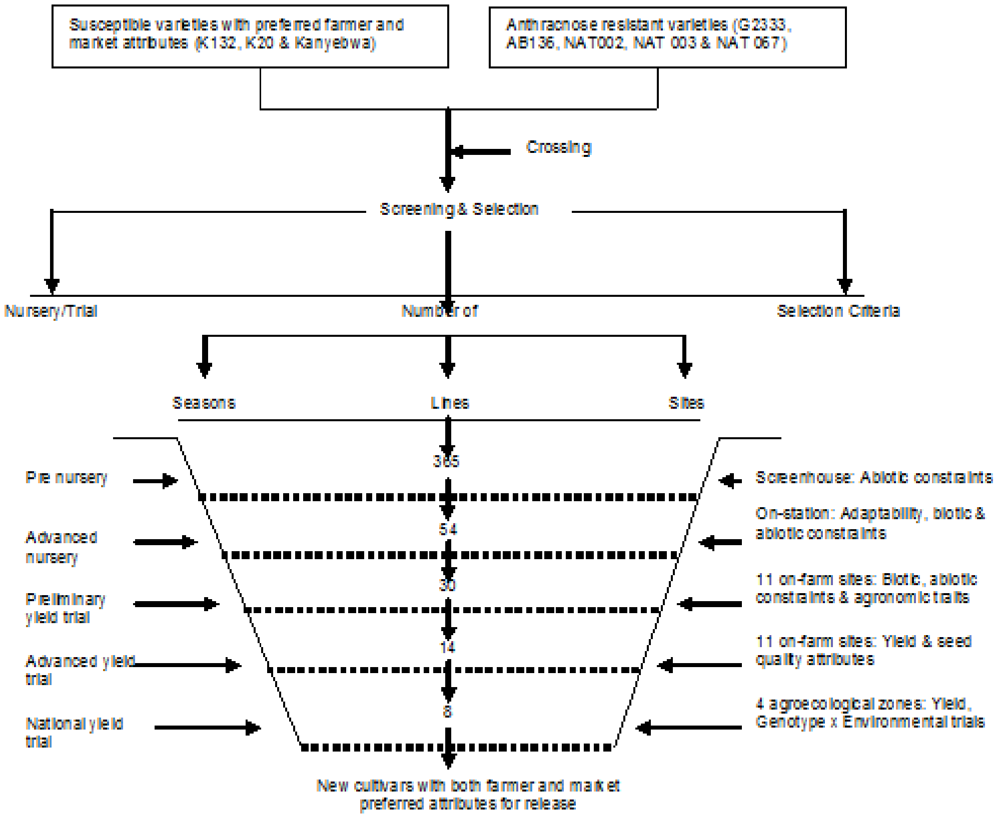

Figure 1. Diagrammatic representation of the breeding process and the farmer participatory variety selection process.

Site and farmer selections

In November 2007, during the second growing season, breeders, agricultural economists and agricultural extension officers conducted a rapid rural appraisal (RRA) to identify potential sites for PVS trials. Since the current studies were aimed at identifying anthracnose resistant bean varieties, site selection was limited to agroecologies that were hotspots for bean anthracnose. In addition to being a disease hot spot, trial sites had to have most farmers in the area involved in bean production. Based on the above criteria11sites were selected from five districts in central and eastern agroecologies of Uganda. The selected districts were Wakiso, Masaka and Mubende(representing the low and mid altitude agroecologies within central Uganda); and Sironko and Kapchorwa (representing the mid and high altitude agroecologies in eastern Uganda).

Site selection was followed by farmer selection. Usinga semi-structured questionnaire, interviews were conducted by key informants, researchers and the agricultural extension officers, to select two farmers per district to host the PVS trials.Similar to site selection, farmer selection was based on the presence of bean anthracnose disease on the farm.Other factors considered included land availability (at least 0.5 acres), willingness of the farmer to host the trial and accessibility of his/her farm toother farmers.

Trial design

Owing to the initial large number of bean lines (54) and limited amount of seed, and land, bean lines were not replicated within site but eachsite was considered a replicate. Each of the 54 lines was planted in two, one meter rows at every site,in a randomised complete block design wheredifferent farmer sites were considered as blocks and replicates.

As the farmers made their selections, the number of bean lines reduced every season and plots for the subsequent trials were increased to 1 x 2 m (3rows per line), 3 x 4 m (7 rows per line) and eventually 10 x 10 m (21rows per line).

Throughout the trials of the bean lines, comparison was made with a local check variety (K132). The resulting data was analysed using ANOVA in GenStat statistical package (Genstat, 2011).

Variety selection procedures

At the different trial sites farmers were invited to evaluate and make selections from the different lines at pre-flowering, poding and harvesting. During the first season, farmers placed a lot of emphasis on adaptability of the different lines to their environments, the growth type and resistance to diseases especially bean anthracnose.

In subsequent seasons, selection was mainly focused on the seed colour, seed size, and yield potential. The farmers' criteria was used in selection and these were later recorded, identified and classified as growth habit, plant vigour, leafiness, disease resistance, number of pods per plant, time to maturity, number of seeds per pod,seed weight (per 100 seed), yield, seed colour, seed size, marketability and taste. Field days, which were meant to bring famers together to assess the pros and cons of different bean lines, were held in one central location per region. Field days were held at preliminary yield trials stage when the bean lines had been reduced to 14. Using the ribbon tagging technique, farmers were requested to make selection of five best and three least performing lines.

Each of the participants received a total of eight ribbons of which five were green and three were purple. Green ribbons were used to mark and identify preferred lines, while purple ribbons marked the least preferred lines. To verify the seed type, a few pods had been threshed before hand and put on a paper beside each plot.

The bean lines selected by farmers in each season were carried over and planted in the next season and those selected against were removed from the PVS trial but retained in the germplasm bank. For the progression of any single bean line to the next generation, data from the different locations were gathered, analysed and compared. Total number of positive selection for each variety was calculated by a generated formula;

Total number of positive selections per bean line variety = {(Percentage selections for/ [percentage selections for + percentage selections against])/total no. of selections}.

Any bean line that received less than 50% of the total selection was deselected. The lines that were selected or deselected in three or more sites were either advanced or discarded, respectively.

Results

Numbers and gender of participating farmers

A total of 313 farmers were involved in participatory variety selection of the new bean lines. However, the number of participants varied from site to site,with the highest number beingin the central agroecological zones of Wakiso and Masaka. With the exception of Mubende and Kapchorwa districts where the male to female ratio was almost one to one, the number of women participants was proportionally higher than that of men. Overall women accounted for 59.1% of all farmers that participated in the PVS trials (Table 1). A chi-square goodness of fit for the participating ratio of men to women was not significant (P=0.714) indicative of equal participation gender numbers.

Characteristics of bean lines introduced for PVS and selection criteria

The new lines introduced for PVS trials were classified into three categories based on growth habit, seed colour and seed size (Table 2). Of the three categories, results showed that farmers made preference for medium to large sized red speckled or mottled bean varieties of the type I & II growth habits (determinate bush).In the first season selection, results show that farmers placed more emphasis on growth type, where by majority of type III-IV lines were eliminated and by the end of the second season selection, all the bean lines with growth type III and IV had been selected against and eliminated from the PVS trials (Table 2). In subsequent seasons, other bean characteristics like seed colour and seed size were critical in selection of lines.We observed that red speckled/mottled and large to medium sized bean types were most preferred (Table 2).

Other sets of criteria used by famers to make selection of preferred bean lines are indicated in Table 3. Result here indicate that the majority of famers (95.5%) used seed colour as the most important criteria for making selection preferences followed by early maturity, marketability, seed size and yield at 94.5%, 93.5%, 92.5 and 90% respectively (Table 3). It was further noted that although female farmers were more interested in early maturing bean lines, the males were more interested in yield capacity and

Table 1. Number of farmersinvolved in the selection of preferred bean linesin districts where participatory variety selection trials were held

District	Number of participants Male	Female	Expected ratio (M:F)	Observed ratio	X^2	Total
Wakiso	18	34	1:1	0.53		52
Masaka	36	54	1:1	0.67		90
Mubende	30	37	1:1	0.81		67
Sironko	19	31	1:1	0.61		50
Kapchorwa	25	29	1:1	0.86		54
Total	128	185		0.69		313
Mean	26	37	-			63

Table 2. Characteristics of the 54 bean lines introduced to farmers and their selection by farmers

Character	Description	No.	Selections		
			1st	2nd	3rd
Growth type	Type I	24	16	12	6
	Type II	15	8	2	2
	Type III	9	4	-	-
	Type IV	6	2	-	-
Total		54	30	14	8
Seed colour	Red	10	6	2	-
	Black	4	-		-
	Maroon	5	3	1	-
	Purple	6	2	1	-
	Red speckled/mottled	16	13	12	8
	Brown	7	2	-	-
	Cream	6	4	-	-
Total		54	30	14	8
Seed size	Large	26	18	9	5
	Medium	15	8	5	3
	Small	13	5	-	-
Total		54	30	14	8

Table 3. Frequency (%) of selection criteria used in the selection process by gender

Selection criteria	Men	Women	Average	Rank
Growth habit	71	89	80	7
Plant vigour	30	62	46	11
Leafiness	8	26	17	13
Resistance to diseases	73	88	80.5	6
Pods per plant	70	89	79.5	8
Early maturity	89	100	94.5	2
Seed per pod	46	68	57	10
Pod filling	32	43	37.5	12
Seed weight	75	84	79.5	8
Yield	100	80	90	5
Seed colour	93	98	95.5	1
Seed size	96	89	92.5	4
Marketability	100	87	93.5	3

marketability. In total, 13 selection criteria were utilised (Table 3). A Kendall's rank correlation coefficient for selection criteria used by famers indicated that nearly that most selection criteria were directly related as shown in Table 4.

Farmer field days

The results of the combined field day PVS exercises conducted in the different agroecologies where a total of 118 farmers of whom 64.4% were female, are shown in Table 4. Results from the selection exercise indicated that farmers preferred bean lines NARBL 114, 60 and NARBL 253 with total positive selection of 1503, 1464 and 1441 respectively of the total possible positive selections of 2950, and the least preferred lines as NARBL 210-1, 244-2 and NARBL 46-1 (Table 5). Chi-square tests on the selection ratios were obtained for all selection made for the different bean lines. Results showed that some bean lines were significantly more preferred (P>0.001) and as such selected for more often than others (Table 5).

Results shown in Figure 2 were obtained using the ribbon techniques to make selection. Figure 2 also indicate the yield performance of the different NARBL lines. The mean yield of all bean lines ranged from 1,005 to 2,085 kg ha^{-1}. All except two bean lines (NARBL 42 and NARBL 224-2) performed significantly better ($P \leq 0.05$) than the local check. Although bean lines NARBL 220, NARBL 122-1 and 69-1 yielded significantly higher ($P \leq 0.05$) than the other bean lines, farmer selection preferences were significantly higher ($P \leq 0.05$) for bean lines NARBL 114, NARBL 60, 110-2 and NARBL 253.

Selected varieties

The characteristics of the bean lines that were selected included those that had seed

Table 4. Kendall's rank correlation coefficient for selection criteria used by famers

	Growth habit	Leafiness	Market ability	Plant vigour	Pod filling	Pods per plant	Resis-tance to diseases	Seed colour	Seed per pod	Seed size	Seed weight	Yield
Growth habit	1											
Leafiness	1	1										
Marketability	-1	-1	1									
Plant vigour	1	1	-1	1								
Pod filling	1	1	-1	1	1							
Pods per plant	1	1	-1	1	1	1						
Resistance to diseases	1	1	-1	1	1	1	1					
Seed colour	1	1	-1	1	1	1	1	1				
Seed per pod	1	1	-1	1	1	1	1	1	1			
Seed size	-1	-1	1	-1	-1	-1	-1	-1	-1	1		
Seed weight	1	1	-1	1	1	1	1	1	1	-1	1	
Yield	-1	-1	1	-1	-1	-1	-1	-1	-1	1	-1	1

Table 5. Participatory variety selection exercises conducted on different on-farm fields fitted on a 1:1 selection ratio

NARBL line	Farmer selections (observed)		Total number of positive selection	Farmer selections (fitted)		X^2	Rank
	For (green)	Against (Purple)		For	Against		
252	92	19	1414	62.0	49.0	5.93*	5
69-1	89	44	1141	74.3	58.7	2.68	7
42	40	73	606	63.1	49.9	4.53	9
114	98	13	1503	62.0	49.0	7.12*	1
60	107	18	1464	69.8	55.2	6.96*	2
30-1	31	71	523	57.0	45.1	5.34	10
110-2	89	18	1424	59.7	47.3	5.88*	4
122-1	76	58	971	74.8	59.2	0.21	8
210-1	15	90	244	58.6	46.4	8.84*	14
244-2	19	92	292	62.0	49.0	8.49*	13
220	87	23	1349	61.4	48.6	5.08	6
253	98	18	1441	64.8	51.2	6.44*	3
46-1	20	89	313	60.9	48.1	8.14*	12
50-1	28	78	451	59.2	46.8	6.3*	11
Local check	63	49	960	62.5	49.5	0.09	9

*Significant at $P < 0.001$; Critical X^2 2.82Total positive selection =(No. of participating famers x total number of green ribbons per farmer x number of location)

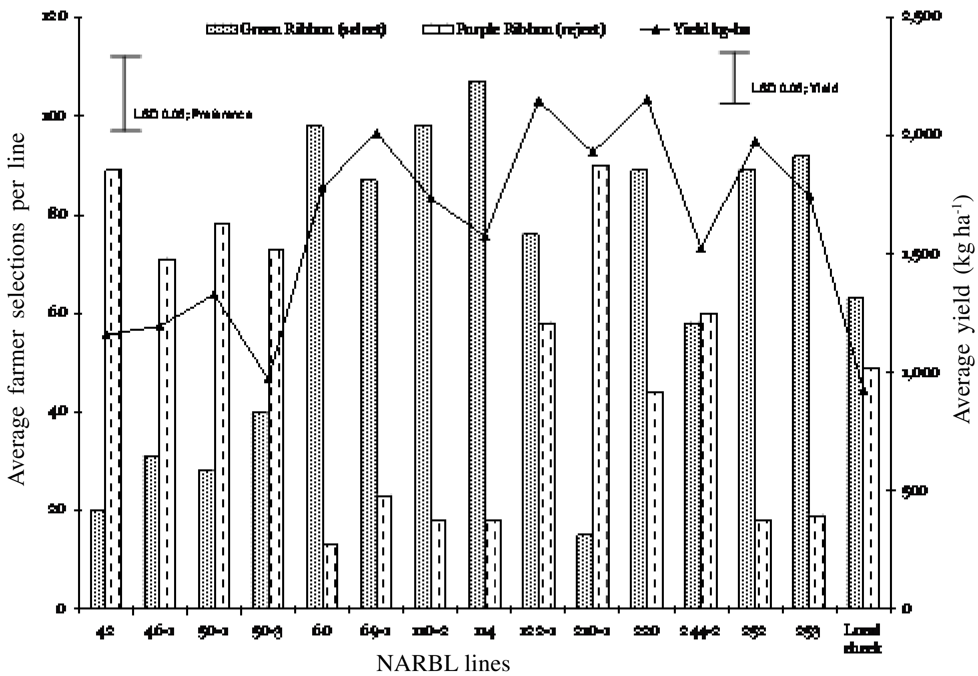

Figure 2. Selections made on 14 NARBL lines in four agroecological zones.

size ranging between 31-60 g/100 seed weight, with most of the seeds being either red mottled/speckled or of tancolour. The physiological maturity of the lines was between 58-70 days and yield ranging from 1500-2500 kg/ha (Table 6).

Discussion

Our study showed that the involvement of farmers in variety selection is critical in changing their perception about new varieties. Participatory variety selection also enables farmers to acquire skills in formal breeding processes, good production practices, farmer-held diversity and seed processes. The fact that the on-farm participatory variety selection trials were dominated by female farmers was expected,given that similar studies conducted in other parts of the world reported the same (Baidu-Forson, 1997; Mekbib, 1997; Almekinders *et al.*, 2007).This confirms the notion that the bean is majorly a women's crop. Common bean being a food security crop in Uganda, the higher numbers of female farmers involved in bean production, compared to their male counterparts is not surprising, because women are known to be responsible for the welfare and food security of a household (Rubyogo *et al.*, 2007). Thus, any new technology on bean production is often of interest to them.

Several varieties have been developed by research institutions but their adoption and utilisation are restricted because farmers continue to prefer their indigenous varieties (David, 1997). As such, farmers often use their seed for starting a new crop, yet bean yields are greatly affected by the type and source of planting materials. Not long ago, new varieties released to famers were selected based on the perception of the farmers' needs

Table 6. Characteristics of new lines selected for release

Bean Lines	Weight g 100^{-1} seed	Seed colour	Flower colour	Growth habit	Number of days		Potential yield (kg ha^{-1})
					Flowering	Maturity	
NARBL 60	33	Tan	Light purple	Type I	32	58	2000-2500
NARBL 69-1	31	Red mottled	white	Type II	37	70	1500-1800
NARBL 110-2	49	Purple speckled	Purple	Type I	34	63	1500-2000
NARBL 114*	37	Tan	Purple	Type I	32	58	1500-1800
NARBL 122-1	60	Red mottled	White	Type I	34	63	2500-3000
NARBL 220	46	Red mottled	White	Type II	32	58	2000-2500
NARBL 252	51	Tan	Light purple	Type I	37	60	2000-2500
NARBL 253*	48	Red mottled	Purple	Type II	32	58	1500-2000

*Released as new varieties (NARBL 114= NABE 15 and NARBL 253 =NABE 16) by researchers. However, researchers are increasingly recognising the importance of involving farmers in the selection of superior lines to be released as new varieties.

The current study was initiated to evaluate participatory plant breeding in bean improvement, with the ultimate goal of disseminating acceptable and productive bean varieties to resource poor farmers. Our results for PVS showed that farmers are capable of making significant contributions to the identification and development of superior cultivars within a relatively short period of time.Despite the complexity of individual preferences and production conditions, farmers effectively evaluated and selected from 54 bean lines using 14 distinct selection criteria.However, it was noted that certain key characteristics were considered key in line selection. These included growth habit, seed colour, earliness, marketability, seed size and yield. This criteria differ from that of scientist who normally consider resistance to biotic and abiotic stresses like diseases, pest, drought low soil fertility and yield as most important traits while making selection for new variety release (Singh, 1992).

Conclusions

Although yield is considered crucial for crop productivity and profitability to farmers, it is secondary to characteristics such as seed colour, seed size and time to maturity.We also observed that bean lines or traits used to make selections were gender sensitive. While female farmer made selections targeting household consumption needs, male farmers' selectionswere based on marketable qualities of bean lines. It is therefore, important to involve farmers in the varietal selection process for such information to be obtained.

Based on the outcome of the PVS trials, two varieties (NARBL 114 and NARBL 253) have been released and are a testimony that plant breeding and PVS are able to meet farmers' variety adoption requirements.Participatory variety selection allowed for the integration of farmers' indigenous knowledge with modern science to identify bean lines with characteristics ideal for consumption and market. Due to this, PVS interventions, it is speculated that variety adoption will be high resulting into increased productivitywhich will eventually translate into food security, increased household income and ultimately into improved livelihoods.

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