International Scholars Journals

African Journal of Tropical Agriculture ISSN 2375-091X Vol. 4 (2), pp. 001-008, February, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Farmer evaluation of improved soybean varieties being screened in five locations in Kenya: Implications for research and development

Jonas Chianu[1*], Bernard Vanlauwe[1], John Mukalama[1], Akin Adesina[2], Nteranya Sanginga[1]

[1]Tropical Soil Biology and Fertility institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Nairobi, Kenya.

[2]Rockefeller Foundation, Nairobi, Kenya

Accepted 10 November, 2015

In order to determine the improved soybean varieties that if recommended to the farmers would have a high probability of adoption, a farmer participatory approach was used to evaluate 12 soybean varieties at full podding in five locations (Oyani, Riana, Kasewe, Akiites, and Mabole) in western Kenya. These comprised of 11 improved varieties (TGx1871-12E, TGx1895-4F, TGx1895-33F, TGx1895-49F, TGx1878-7E, TGx1893-7F, TGx1893-10F, TGx1740-2F, TGx1448- 2E, NAMSOY 4m, and MAKSOY 1n) and one local variety (Nyala). Farmers generated all the 17 criteria for use in the evaluation, with researchers only facilitating. One hundred and two farmers (52% females) participated in the evaluation. A scoring matrix was employed to articulate the results. Data analysis was done using Microsoft Excel. This paper shows that of the seven dual-purpose varieties tested in all the five locations, only TGx1740-2F was acceptable in all. Some varieties were acceptable in specific locations: TGx1895-49F in *Oyani*, Nyala in Kasewe, TGx1448-2E in Akiites, and TGx1893- 7F in Mabole. This result shows that to avoid low adoption, a blanket recommendation of varieties that were accepted only in selected locations must be avoided. TGx1740-2F was the only variety that could be recommended across locations and that was clearly better than the existing farmers' own variety, Nyala.

Key Words: Adoption, Effective recommendations, Improved soybean varieties, Participatory farmer evaluation, Western Kenya.

INTRODUCTION

Several instances exist where huge investments have been made to develop improved agricultural technologies that were not eventually adopted by the target population (Emad, 1995; Becker et al., 1995; Kormawa et al., 1999). Many such situations have often been associated with technologies developed using the top-bottom approach, characterized by the involvement of the target population only when the development of the technology has been finalized by scientists and would not normally involve the farmers. Many a time, the reasons for lack of adoption of the lone developed technologies by the scientists border on lack of fit into the resources (land, labor, capital, management, etc.) available to the target population and the failure to take into account the local experience and needs of the target population (Warren, 1991). Such technologies are therefore inappropriate. Sometimes, the reasons for lack of adoption are related to issues of perception among the target population. This explains the limited farmer adoption of technologies derived from on-station research (Wortmann, 1992; Giller et al., 1994; Becker et al., 1995).

Donor agencies are more likely to support research agenda that would likely lead to the development and recommendation of improved agricultural technologies that have high probabilities of adoption and often support research and development efforts that employ farmer participa-

*Corresponding author's Email: j.chianu@cgiar.org, Tel: +(254 20) 7224778; Fax: +(254 20) 7224764/3.

tory approaches in technology development. The emphasis in farmer participatory research is to enable farmers to make their own analysis and decisions based on their own perceptions and criteria. The assumption is that since such an approach implies that farmers participate in all aspects of the technological development (as important partners to scientists) and that researchers evaluate alternative technologies from the farmers' point of view, the technologies recommended would have higher chances of widespread adoption (Johnson et al., 2003). It is also important that the participatory approach also includes a double feedback: from the farmers to researchers and from the researchers to the farmers. This is because, in several cases the farmers' point of view is influenced by education and tradition which could orient them towards some criteria that are not always relevant. In such situations, the role of the researchers is to try to improve the specific knowledge of farmers.

Participatory techniques reveal selection criteria for new technologies, preferences for established technologies, and constraints. A review of soil fertility research in Africa blamed lack of farmer adoption of improved soil fertility management technologies on poor farmer participation in their development and on poor representation of farmers' conditions while developing the technologies (Bekunda and Bationo, 1997; Barrios et al., 2006). The importance of farmer participatory research in reorienting technology development, accelerating adoption and creating wider impacts in smallholder farming has also been documented by Pretty and Hine (2001) and Johnson et al. (2003).

The objective of this paper is to demonstrate the usefulness of farmer participatory research in the evaluation of nine improved dual-purpose soybean varieties (TGx1871-12E, TGx1895-4F, TGx1895-33F, TGx1895-49F, TGx1878-7E, TGx1893-7F, TGx1893-10F, TGx1740- 2F, and TGx1448-2E, NAMSOY 4m, and MAKSOY 1n) obtained from the International Institute of Tropical Agriculture (IITA) in Nigeria, two improved varieties (NAMSOY 4m and MAKSOY 1m) obtained from Uganda, and Nyala, a local check (since it is the variety that is already being grown by some farmers in Kenya) at full podding stage in western Kenya. The paper would lead to the knowledge of soybean varieties that need to be further tested, multiplied, and extended to the farmers.

The farmer evaluation study is a way of identifying and characterizing the different criteria that farmers would want to use in choosing from among the varieties of soybean screened in various locations in western Kenya. Through this process, we aim at understanding where different improved soybean varieties aimed at addessing poverty, improved household nutrition, and alleviating soil fertility decline will best fit and avoid lack of adoption that usually accompany blanket recommendation of improved technologies that often results in abysmal rate of adoption.

MATERIALS AND METHODS

Study area

This study was conducted in five locations (Oyani, Migori district; Riana, Kisii district; Kasewe, Rachuonyo district; Akiites, Teso district; and Mabole, Butere-Mumias district) in western Kenya. Although these locations were also chosen because they have had some history of soybean activities, the major criteria were a large and representative agro-ecological spread. Riana and *Oyani* sites were included in order to evaluate the performance of the germplasm under high altitude (1500 to 2100 m.a.s.l for Riana and 1300 to 1800 m.a.s.l for Oyani) environments. The sites in Mabole and Akiites represent medium altitude (1270 to 1320 m a.s.l for Mabole and 1219 to 1295 m.a.s.l for Akiites) environments while the site in Kasewe represents a low-medium altitude (1000 to 1300 m a.s.l) environment (Jaetzold and Schmidt, 1982) . Average annual rainfall is ranging between 1200 to 2100 mm for Riana, 1400 and 1600 mm for Oyani, 1300 and 2000 mm for Mabole, 900 and 2000 mm for Akiites, and 1000 and 2200 mm for Kasewe (Jaetzold and Schmidt, 1982). The annual mean temperature is ranging between 16.2 and 20.5^{O}C for Riana, 20.5 and 21.7^{O}C for Oyani, 22 and 27^{O}C for Mabole, 21 and 22^{O}C for Akiites, and 20 and 21.5^{O}C for Kasewe (Jaetzold and Schmidt, 1982).

Evaluation approach

Farmers led all the major aspects of the evaluation reported in this paper. The exercise was based on farmer participatory research (FPR) methodology. FPR has been noted to offer alternative methods for developing technical options (Fischler and Wortmann, 1999). Several cases where technical options were successfully generated and adopted through involving farmers in the research process have been demonstrated (Fujisaka, 1989; Fernandez, 1991; Versteeg and Koudokpon, 1993).

Soybean varieties screened in different locations

Eight varieties (TGx1871-12E, TGx1895-33F, TGx1895-49F, TGx1893-7F, TGx1893-10F, TGx1740-2F, TGx1448-2E, and Nyala) were screened in all the five locations (Oyani in *Migori* district, Riana in *Kisii* district, Kasewe in *Rachuonyo* district, Akiites in *Teso* district, and Mabole in *Butere-Mumias* district). Two varieties (TGx1895-4F and TGx1878-7E) were exclusively screened in three locations (Oyani, Kasewe, and Mabole), while NAMSOY 4m and MAKSOY 1n varieties were screened only in two locations (Riana and Akiites).

Fertilization treatments for the screened soybean varieties

The above- mentioned soybean varieties were screened under three treatments: P (Phosphorus application), P + Lime, and P + Lime + Nitrogen while the control was no external input use. The design was a strip plot design with 3 replicates with variety as main factor and inputs as sub-factor. The inputs were: none; +P (40 kg P ha^{-1}); +lime (1 t ha^{-1}) + P; +N (90 kg N ha^{-1}, split applied) + lime + P (to establish the need for inoculation). Lime was applied before planting. P was applied at planting. N was split applied– at planting and during top dressing. The fertilization treatments were applied at all the five sites (Oyani, Riana, Kasewe, Akiites, and Mabole). The farmer participatory evaluation of the germplasm was, however, articulated across treatments.

Criteria Used In Germplasm Evaluation

In each location, the farmers discussed among themselves to generate all the criteria with which to evaluate the soybean varieties taking the following steps:

Initial observations

Farmers went round the plots, making observations with particular attention to the performance of each of the varieties under each treatment. During this step each farmer also took a count of the number of pods from four plants of each soybean variety.

Discussion to generate the evaluation criteria

Based on the observations made by the farmers, they discussed and came up with a set of criteria to use in evaluating the different soybean varieties. Overall, this resulted to 17 different criteria across the five locations. The criteria were number of pods, size of pods, number of seeds per pod, filling of pods, perception about yield, grain size, number of leaves, plant height, number of branches, size of leaves, maturity period, disease tolerance, ability to grow in low fertile soils, ability to adapt to local rainfall conditions, standability, color of leaves, and perception about cooking time. Although the dual-purpose soybean varieties screened has numerous attributes (including cash generation, soil fertility improvement through atmospheric nitrogen fixation, human and livestock health and nutrition, etc.), most of the criteria listed by farmers were related to grain and biomass production and agronomic traits, probably because it was a field evaluation.

In summary, although there are some differences in opinions, farmers generally prefer soybean varieties with more pods, larger sized pods, more seeds per pod, better filled pods, higher yielding, larger grains, more leaves, more branches, larger leaves, early maturing, more tolerant to diseases, higher ability to grow in low fertile soils, higher ability to adapt to local rainfall conditions, higher standability, and shorter cooking time. They showed mixed reactions with respect to plant height and color of leaves. While some farmers prefer tall varieties (associating it with more branches, more pods, and better ability to suppress weed), others prefer the short ones (associating it with the ability to fit into the intercropping system).

The development of the criteria for evaluating the improved soybean varieties was followed by a thorough explanation of the different criteria in local language to ensure that every participating farmer could differentiate one criterion from the others.

Development of matrix scoring procedure

The researchers helped to develop a matrix scoring procedure with the different varieties on the X-axis and the criteria on the Y-axis. This was initially developed on a flip chart and later multiplied on A4 paper to ensure that every participating farmer had one for own scoring.

Explanation of the matrix scoring procedure

Participants were given clear explanations about how, using each criterion, they could make the ranking of the soybean varieties. All explanations were given in *Kswahili* complemented by the local dialect of the people. Since, we screened ten varieties in each location, it was decided that for each criterion, the soybean variety that a farmer considers has the best attribute related to the criterion should be given the rank 10, the next variety should be ranked 9 and it continues in that order with the least evaluated with respect to a particular criterion being ranked 1. So, the ranking was done on criterion-by- criterion basis. For easy comprehension, each participating farmer, especially the less literate ones could also use 55 chips or stones (derived using the formula $\sum_{i=1}^{10} X_i$, where X_i represents the possible scores 1 to 10] in ranking the soybean varieties based on each criterion. Research assistants helped to translate the rankings by the less literate farmers into the scoring matrix used for collating the results of the exercise.

Practical scoring by the farmers

The purpose of this exercise was to give each participant in the evaluation the freedom to give his/her own vote by using his or her own judgment. Each participating farmer was given one of the matrix scoring procedure papers and a pencil to go ahead and make his/her rankings of the soybean varieties for each criterion. In addition to this, each farmer was expected to come up with his or her overall best three soybean varieties, putting all the criteria together. Farmers also ranked the treatments in two of the five locations (Riana and Kasewe). One hundred and two farmers participated in the matrix ranking exercise in all the five locations.

Matrix of criteria and improved soybean varieties

This matrix was developed with the criteria of interest to the farmers listed in the vertical axis and the soybean varieties listed along the horizontal axis. This was in preparation for the scoring of the soybean varieties on the basis of each criterion.

Researchers role in the evaluation

Researchers served as facilitators with the sole aim of letting all the decisions be those of the farmers. This is based on the realization that researchers posing, as “experts” dispensing packaged technical advice have not resulted in good adoption outcomes in the past. Besides, farmer participation in the green manure research resulted in efficient generation of green manure technology now being promoted in eastern and central Uganda (Fischler and Wortmann, 1999).

Data analysis

Data analysis was performed in Microsoft Excel. As a prelude to the calculation of the mean scores, the total scores were computed across all the participants using a particular criterion. The effective sample size (n) was determined and used to obtain the mean score. This ensures that the means obtained represent the averages across only the observations that actually participated in the scoring. This is important since some instances occurred where a farmer did not assign any rank to a particular variety when assigning ranks, based on a criterion. So, we determined the effective means of the rankings across the exact number of the respondents that participated in ranking each variety using each criterion. By visual inspection, we compared the mean scores of a particular criterion among the soybean varieties assigning new ranks (1 for the best improved soybean variety and 10 for the least).

Table 1. Distribution of participants by gender.

Location	Number of participants by gender[1]		
	Male	Female	Total
Oyani	4 (40)	6 (60)	10
Riana	16 (64)	9 (36)	25
Kasewe	14 (52)	13 (48)	27
Akiites	8 (80)	2 (20)	10
Mabole	7 (23)	23 (77)	30
Total	49 (48)	53 (52)	102

[1]Figures in parenthesis are percent values

Table 2. Criteria developed by farmers for evaluating the soybean varieties

Criteria	Location				
	Oyani	Riana	Kasewe	Akiites	Mabole
Grain yield-related criteria:					
Number of pods	X	X	X	X	X
Size of pods	X			X	X
Number of seeds per pod		X			
Filling of pods	X	X	X	X	
Perception about yield			X		
Grain size		X	X		
Non-grain biomass-related criteria:					
Number of leaves		X	X	X	X
Plant height	X	X		X	X
Number of branches	X				
Size of leaves	X				
Environmental adaptability-related criteria:					
Maturity period	X	X	X	X	X
Disease tolerance	X		X	X	
Ability to grow in low fertile soils		X			
Ability to adapt to local rainfall conditions		X			X
Standability		X		X	X
Farmers' perception-related criteria:					
Color of leaves	X				
Cooking time		X			
Total	**9**	**11**	**7**	**7**	**7**

X = Indicates the location where a particular criterion was listed

RESULTS AND DISCUSSION

Gender distribution of the farmers

Across the five locations, a total of 102 male and female farmers participated in the soybean evaluation. These comprised 52% female farmers and 48% male farmers – with female participation varying between 20% and 77% across the locations compared to male participation of between 23% and 80%. There was no attempt at balancing male and female participation since all farmers in the village where the experiment was located were encouraged to participate in the evaluation exercise. The

Table 3: The best soybean varieties (among the eight screened in all sites) based on farmers' evaluation

Rank	Oyani	Riana	Kasewe[1]	Akiites	Mabole	All locations[1]
First	TGx 1895-49F	TGx 1740-2F	NYALA	TGx 1448-2E	TGx 1893-7F	TGx 1740-2F
Second	TGx 1895-33F	NYALA	TGx 1740-2F	TGx 1740-2F	TGx 1740-2F	NYALA
Third	TGx 1740-2F	TGx 1895-33F	TGx 1893-7F	TGx 1895-49F	TGx 1871-12E	TGx 1893-7F
Fourth	TGx 1448-2E	TGx 1871-12E	-	TGx 1893-10F	NYALA	-

[1] - = Ranking was not extended to Fourth rank.

location specific distribution of the participants is presented in Table 1.

The evaluation criteria developed by the farmers

Across the five locations, farmers came up with a total of 17 criteria (nine in Oyani, 11 in Riana, seven in Kasewe, eight in Akiites, and seven in Mabole) with which they evaluated the improved soybean varieties screened (Table 2). Across gender and location, the most important criteria used in evaluating the improved soybean varieties were number of pods and the maturity period. The reason for preferring soybean varieties with large-sized grains was different between male and female farmers. Male farmers preferred soybean varieties with large-sized grains for trade and high market prices, while female farmers selected this character as perceived factor of fast cooking.

The criteria were classified into four groups (i) grain yield-related criteria (number of pods, size of pods, number of seeds per pod, filling of pods, perception about yield, and size of grain), (ii) non-grain biomass-related criteria (quantity of leaves, plant height, number of branches, and size of leaves), (iii) environmental adaptability-related criteria (maturity period, tolerance to disease, ability to perform well in low fertile soils, ability to perform well under limited rainfall situation or matching with the local environment, and standability), and (iv) farmers' perception-related criteria (color of leaves and fast cooking) . The last class 'farmers' perception-related criteria' was not encountered in Kasewe, Akiites, and Mabole.

Importance of the criteria

Depending on their frequency of mention, the different criteria were arranged in order of importance. The two most important were number of pods and maturity period. These were mentioned in all five (100%) locations (Table 2). Filling of pods, quantity of leaves, and plant height were mentioned in 80% of the locations. The other set of important criteria comprising size of pods, disease tolerance, and the standability were mentioned in 60% of the locations. Grain size and adaptability to rainfall conditions were mentioned in 40% of the locations. Seven of the criteria (number of seeds per pod, perception about yield, number of bran-ches, size of leaves, color of leaves, ability to grow in low fertile soils, and perception on the ability to cook fast) were less important because each of them was mentioned in only one (20%) of the locations.

New ranks of soybean varieties based on the mean scores

The results of the new ranks based on the mean scores of a particular criterion among the improved varieties of soybean were summarized in Table 3 for the eight soybean varieties (TGx 1871-12E, TGx 1895-33F, TGx 1895-49F, TGx 1893-7F, TGx 1893-10F, TGx 1740-2F, and TGx1448-2E and Nyala,) screened and evaluated in all the five locations. Of all these eight varieties, each one was among the best four ranked varieties in at least one of the locations. Further details are discussed below.

TGx 1740-2E was the only variety that was among the best ranked four varieties in each of the five locations. The outstanding characteristics of TGx 1740-2E included: large number of pods, large number of seeds per pod, early maturity, ability to adapt to local conditions, and perceived ease of cooking. This implies that TGx 1740-2E gives farmers greater flexibility in the use of their land and labor. TGx 1740-2E ranked first in Riana, second in Kasewe, Akiites, and Mabole, and third in Oyani. This implies that TGx 1740-2E was the most popular improved soybean variety among the farmers in western Kenya.

Nyala, the local check, followed in popularity and ranked first in Kasewe, second in Riana, and fourth in Mabole. TGx 1895- 49F and TGx 1893-7F exhibited similar ranking behaviors, having been ranked first (Oyani for TGx 1895-49F and Mabole for TGx 1893-7F) and third (Akiites for TGx 1895-49F and Kasewe for TGx 1893-7F) in two of the five locations each. TGx 1448-2E was among the best four soybean varieties in two of the five locations (Oyani and Akiites). It ranked first at Akiites and fourth at Oyani. TGx 1895-33F was among the best soybean varieties in two of the five locations, ranking second in Oyani and third in Riana. TGx 1871-12E was among the best varieties in two of the five locations, ranking third in Mabole and fourth in Riana. TGx 1895- 4F and TGx 1893-10F exhibited similar ranking behaviors. Both were among the best four varieties in only one each of the five locations. While TGx 1895- 4F ranked fourth in Kasewe, TGx 1893-10F ranked fourth in Akiites.

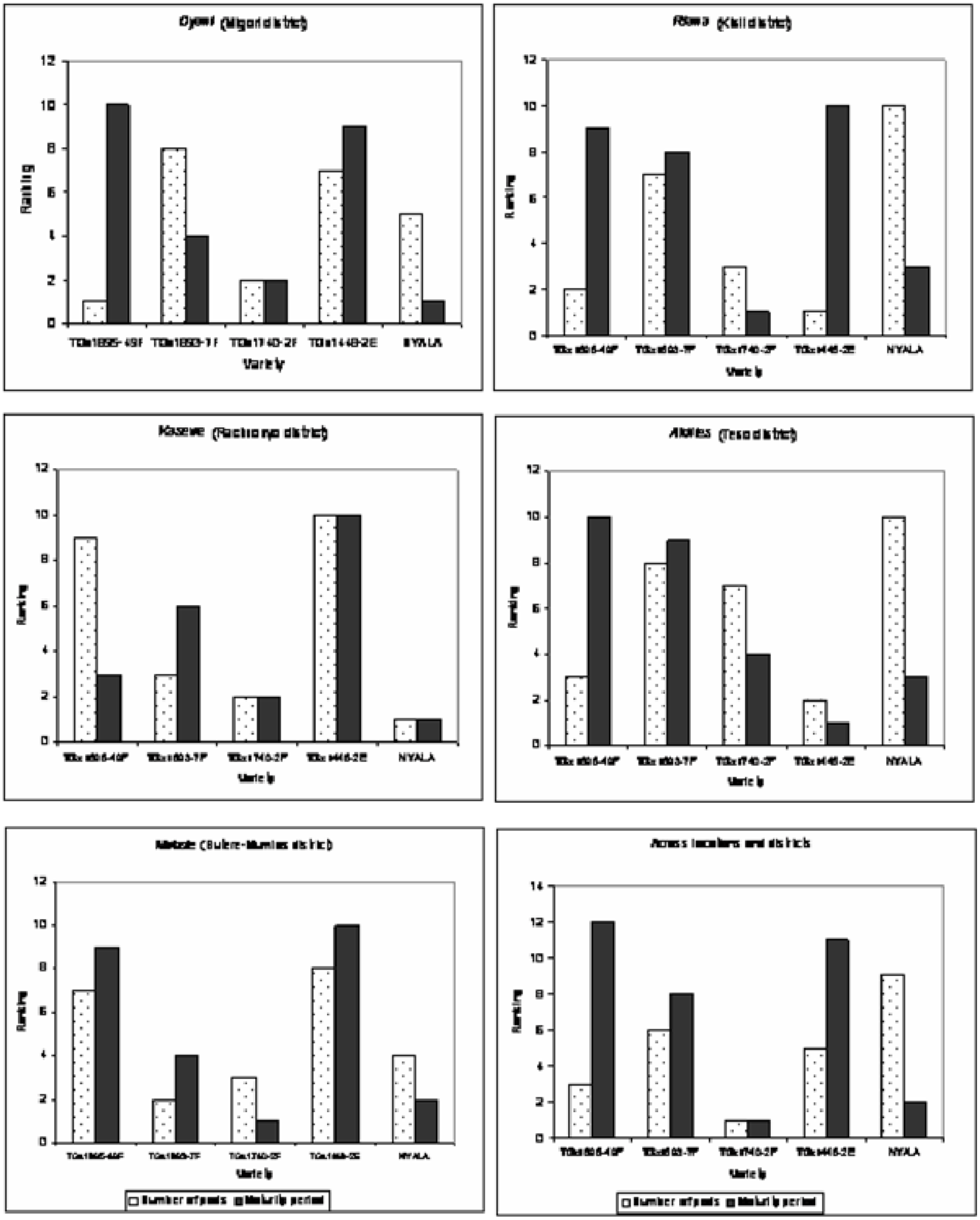

Figure 1. Farmers' mean ranking of the two most important criteria (number of pods and maturity period) among the major soybean varieties in Western Kenya

Ranking of number of pods and maturity period for first ranked soybean varieties

Number of pods and maturity period were the only two criteria for selecting soybean varieties that were considered in all the five locations. We assessed the relative importance of these criteria using the five soybean varieties that ranked first in at least one evaluation location. At evaluation location levels, the result seems to be mixed. However, the pooled data suggests that number of pods seems to be a more important criterion than maturity period (Figure 1). This underscores the importance of biological

Table 4. Overall best soybean varieties (including some varieties not tested in all the five locations) by location

Overall rank	Location				
	Oyani	Riana	Kasewe	Akiites	Mabole
First	TGx 1893-10F, TGx 1740-2F	TGx 1740-2F	Nyala	TGx 1448-2E	TGx 1740-2F
Second		Nyala	TGx 1740-2F	Maksoy 1n	Nyala
Third	Nyala	Namsoy 4m	TGx 1893-10F	TGx 1740-2F	TGX 1895-4F

Table 5. Farmers' opinions and ranking of the fertilization treatments and the control

	Based on crop performance		Based on practicality (what could afford and or do)	
Fertilization treatment*	Riana	Kasewe	Riana	Kasewe
Control	4	4	2	4
P	3	3	1	1
P + Lime	2	2	3	3
P + Lime + N	1	1	4	2

* P = Phosphorus, N = Nitrogen

gical yield much more than anything else when farmers are evaluating improved varieties of crops.

Farmers overall best varieties

This was based on the best three ranked by the participating farmers and on each farmer's overall best three soybean varieties (presumably putting all the criteria together). The result is presented in Table 4. This result once again brought out farmers' general preference for TGx 1740-2F over the other varieties. It ranked overall first choice in three locations (Oyani, Riana, and Mabole), second in one location (Kasewe), and third in one location (Akiites). The local check, Nyala, again came next to TGx 1740-2F, occupying first choice position in one location (Kasewe), second choice position in two locations (Riana and Mabole), and third choice position in one location (Oyani).

Farmers' ranking of the treatments

In addition to their practicality (what they think that they could afford and or do), farmers had observed the effects of various treatments (Phosphorus P, P + Lime, and P + Lime + Nitrogen N) and the Control (no external input) on crop performance. We evaluated their opinions about the treatments in two locations (Riana and Kasewe). While rank 1 stood for the most preferred treatment, rank 4 stood for the least preferred treatment. The result (Table 5) shows that with respect to crop performance, farmers in both Riana and Kase-we would go for P + Lime + N, P + lime, P, and Control in that order. However, with respect to affordability, farmers' first choice treatment was P in both Riana and Kasewe. The farmers in both locations differed in their second best treatment. While Riana farmers opted for the Control, those in Kasewe would go for P + Lime + N. The farmers in both locations converged again with respect to their third choice of treatment, opting for P + Lime. Finally, they differed again with respect to the last choice of treatment with Riana farmers opting for P + Lime + N and Kasewe farmers opting for the Control. We further investigated why in terms of practicality, farmers from Kasewe ranked P + Lime + N second. Their response reads 'although we knew that lime was not available, we felt that we could buy DAP fertilizer that contains both P and N'.

Conclusion

Since the final test of success is the acceptance of new crop varieties by producers, it is extremely important that in promoting soybean, research and development workers must pay attention to the needs and priorities of target communities. This paper has demonstrated that farmers can lead technology evaluation and determine their choices. Scientists must facilitate farmers to effectively evaluate and select technologies. To increase the probability of adoption, technology promotion must concentrate on the options selected by the farmers.

Among the soybean varieties evaluated in all the five locations, only one (TGx 1740-2F) was not only clearly better than the local check, Nyala, but also had a high approval rate in all locations. Other varieties were acceptable in specific niches and must only be recommended for cultivation in those niches for adoption and impact. A blanket recommendation of location-specific varieties risks low adoption and must be avoided. In choosing among treatments for on-farm research, it is extremely important that farmers' views are considered. The inclusion of treatments that are beyond the resource capacities of the farmers is of limited value since adoption will be hampered by lack of resources.

Much more than any other single criterion, the overall importance of yield-related criteria in influencing farmers' choice has been demonstrated by this result. Future evaluations must be planned to account for the performance of varieties around important growth phases (flowering, podding, and maturity). Such evaluations need to be extended to verify issues of allergy to soybean protein, taste and palatability with the involvement of multi-stakeholders.

ACKNOWLEDGEMENT

The authors thank the Rockefeller Foundation, Nairobi for its financial support for the study that led to this paper and the farmers that participated in the soybean evaluation.

REFERENCES

Barrios E, Delve RJ, Bekunda M, Mowo J, Agunda J, Ramisch J, Trejo MT, Thomas RJ (2006). Indicators of soil quality: A South-South development of a methodological guide for linking local and technical knowledge. Geoderma (in press).

Becker M, Ladha JK, Ali M (1995). Green manure technology: potential, usage, and limitations: A case study for lowland rice. Plant Soil 174: 181–194.

Bekunda M, Bationo A (1997). Soil fertility management in Africa: A review of selected research trials**.** In: Replenishing soil fertility in Africa. Eds. R.J. Buresh, P.A. Sanchez, and F. Calhoum.. SSSA Special publication Number 51. Madison, USA pp 63–79.

Emad A (1995). An assessment of the impact of agricultural technology on output in the rainfed farming areas in Jordan. Arbeiten zur Agrarwirtschaft in Entwictlunslanderern, Wissenschaftsverlag Vaul Kiel KG, Dissertation, veroffentlicht mit Genehmigung der Agrarwissenschaftlichen Fakultaet der Christian-Albrechts-Universitaet, Kiel, Germany.

Fernandez ME (1991). Participatory research with community-based farmers. *In* Joining Farmers' Experiments. Eds. B. Haverkort, J. van der Kamp and A. Waters-Bayer. pp 77–92. Intermediate Technology Publication, London, UK.

Fischler M, Wortmann CS (1999). Green manures for maize-bean systems in eastern Uganda: Agronomic performance and farmers' perceptions'. Agrof. Systems 47: 123–138.

Fujisaka S (1989). A method for farmer-participatory research and technology transfer: upland soil conservation in the Philippines. Exp. Agric. 25: 423–433.

Giller KE, McDonagh JF, Cadisch G (1994). Can biological nitrogen fixation sustain agriculture in the tropics? In Soil Science and Sustainable Land Management in the Tropics. Eds. J.K. Syers and D.L. Dimmer.. University of Newcastle upon Tyne, UK. pp 173–191

Jaetzold R, Schmidt H (1982). Farm management handbook of Kenya Vol. II – Natural conditions and farm management information – Part A West Kenya (Nyanza and Western Provinces). Ministry of Agriculture, Kenya, in Cooperation with the German Agricultural Team (GAT) of the German Agency for Technical Cooperation (GTZ). p.397

Johnson N, Lilja N, Ashby J (2003). Measuring the impact of user participation in agricultural and natural resource management research. Agric. Syst. 78: 287–306.

Kormawa PM, Kamara AY, Jutzi SC, Sanginga N (1999). Economic evaluation of using mulch from multipurpose trees in maize-based production systems in south-western Nigeria. Exp.Agric. 35: 101–109.

Pretty J, Hine R (2001). Reducing food poverty with sustainable agriculture: a summary of new evidence. Final report from the SAFE-World Research Project. University of Essex, Cochester, UK.

Versteeg MN, Koudokpon V (1993). Participative farmer testing of four low external input technologies to address soil fertility decline in Mono Province (Benin). Agric. Syst. 42: 265–276

Warren DM (1991). Using indigenous knowledge in agricultural development. Discussion Paper, vol. 127. The World Bank, Washington DC.

Wortmann CS (1992). Agriculture technology evaluation – some considerations. In: Proceedings of a Working Group Meeting on Soil Fertility Research for Maize and Bean Production Systems of the Eastern Africa Highlands. 1 – 4 September, Thika, Kenya. pp 49–58

.