Participatory Evaluation of Common Bean for Drought and Disease Resilience Traits in Uganda

Working Paper No. 143

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Photos: CIAT-PABRA, Nkalubo S, Mukankusi C

Summary

The use of genetic resources to respond to occurring and unpredictable climatic changes is one of the coping mechanisms for small scale farmers in Africa. This paper summarizes findings of a participatory action research (PAR) project evaluating different common bean (*Phaseolus vulgaris*) varieties with nine farmer groups across nine villages in two CCAFS sites of Rakai and Hoima districts in Uganda. Six and fifteen bean varieties including local landraces, farmer variety (commonly grown by farmers), Uganda officially released varieties and new germplasm bearing different characteristics were evaluated with over 300 farmers in replicated trials in the first season of 2012, and two seasons of 2013, respectively. Mother-baby trials involving one mother trial and five baby trials were established per village (nine mother trials and 45 baby trials in total) in 2013, while nine mother trials were established in 2012. The effects of DAP fertiliser on variety performance was assessed in the 2013 trials. Mother trials were hosted by one farmer per location identified by members of the group. Data was collected on major agronomic parameters, pests and diseases. In total, 320 farmers participated in the trial evaluations across the two districts (56% of which were females) during the project life line, with two hundred (60% female) being consistent participants through-out the project cycle. The participatory evaluations and selection were conducted using the card method with follow up discussions. The performance of each variety was assessed based on a number of parameters that included days to 50% flowering, days to maturity, plant height, number of pods per plant, disease incidence and severity, and total and clean yield.

The evaluations showed significant statistical differences (p=0.05) in agronomic parameters, diseases resistance and yield among the varieties over the different environments. Five mega environments characterised by similarity in clean yield performance were identified. The ordering of the environments into mega environments implies similarities between them, where similar technologies may be promoted. In general, the test varieties significantly outperformed the local varieties, though the local landrace *Masindi yellow* was both stable and high performing, maintaining very good yields across all the sites proving to be widely adapted even though it was the most susceptible to the occurring disease. None of varieties

performed highly in more than one mega environment, with the best performing varieties being; *NABE2, RWR719, NABE21* and *NABE14* with *NABE2* being the most superior, performing well under both drought and high rainfall conditions. However, *NABE2* was not preferred by farmers due to its black small seeds. The *CAL143, NABE17* and *Masindi yellow* varieties were the most stable with consistent performance, while *RWR719, KATB1* and *NABE15* were the least stable. Results of the baby trials indicated high climatic, edaphic and crop management differences within very small physical areas (e.g. within a village) and reinforced each other to determine variations in crop yield at plot level. Improper spacing was highlighted as a major challenge in closing the common bean yield gap as the results of this study showed that farmers used varying planting methods leading to either low or higher seed rates and hence resulting into poor land utilization and low yields. Also land utilisation was tagged towards market availability, with more market oriented farmers having better land utilisation compared to other farmers.

Marketability (based on seed size and colour), yield and adaptability were the major drivers for farmer selection. In general, farmers in Hoima tended to be more market oriented than farmers in Rakai hence better management practices were observed in baby trials in Hoima. Despite high climatic variability and hence risks, bean farmers demonstrate high preferences for marketability of their beans, implying that the magnitude of allowable trade-offs between market and adaptability are small. Women farmers, however, were found to be more inclined to make trade-offs between climate adaptability and marketability. The findings also indicate that diversified cropping systems do stand a better chance in the face of the changing climatic conditions as there is a buffering effect when there is failure of a component of the system. Possible hindrances to achieving yield potential of improved varieties on-farm included poor or lack of weeding and large plant spacing.

Farmers' variety was ranked relatively higher by farmers compared to some of the improved varieties, an important lesson for breeders working to enhance the adaptation of crop varieties to climate change. The study provides evidence that breeders and farmers look out for similar traits, with yield being the major driver, and in most cases end up with the same results with a few discrepancies. Some key lessons emerged from the findings. First, making blanket variety and management recommendations to cover large physical areas is erroneous. Site and context specific recommendations, especially in the view of the variability in climatic

conditions and soils are probably the best option. Second, the results highlight the need for plasticity in bean varieties (i.e. ability to change structure and function when exposed to changes in the environments hence suitability to a wide range of environments) in addition to having farmer preferred traits. Lastly, the project also highlighted the ability, capacity and willingness of farmers to adopt and adapt new technologies in the face of varying climate scenarios.

Keywords:
Common bean; climate change and variability; farmer variety evaluation; genotype by environment interaction.

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Contents

Acronyms

ALS	Angular Leaf Spot
AMMI	Additive Main Effects Multiplicative Interactions
BSM	Bean Stem Maggot
CBB	Common Bacterial Blight
FW	Finlay Wilkinson Model
GXE	Genotype x Environment Interaction
NAADS	National Agricultural Advisory Services
NaCRRI	National Crops Resources Research Institute
NARO	National Agricultural Research Organisation
NGO	Non-Governmental Organisations
PABRA	Pan Africa Bean Research Alliance
PAR	Participatory Action Research
PVS	Participatory Variety Selection
RCBD	Randomised Complete Block Design

1. Introduction

Common beans, grown on more than 6.3 million ha annually (FAO 2013) and consumed and traded by more than 100 million households, are vital to Africa's struggle in achieving the Millennium Development Goal (MDG) targets of reducing poverty and hunger. Beans provide an inexpensive source of protein for rural and urban households, especially in Eastern and Southern Africa. However, production is greatly curtailed by several environmental stresses notably, drought, excessive rain, flooding, heat, and cold temperatures as well as biotic constraints that include field and post-harvest pests and diseases. These problems are predicted to increase as climatic conditions change and become increasingly variable (Christensen et al. 2007, Beebe et al. 2012). Although research has developed improved germplasm capable of averting some of these climatic related constraints, only about 25.3% of the farming households in Uganda were found to grow at least two of the improved varieties developed by the Ugandan bean breeding program (Larochelle et al. 2013). Low adoption of improved varieties is partly attributed to their low adaptability to the multi-stress conditions prevailing in the farmers' fields in addition to the poor undeveloped seed system in the country.

Managing risks related to climate variability is fundamental to a complete strategy for adapting agriculture and food systems to a changing climate. Common beans (Phaseolus vulgaris L.) are system based, often grown in association with other crops and hence a good entry point for interventions seeking to help communities adapt to climate change. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in collaboration with the International Center for Tropical agriculture (CIAT) and National Crops Resources Research Institute (NaCRRI), Uganda bean program through the Pan African Bean Research Alliance (PABRA) carried out a study to identify and test innovations in partnership with rural communities that enable them to better manage climate-related risks and build more resilient livelihoods. The overall objective of the study was to contribute to adaptation to immediate climate change related stresses by building on farmers' functional coping strategies, and introducing novel elements which can help spur greater system resilience with common bean as the driver. Growing climate resilient crop varieties and increasing the crop and variety diversification is among the coping strategies farmers use to deal with climate variability. The study was conducted in two CCAFS sites of Hoima and Rakai. The specific objectives were as follows:

- Establish the factors influencing bean productivity in the two sites of Hoima and Rakai;
- Test Genotype by Environment (GX E) interactions as a model for breeders to make variety recommendations in the face of climate change and climate variability;
- Understand farmers preferred varieties, their selection criteria and examine sources of heterogeneity under climatic variability;
- Compare selection criteria used by farmers and breeders to determine where there is converge or divergence and its implications for adaptation to climate change;
- Introduce and promote bean diversity as a way of coping with climate variability and change.

2. Materials and methods

2.1 Study sites

The CCAFS sites of Hoima in the Albertine Rift and Rakai in the Kagera basin (Figure 1) represent areas that are becoming both drier and wetter, and are focal locations where participatory action research (PAR) efforts are expected to generate results that can be applied and adapted to other similar regions worldwide. Both sites are characterized by highly degraded landscapes, decreasing soil fertility, increasing rainfall variability, drought and excessive rainfall with negative impacts on crop and livestock. Information from previous CCAFS East Africa project reports (Kristjanson et al. 2010, Kyazze and Kristjanson 2011, Kristjanson et al. 2012a) were used to identify and contact a number of stakeholders for collaboration through phone calls and a familiarisation visit by the project team. Through these avenues, consultations with opinion leaders that included sub-county chiefs, local government staff, and local council community leaders led to the selection of the relevant partners and facilitators to be engaged in the study. From the consultations, nine farmer groups were selected to implement the project. Inception workshops of the partners, facilitators and opinion leaders were organized, where the project objectives, design and expected outcome were refined as a means of gaining a common understanding among all players. A total of 65 participants from the two sites participated in these workshops and included representatives of the nine selected farmers groups, parish chiefs, district representatives, NAADS representatives, local council officials, community development officers and technocrats (extension workers, NGOs).

2.2 Partners and their roles

To kick start the project, four groups of partners that were key to the success of the project were selected. They included researchers, farmer groups, focal government officers and community development workers. Their roles were defined and agreed upon as summarised below:

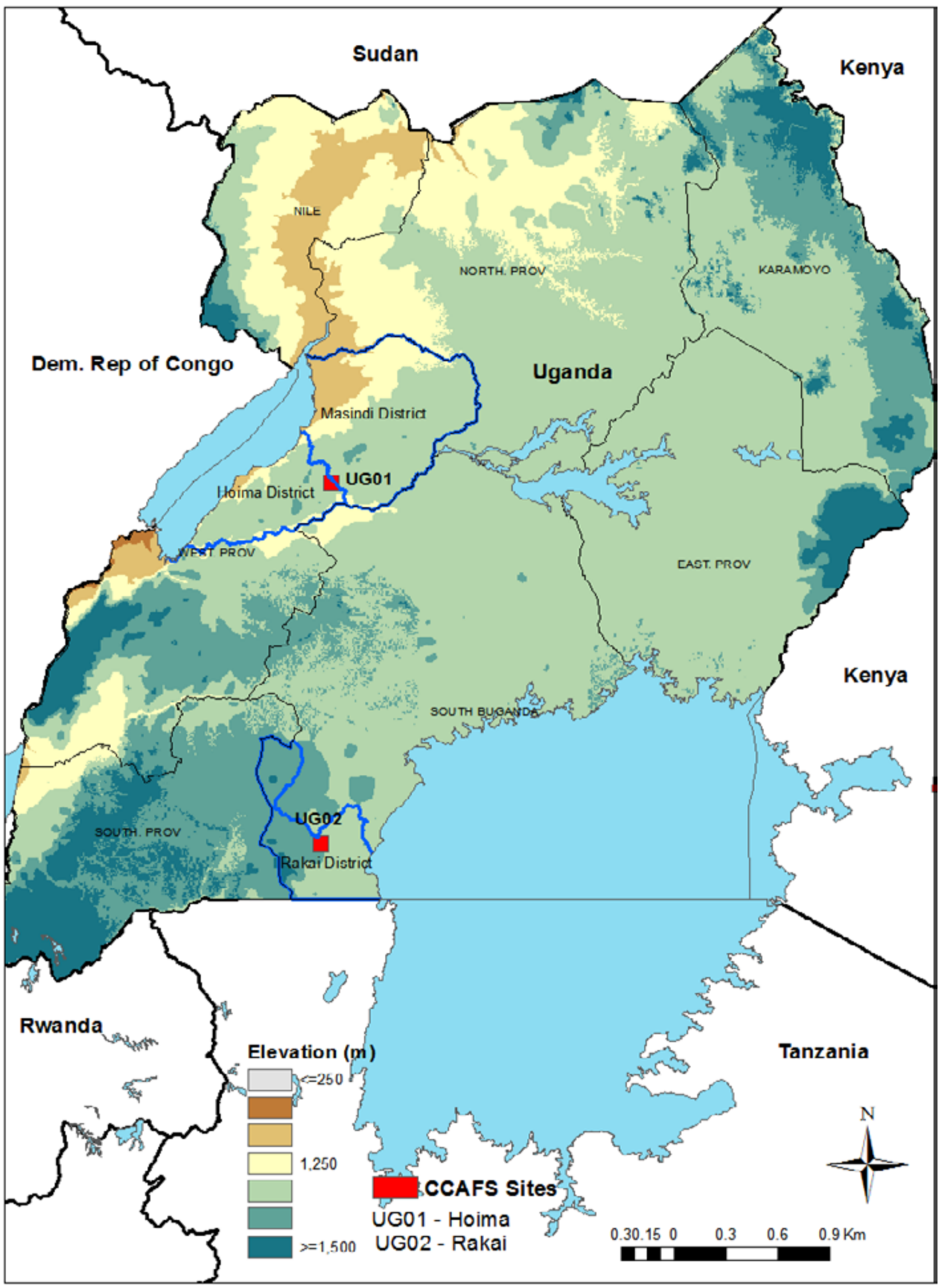
Researchers: Included scientists from CIAT and NARO-NaCRRI to provide seeds for the trials; train farmers in bean crop management; guide farmers in trial layout and planting; provide simple farm implements and inputs for the trials (e.g. rain gauge, paper bags, plot labels and other inputs necessary for the success of the trial); coordinate the project activities with different stakeholders; provide technical backstopping; conduct soil assessment and analysis: undertake data collection and documentation; design farmer participatory variety selection protocols to ensure rigour; analysis of results; report writing; and giving feed-back to farmers.

Farmer groups: Provide and prepare land for the trials; plant the seeds; provide general crop management (i.e. weeding, pesticide use, and roguing); and keep records of rainfall patterns and any activity done on the trials, including performance of the individual varieties (i.e. germination date, days to 50% flowering, days to 50% physiological maturity). Farmer groups were also responsible for selecting their preferred varieties during the participatory variety selection (PVS) sessions, mobilizing communities to participate in project activities, and identifying host farmers and assessing seed after harvesting (cooking time, taste and others).

Local government leaders and councillors: Mobilize and motivate farmers to participate in project activities, provide any assistance as the sub-county budget may allow, overseeing the project, physical participation and evaluation of the project.

Community development officer, extension workers and NGOs: Provide technical advice on crop production, harmonize groups to work together, monitor project activities, mobilize farmers to engage in the project and link the project with the different stakeholders.

Figure 1. CCAFS study sites in Uganda



Source: CCAFS East Africa

2.3 Trial sites and selection of host farmers

The project was implemented in two phases with nine farmer groups selected from two sub counties: Lwanda and Kasaali in Rakai, and Kyabigambire and Kiziranfumbi sub counties in Hoima with each hosting a trial (Table 1).

Table 1. Farmer groups used in the study

District	Sub-county	Village	Name of farmer group*
Hoima	Kyabigambire	Kikira Ngobya	Akumurukire
Hoima	Kyabigambire	Kyakamese	Kakindo Sustainable Agriculture
Hoima	Kyabigambire	Mpalangasi	Kyamaleera
Hoima	Kiziranfumbi	Butimba	Butimba
Hoima	Kiziranfumbi	Butyamba	Katweyambe Butyamba
Rakai	Lwanda	Gosola	Kiyovu
Rakai	Lwanda	Kyegenza	Kyengeza Twezimbe
Rakai	Kasaali	Ninzi	Agaliawamu Ninzi
Rakai	Kasaali	Kalagala	Kwewayo

Host farmers were selected by farmer group members throughout the project life. Baby trials were conducted and hosted by farmers that did not belong to any farmer group to allow more in-depth discussions between gender groups and avoid bias in perceptions and help to expand the project activities to more communities within the two CCAFS sites. Each group hosting a mother garden identified five farmers' preferably non-group members to host the baby trials within the sub-county making a total of 45 baby trials across the two districts. Planting was done by farmers together with the research team.

2.4 Bean varieties evaluated

In Phase 1, the project focused on drought as a pre-determined climate-related constraint, hence five drought tolerant varieties: *KATB1, KATB9, KATX69, KATX56* (released in Kenya) and *NABE15* (released in Uganda) were evaluated against a farmer selected variety as a local check for one cropping season (2012a-first season; March-June). These varieties all possessed characteristics preferred by Ugandan farmers, with seed colours of red, red mottled and yellow, medium to large seed size, early maturing (65 days), high yielding, fast cooking, swelling up to three times when cooked, sweet taste and gentle on stomach (no gas). The farmer varieties were selected depending on what was prominently being grown by the farmers in a particular area and included i) *Masindi Yellow* - a local landrace, ii) *Nambale Omumpi* also known as *Kaduli* but released as *NABE1*, iii) *Nambale Omunene* (released as *K132*), iv) *Roba-1* which is not released but was introduced by the National Bean program through PVS trials, and v) *Nambale Omutono* released as *K20* (http://database.pabra-africa.org/).

Results from Phase 1 showed that apart from drought, many other constraints such as poor soils, intermittent spells of dry and wet weather, excessive rainfall, pests and diseases affect common bean productivity across the two sites. Therefore, evaluation of a more diversified group of varieties was necessary. Phase 1 also highlighted the existence of high climatic, edaphic and crop management variations within very small physical areas (e.g. within a village) that would require a diversity of varieties. Also, farmers involved in Phase 1 were group members who had self-selected themselves into groups and were nearly homogenous which necessitated a different PVS methodology to diversify this group. These results and lessons influenced the focus of Phase 2, where 15 bean varieties of varying genetic backgrounds and traits were evaluated in two cropping seasons—2013a-first season (March-June) and 2013b-second season (August-November) Table 2.

Table 2. Characteristics of common bean varieties evaluated in Phase 2

Variety number	Variety name	Traits	Source	Year of release in Uganda	Market class*
G1	NABE15	Drought tolerance, early maturing, and multiple disease resistance	Uganda	2006	Sugar bean
G2	NABE2/MCM 1015	Drought tolerance and BCMV resistance	Uganda	1995	Small black
G3	Farmer seed	Various types	Uganda	n/a	Medium red mottled
G4	RWR719	Multiple disease resistant	PABRA	n/a	Small red
G5	Masindi Yellow long	Farmer preferred	Land race	Landrace	Yellow medium
G6	NABE17	Early maturing/multiple disease resistant	Uganda	2011	Red mottled medium
G7	ROBA1	High Fe grain content and multiple disease resistant	PABRA	n/a	Small Khaki
G8	KATX56	Drought tolerant, early maturing	Kenya	n/a	Large red kidney
G9	KATB1	Drought tolerant, early maturing	Kenya	n/a	Yellow medium
G10	KATB9	Drought tolerant, early maturing	Kenya	n/a	Medium red round
G11	KATX69	Drought tolerant, early maturing	Kenya	n/a	Large red mottled long
G12	NABE14	Root rot resistant	Uganda	2003	Large red kidney
G13	CAL143	Drought tolerance, low soil nitrogen tolerance and resistance to ALS	Malawi	n/a	Large red mottled
G14	CAL96/K132	Farmer preferred	Uganda	1994	Large red mottled
G15	NABE21	Early maturing , market class	Uganda	2011	Large sugar bean

**Seed size and colour, BCMV=Bean common mosaic virus disease*

Source: database.pabra-africa.org

Photo 1. Seed types of common bean varieties evaluated. Credit: CIAT-PABRA

2.5 Trial design

The trial design in Phase 1 was a randomised complete block design (RCBD) with two replications. Plot size was 4 x 4 m^2. In Phase 2, a mother-baby trial design (Snap 1999) was utilized to allow for evaluation of more varieties in different environments and capture more of gender and other social diversity drivers of adaptation to climate change and variability. The mother-baby trial designs included a community plot with all test varieties and smaller plots having smaller sets of the varieties on different farmers' fields. The approach enables collection of quantitative data at the mother trial and cross-checking the performances of the technologies under the farmer management (baby trials) (Snapp 2002).

Mother trial: The mother trial was an RCBD trial with two replicates. Fertilizer was included as soil fertility had been recognized as a major constraint in all the trial sites (especially low P) that would affect the performance of the varieties and hence 15 bean varieties with and without fertilizer (50 kg ha-1 of DAP) were evaluated (Table 3). The trial plots measured 3 x 2m^2 and were planted with 150 seed per plot. The reason for the utilization of fertilizers, randomization and replication was explained to the farmers who appreciated its importance. Planting dates greatly differed for the two districts in the 2013b season with planting being completed in August in Hoima and only started in October in Rakai due to the late rains in Rakai and very early rains in Hoima. Planting dates for the 2013a season was similar in both sites, with planting being started and completed in April. The mother gardens being research driven, emphasis was put on proper agronomic practices for common bean and included a control plot that bore the farmers seed.

Table 3. Mother trial field experiment layout

Variety no. and no fertilizer	Variety no. and +DAP fertilizer	Variety no. and no fertilizer	Variety no. and +DAP fertilizer
G15	G15	G14	G4
G14	G14	G9	G7
G13	G13	G7	G2
G12	G12	G13	G6
G11	G11	G6	G8
G10	G10	G8	G13
G9	G9	G12	G9
G8	G8	G4	G14
G7	G7	G1	G12
G6	G6	G3	G11
G5	G5	G5	G15
G4	G4	G2	G3
G3	G3	G15	G10
G2	G2	G11	G5
G1	G1	G10	G1

Rain gauges were set up in each sub county at the homestead of one of the host farmers and farmers were trained on how to record the daily rainfall amounts and draw field maps (Photo 2 and 3). In addition, farmers not staying near the farmer hosting the rain gauge were requested to record the date and describe qualitatively the intensity of rainfall received in small exercise books given to them. In addition, the monthly rainfall and temperature readings were obtained from the district meteorological stations.

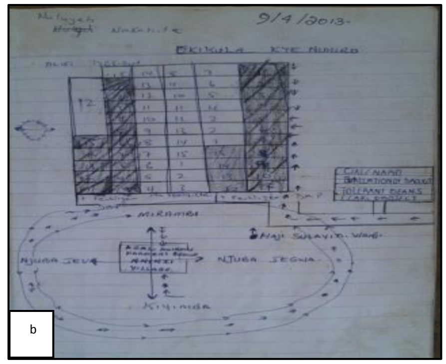


Photo 2 (left). A farmer's field prepared for planting. Credit: Nkalubo S
Photo 3(right). A filed map drawn by farmers. Credit: Nkalubo S

Baby trials: Five baby trials were set up in each village by individual farmers making a total of 45 baby trials across the two sites (details are available on request). The baby trials were composed of a subset of the mother garden—three varieties from the 15 varieties randomly assigned—but ensuring that each variety is repeated twice in each sub county (Table 4). Each farmer received 150 gm of bean seed for each variety and was given liberty to decide on when to plant and how to plant and manage the crop with no supervision from the researchers. The researchers, however, made a follow up visit to the baby trial host farmers about three weeks after the establishment to record the bio data of the host farmers (names, village, varieties received, and cropping system, planting style, plot size per variety and GPS location of field). At harvest time, a team of field assistants worked with the host farmers to harvest and measure the plot yields per variety while at the same time assessing the perceptions of the farmers on performance of the varieties compared to their traditional varieties.

Table 4. Bean variety combinations evaluated in baby trials in three villages of Rakai and a village in Hoima over two seasons.

VC	Village	F Codes	Bean Combination		VC	Village	F Codes	Bean Combination
A	Gosola	F1	(G13, G11, G4)		C	Kalagala	F11	(G13, G12, G7)
A	Gosola	F2	(G14, G2, G15)		C	Kalagala	F12	(G14, G3, G4)
A	Gosola	F3	(G3, G10, G5)		C	Kalagala	F13	(G9, G10, G6)
A	Gosola	F4	(G8, G9, G6)		C	Kalagala	F14	(G11, G1, G15)
A	Gosola	F5	(G12, G1, G7)		C	Kalagala	F15	(G8, G5, G2)
A	Ninzi	F6	(G13, G11, G4)		D	Mpalangasi	F16	(G2, G14, G15)
B	Ninzi	F7	(G14, G2, G15)		D	Mpalangasi	F17	(G6, G8, G9)
B	Ninzi	F8	(G3, G10, G5)		D	Mpalangasi	F18	(G3, G5, G10)
B	Ninzi	F9	(G9, G8, G6)		D	Mpalangasi	F19	(G4, G11, G13)
B	Ninzi	F10	(G12, G1, G7)		D	Mpalangasi	F20	(G1, G7, G12)

Where: G1- G15= Bean variety codes as in Table 1. VC = Village codes, F Codes = Farm Codes, A, B, and C = villages in Rakai, D = village in Hoima district

2.6 Monitoring and evaluation of the trial

2.6.1 Agronomic data collection

Both farmers and the researchers evaluated the trials. Data recorded by the farmers included planting, germination and weeding dates, and daily rainfall amounts from rain gauge readings as well as date and rainfall intensity. Data on the occurring diseases, plant height, plant vigour, leaf size, plant stand, pods per plant and yield were collected by the research team (Photo 4). Trials were evaluated at three plant stages: podding stage (R5-R7), physiological maturity (R8-R9) and harvest time (CIAT 1987). At three weeks after planting of baby trials and distribution of seeds to farmers, a team of researchers visited the baby trial host farmers. The purpose of the visit was to establish the existence and status of the baby trials considering that these were not managed by the researchers. During this field evaluation exercises, data was recorded on the location of the trial (GPS position taken), size of individual plots per variety and the agronomic practices and farming system under which the famer had planted the varieties. More data was collected at podding stage and physiological maturity on the following parameters based on the IPHIS trait dictionary (The Breeding Management System Version 3.0. 2015).

- Plant height was estimated based on five randomly selected plants whose height was measured from the plant base to the first stem branching.
- The number of pods per plant was estimated by counting the number of pods per five randomly selected plants.
- Plant stand was estimated by counting the number of plants per two center rows of each experimental plot.
- Plant vigour (vegetative adaptation) was assessed based on a scale of 1-5 of CIAT, where 5=excellent, and 1=very poor.
- Leaf size measurements were based on measuring the leaf width and length of randomly selected plants. Ratings were done for five common foliar diseases; anthracnose, angular

leaf spot, common bacterial blight, rust, web blight and floral leaf spot using the disease severity ratings.

- Pest ratings - whiteflies and aphids were the most common pests, however, data on these were not collected.
- Yields were measured from each of the harvested plots, where data was recorded on total plants harvested and number of pods per 10 randomly selected plants. All plants from the same plot were then separately put in a gunny bag, and threshed, winnowed and total yield measured using a portable kitchen weighing scale/balance. The beans were then sorted and reweighed to get the clean weight per plot and measurements recorded. The same physical data collection procedure was used for the baby trials.

Photo 4. Researchers taking field data in the mother trials in Kyabigambire sub-county in Hoima. Credit: Mukankusi C

2.6.3 Participatory selection of varieties by farmers

Rounds of participatory variety selection were organized and implemented each season to identify the varieties preferred by farmers, elucidate farmers' variety selection criteria and evaluate the degree of heterogeneity in farmer variety preferences. For each round of variety selection by farmers, same registers of participants were made and a few socioeconomic characteristics of the participants recorded. This was to enable analysis of sources of heterogeneity in preferences revealed by farmers during the selection of varieties.

Two methodologies that utilized paper cards were used in Phase 1 and 2 evaluations. In Phase 1, cards of three different colours representing varying levels of preference were used: Pink to represent most preferred, blue second most preferred and yellow third most preferred variety. Each card was identified by a number given to the farmer during registration and his/her respective gender (male/female). This enabled identification of each card with the characteristics of the farmer and be able to evaluate any interactions between choices made with gender of the farmer. However, this method proved to be cumbersome with large groups of farmers.

In Phase 2, the PVS method used in Phase 1 was reviewed by researchers in consultation with community key informants and modified to improve data quality and simplify the method further for farmers. The cards used in the ranking of varieties were differentiated by four colours instead of three used in Phase 1 to distinguish between preferred and rejected varieties. Two of the colours were used to represent most preferred, distinguished by gender: white for men and yellow for women. Similarly, two cards of different colours were used for the least preferred varieties: blue for men and pink for women.

The PVS were conducted with farmers in each group hosting a mother trial and individually by those farmers who participated in the baby trials. In the mother trial, farmer participants were mainly the group members who had regularly managed and observed the variety lines during growth. The ranking method was used because of its simplicity when the number of varieties is large. Under the baby trial design, each farmer was interviewed on the most important traits when selecting varieties for planting and asked to evaluate each variety planted against a predetermined scale.

The selection procedure was implemented through a sequence of steps clearly explained to farmers. Firstly, farmers were taken through a short training of an hour on how to carry out the evaluation and selection of varieties using the card system. Secondly, farmers were asked to assess the varieties and choose three best/most preferred out of the 15 varieties. Each male and female farmer was given three cards to select three most preferred varieties. The set of cards given to the females and the males were of different colours to allow tracking of gender differences in the selection. Each card was identified by a unique number given to each farmer during registration as in Phase 1 to be able to evaluate any interactions between choices made with the socioeconomic profile of the participant. Thirdly, each male and female farmer was given a second set of three cards to select three worst or not preferred varieties from the remaining 12 varieties. These were of different colours from the ones used to select preferred traits. Farmers were reminded that the choice of varieties should be based on their own criteria. Farmer selection of varieties was carried out on the trials with fertilizers and trials without fertilizers in order to assess whether farmers evaluation of variety performance was conditional on management. Farmers were guided through the field while being allowed to independently evaluate and select varieties (Photo 5). Seed samples of each variety were displayed in front of the variety trial plot to enable the farmers compare agronomic and postharvest traits during the selection. This facilitated the analysis of trade-offs between agronomic and market traits during discussions.

Photo 5. Participatory variety selection with Kakindo sustainable farmers group in Kyakamese village in Hoima. Credit: Mukankusi C

When voting was completed, a general plenary session was held to elicit the important criteria used during selection and analyse trait trade-offs. The plenary session was structured in such a way as to enable discussion of positive and negative traits that could facilitate adoption or rejection of new varieties adapted to climate change. Although the consultations with community key informants at the beginning of the study in Phase 1 did not reveal any gender related barriers that would hinder or bias individual participation, clear differentiation of men and women voting patterns was maintained. Discussion to ensure gender disaggregated data and analysis of whether men and women farmers use the same criteria to evaluate varieties were held.

2.6.4 Social economic data from the baby trials

A survey tool was designed and used to collect data on farmers' assessment and perceptions about varieties under baby trials, and compare it with their varieties planted within the same season. Farmers were interviewed individually on their farms to facilitate direct observation of the farmer circumstances and the crop while in the garden. One round of evaluation was conducted at harvest time of each season when the farmers had fully observed the complete growth cycle of the variety. The performance criteria used during the baby trial was derived from literature and the experiences in Phase 1. These included agronomic traits (yield, tolerance to drought, pests and diseases, soil related constraints), marketability (seed size and colour) and consumption attributes (cooking time, taste) (Snapp et al. 2002). Data were collected on socioeconomic characteristics, soil fertility status of the plots on which the varieties were planted, their usual sources of seed, management used on the varieties, and market access to provide a deeper analysis of the interaction of these factors with choices farmers make regarding varieties to plant. Farmers were also asked to rate the disaggregated bean traits; marketability, grain price, early maturity, yield, taste, cooking time, grain size, drought, uniform maturity, grain colour, disease tolerance, storability, nutritional value, and leaf palatability according to the importance they attach to each.

2.6.5 Data analysis

Due to differences in field designs in 2012 and 2013, data was analysed separately for Phase 1 and Phase 2. The 2012 trials were implemented for one season and the data was analysed using the general analysis of variance in Genstat, with the sites (Kyabigambire and Kiziranfumbi sub counties in Hoima; and Lwanda and Kasaali sub counties in Rakai) as the environments and trials as replications. In the 2013 (a & b) trials, each of the mother gardens was considered as an environment. Due to lack of adequate land, some mother trials were not replicated and as such were not included in the analysis. However, their plot means were considered in discussing the results. Table 5 shows the environments considered in analysing the results for 2013a and 2013b trials. Variety x environment interaction (GEI) was analysed using the Breeding View tool of the Breeding Management System (BMS) which utilizes the Genstat statistical program interface to estimate some of these components of G x E (The Breeding Management System Version 3.0. 2015).

Table 5. Environments for the mother gardens analysed in 2013a and b

District	Sub-county	Village	Name of farmer group	Environment
Rakai	Lwanda	Gosola	Kiyovu	1
Rakai	Kasaali	Ninzi	Agaliawamu Ninzi	2
Hoima	Kyambigambire	Kyakamese	Kakindo Sustainable Agriculture	3
Hoima	Kyabigambire	Mpalangasi	Kyamaleera	4
Hoima	Kiziranfumbi	Butimba	Butimba	5
Hoima	Kiziranfumbi	Butyamba	Katweyambe Butyamba	6

The data from the farmer PVS was compiled and analysed using descriptive statistics, partial correlations and non-parametric statistics, where positive votes were coded as 1 while the negative votes were coded 0. This allowed quantification of the number of votes obtained by each variety and evaluation of the top most ranked varieties (most preferred varieties) and those evaluated as worst varieties (least preferred varieties) and compared the preferences between the gender groups based on nonparametric tests. Since the cards were labelled by the number of each participant, we were also able to correlate the socioeconomic characteristics of the participants with the variety choices they made to draw insights on the possible sources of heterogeneity under conditions of climatic variability.

3. Results and discussion

3.1 Site characterisation

3.1.1 Soil characteristics

Soil nutrient content of the nine sites was analysed to obtain the organic matter content (%OM), Nitrogen (N), Phosphorous (P), Calcium (Ca), Magnesium (Mg), and Potassium (K), as well as the soil composition based on the proportions of the content of sand, clay and silt and classification of the soils into specific textural classes. There were major differences in the soil nutrient content of the different experimental sites used in each season, indicating the wide variability of soil fertility within very short physical distances an aspect that should be considered when promoting crop management practices. For most of the sites, the textural class of the soil was sandy clay loam soil with the exception of Ngobi/Kakira that had clay loam to loamy soils and Butyamba that was characterized by sandy clay soil (see Appendix 1 and 2). All sites were characterized by very low (<45ppm) to low levels (45-90ppm) of P in the soil, ranging between 0.65-4.2 ppm in Mpalangasi to 52-73 ppm in Gosoola as the highest. Sufficient levels of P for crop production range between 90-230 ppm. Most of soils had sufficient levels of N with the exception of three villages—Ninzi, Butyamba and Kalagala. The effects of drought and high temperatures become more severe when combined with low levels of P supply and/or aluminum (Al) toxicity (Beebe et al. 2010). In the tropics, high air temperature is often accompanied by high soil temperature in the rooting zone (top 20 cm of soil), leading to poor root formation. The pH of the soils ranged from 5.5 to 5.9. Adequate levels of calcium and magnesium ions were observed in 2013a and 2013b. In all the villages, organic matter content of the soils were mostly above the critical levels, with some villages having above sufficent levels of 6% in the two seasons of 2013 (a and b (see Appendix 2 and 3).

3.1.2 Rainfall patterns

Data collected by the farmers from the rain gauges in each of the sub-counties showed variations in the amount of rainfall received within and between the two sites (Hoima and Rakai) from the time of establishing the trials to harvest. For instance in season 2013a in Hoima, the rains begun as early as 21st March in Kyabigambri sub-county but did not start until the 8th of May in Kiziranfumbi sub-county (Table 6). In Rakai the earliest rains were received in the last half of April. Generally farmers received a lot more and continuous rains in the second season (August-November) and the two sub-counties of Kyabigambire and Kiziranfumbi in Hoima received more than three times the rainfall received in the sub-counties of Lwanda and Kasaali in Rakai district (Table 6). But as a single sub-county, Kiziranfumbi received the highest amounts of rainfall. Whereas there was a break in rainfall between the first and second season, for the sub-counties of Lwanda, Kasaali and Kyabigabire, it was a different story for the sub-county of Kiziramfumbi. In this later sub-county located in Hoima, farmers received continuous rains from May to November with a peak being experienced during the harvest period of mid-July to early August (Table 6). This continuous rainfall has a lot of implication in as far as yield losses are concerned, for it contributes to increases in diseases and pod pests effects.

Table 6. Rainfall patterns for 2013 seasons in Hoima and Rakai villages

Site	Sub-county	Village	Season 2013a (rainfall in mm)				
			March	April	May	June	July
Hoima	Kiziranfumbi	Butimba and Butyamba	-	-	45.8	34.1	227.2
Hoima	Kyabigambire	Mpalangasi and Kyakamese	59.6	127.9	106.7	85.5	-
Rakai	Kasaali	Kalagala and Ninzi	-	79.6	13.8	-	-
Rakai	Lwanda	Kyengeza and Gosola		-	-	-	-
			Season 2013b (rainfall in mm)				
			August	September	October	November	December
Hoima	Kiziranfumbi	Butimba and Butyamba	128.1	111.6	194.5	125.3	3.6
Hoima	Kyabigambire	Mpalangasi and Kyakamese	2.3	136.1	147.8	156.2	53.4
Rakai	Kasaali	Kalagala and Ninzi	-	75.5	50.8	154.5	16.5
Rakai	Lwanda	Kyengeza and Gosola	-	0	110.1	156.0	0

-- =missing data

3.1.3 Socioeconomic characteristics of participating farmers

In Phase 1, a total of 320 farmers across the nine farmer groups participated in the PVS, translating to an average of 36 farmers per group (Table 7). In Phase 2, the number of farmers who participated in PVS in each season reduced significantly to ensure data of high quality given the large number of bean varieties (15). Across the sites, 162 farmers participated in season 2013a (March-June) out of which 56.6% were women, while 199 farmers participated in season 2013b (September-February) of which 60% were women (Table 7). The number of participants for baby trials, however, was fixed at 45 for each season, out of which 58% were women.

Table 7. Number and gender composition of farmers participating in PVS in Rakai and Hoima by season

Site	Sub-county	Farmer group	Number and composition of participating farmers by season					
			Season 2012a (April-July)		Season 2013a (March-June)		Season 2013b (September-February)	
			Total	Percent of women	Total	Percent of women	Total	Percent of women
Hoima	Kyabigambire	Akumulikire	30	43.3	18	61.1	25	60.0
Hoima	Kiziranfumbi	Butimba	29	27.6	17	41.2	20	35.0
Hoima	Kyabigambire	Kakindu Sustainable Agriculture	33	57.6	20	65	22	77.3
Hoima	Kyabigambire	Kyamalera	55	76.4	28	73.1	29	79.3
Hoima	Kiziranfumbi	Katweyambe Butyamba	45	62.2	42	51.4	42	50.0
Rakai	Kasali	Agaliawamu Ninzi	33	66.7	17	64.7	19	78.9
Rakai	Lwanda	Kiyovu	41	51.2	14	50	18	61.1
Rakai	Kasaali	Kwewayo	14	85.7	28	50	9	44.4
Rakai	Lwanda	Kyengeza Twezimbe	40	37.5	-	-	15	33.3
		Total	320	56.3	184	56.54	199	59.3

Across the two_sites (Hoima and Rakai), farmers who participated in the PVS differed in terms of their household composition, education levels and landholdings (Table 8). On average, farmers in Hoima had higher levels of education and landholdings compared to farmers in Rakai. Household size was equally high in Hoima (6.9), compared to about 5.8 in Rakai. Average landholdings ranged from 1.16 hectares in Rakai to 2.18 hectares in Hoima, similar to the scale of bean production. On average, a participating farmer in Hoima allocates about 0.34 ha (0.77 acres) of land to bean production per season, translating to 0.66 ha per year. This is not statistically different from the average of 0.31 ha reported by participants from Rakai per season. Since these farmers were group members who select themselves voluntarily into farmer associations, it can be interpreted that associations in Rakai are comprised of individuals with low levels of education, while land is more limiting in Rakai than in Hoima. Due to land scarcity, land degradation is more pronounced in Rakai, with slightly more than a half of the farmers reporting low soil fertility of their bean plots (Table 9).

Table 8. Household characteristics

Characteristics	Hoima		Rakai	
	Mean	SD	Mean	SD
Age of the participant	39.5	12.86	40.2	12.18
Household size	6.86**	2.9	5.98	2.89
Years of formal education	7.56***	3.28	6.34	3.07
Landholding (hectares)	2.18***	2.01	1.16	1.43
Per capital landholding (ha)	0.34***	0.31	0.21	0.17
Bean area (ha)	0.34	0.52	0.31	0.37

; * denote significant at 5% and 1%

In terms of gender, majority of the farmers were from dual households (husband and wife), engaged in farming as their main occupation, complimented with off-farm petty businesses and activities to cope with agricultural shocks (Table 9). There were no differences in age between the men and women farmers. However, the men on average had higher levels of education than the women.

Table 9. Socioeconomic characteristics

Characteristic	Rakai	Hoima	
	Percent of households	Percent of households	Chi-square (χ^2) statistic
Marital status			1.72
Single	15.3	15.0	
Married	77.6	77.2	
Divorced	3.1	1.6	
Widowed	4.1	5.3	
Others		0.8	
Main occupation			12.89
Farming (crop and livestock)	87.8	89.0	
Salaried employment	3.1	0.8	
Self-employed off farm	7.1	2.8	
Agricultural causal laborer	16.3		
Off farm casual labourer	1.0		
Schooling	1.0		
Other occupation			8.36
Farming (crop and livestock)	9.2	4.5	
Salaried employment	2.0	0.8	
Self-employed off farm	52.0	29.7	
Agricultural causal laborer			
Off farm casual labourer		3.3	
Schooling		1.2	
Household chores		7.3	
Soil fertility rating/perceptions			70.26***
Good	15.3	24.4	
Average	34.7	63.8	
Poor	45.9	4.1	

3.2 Performance of bean varieties across the different environments and fertilizer treatments

3.2.1 Agronomic performance

Based on the multiple sites analysis of variance, there were no significant effects (p=0.05) of the interaction of Environment (season and location x fertilizer) x Variety on all the agronomic parameters measured. However, the interaction of Fertilizer x Varieties was significant for plant height and plant stand at podding, implying that varieties behaved differently depending on whether or not fertilizer was applied. The interaction of Environment x Varieties was significant (p=0.05) for plant vigour, pod number at podding, leaf area, plant stand at harvest, clean and total yield. This suggests that ranking of varieties varied significantly among the six environments. The Environment x Fertilizer interaction was significant for all parameters apart from plant stand at harvest, implying that fertilizer effect on these parameters depends on the environmental factors. All the three single factors—environment, variety and fertilizer—had significant effects on all the parameter measured.

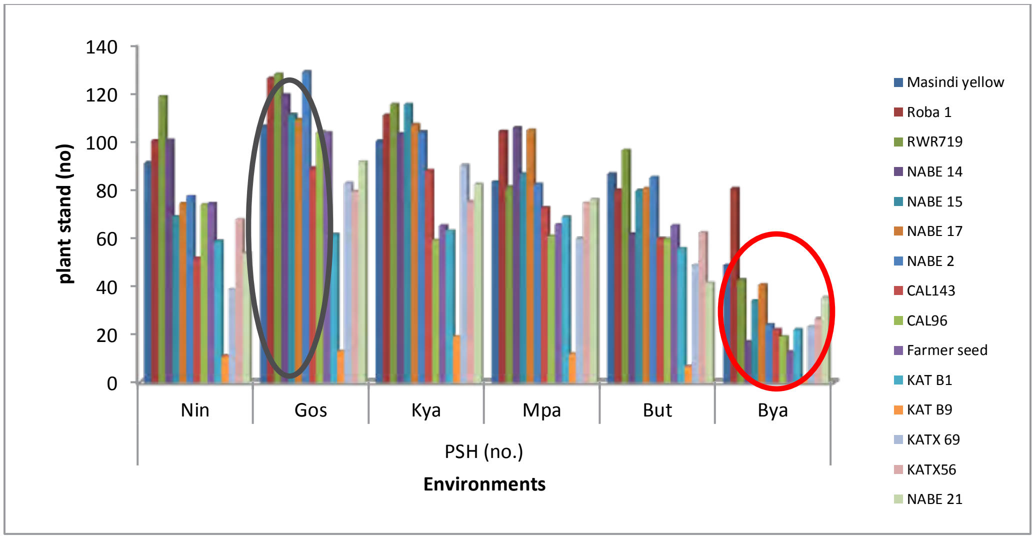
Plant vigour (vegetative adaptation) varied between 1.3–4.5 on a scale of 1–5 (i.e. very poor to excellent vigour). Vigour was highest for *NABE14* in Kyakamese and lowest for *KATB9* in Butyamba. In general, most of the varieties had very good vigor (>3) with the exception of *KATB9* whose highest vigor was 2.8 in Kyakamese. This could be attributed to the fact that the seed planted was old and hence general performance was poor for *KATB9* for all parameters across all the sites. Vigour was highest in Kyakamese and Butimba and lowest in Butyamba for 70% of the varieties. All these sites were in Hoima. *NABE14* had the highest vigor in all sites followed by *CAL143* and *KATX56*. There was poor vigor in the two sites of Gosola and Ninzi in Rakai.

Pod number at podding varied between 2-3 pods per plant on *ROBA*1, *RWR719* and *NABE14* in Gosoola and 20-21 pods per plant on *NABE2* in Butimba and Kyakamese in Hoima. In general, the number pods per plant was lowest in Gosoola and highest in Butimba. Leaf area varied between 40.4cm^2 on *ROBA1* and in *NABE2* in Ninzi to 135.9 m^2 on *NABE14* in Ninzi. Leaf area was highest for *NABE14* and lowest for *RWR719 (*and highest in Kyakamese in Hoima and lowest in Ninzi in Rakai). Plant stand of the different varieties at podding did not significantly vary across the different sites. However, plant stand varied significantly at harvest across the sites. On average, all varieties exhibited higher plant stand at harvest in Rakai (Ninzi and Gosoola) than in the Hoima sites. Varieties that had significantly higher plant stand across the sites included *RWR719*, *ROBA1*, and *NABE2* (Figure 2). This was probably due to their small seeds, thus it may be presumed that more seeds were planted per hole during planting. The other reason contributing to their higher plant stand could be their ability to resist the diseases that were prevalent in these sites. Across all sites, variety *KATB9* performed the worst due to poor stand establishment, that was attributed to the use of aged seed.

3.2.2 Reaction of the fifteen varieties to diseases across the six environments

In the case of the occurring diseases, the effects of the three different interactions—Environment x Variety x Fertilizer, Environment x Fertilizer, and Environments on their own—were significant for all the diseases except for incidences of bean root rot and severity of BCMV. The interaction of Fertilizer x Varieties was significant for all diseases with the exception of incidence of bean root rot, while the interaction of Environment x Varieties was significant for all diseases apart from root rots and ascochyta blight. Varieties significantly differed in terms of severity of all the diseases, except for the incidence of BRR and severity of ascochyta blight. Significant differences were observed for angular leaf spot on leaves (ALSL), ascochyta blight, BCMV, floury leaf spot (FLS) and rust among the two fertilizer treatments. Table 10 shows the differences in the ranking of the varieties according to angular leaf spot severity on the leaves across the six environments. For instance, farmer's seed consistently had high disease severity scores across the environments while *KATB9* had low severity. On the other hand, *ROBA1* had the lowest severity in Gosola and Mpalangasi, ranked fourth in Ninzi and Butyamba, second in Butimba and sixth in Kyakamese depicting G x E effects.

Figure 2. Plant stand at harvest of 15 bean genotypes in six environments



Where: Kya=Kyakamese, Mpa=Mpalangasi, But =Butimba, and Bya=Butyamba

Table 10. Mean angular leafspot severity for 15 bean varieties in villages where there was a significant G x F x S interaction and genotypic effect

Village	Butimba					
Season	2013a		2013b		Butyamba	Kyakamese
Varieties/Fertiliser	DAP	No DAP	DAP	No DAP	Mean	Mean
NABE14	1.0	1.5	2.0	2.0	2.0	1.6
NABE2	1.5	1.5	2.0	2.5	2.6	2.0
ROBA1	1.5	2.0	3.5	3.0	3.1	2.3
RWR719	1.5	1.5	2.0	2.5	3.3	2.9
CAL143	2.0	1.5	2.0	2.0	3.2	3.1
KATX69	2.0	2.5	2.5	2.0	2.5	2.5
NABE15	3.0	2.5	2.5	2.0	3.0	2.6
NABE17	3.0	2.0	2.5	3.0	3.1	2.4
NABE21	3.0	3.0	2.5	2.5	2.4	1.9
CAL96 (K132)	4.5	2.0	3.0	2.0	2.1	2.3
KATB1	4.5	2.5	3.5	3.5	3.1	2.4
KATB9	4.5	2.5	3.0	2.5	2.0	1.8
Farmer seed	5.5	3.0	3.0	3.0	2.8	2.0
Masindi Yellow long	5.5	2.5	3.0	2.5	2.4	1.9
KATX56	6.0	2.5	3.0	2.5	2.3	1.4
Mean	**3.3**	**2.2**	**2.7**	**2.5**	**2.7**	**2.2**
LSD	**1.1**	**ns**	**ns**	**ns**	**0.8**	**0.6**
CV%	**16.1**	**31.8**	**21.2**	**19.9**	**27.9**	**26.2**

In general, disease severity was low to medium, ranging between 1-6 for ALSL, 1.0-2.5 for Anthracnose on the leaves, 1-3.8 for anthracnose on pods, 1.5-6.5 for FLS, 1-4.8 for CBB, 1-3.6 for rust and 1-4 for web blight (on a disease score scale of 1-9|). ALSL severity was highest on *KATX56*, followed by *Masindi Yellow* in Butyamba and lowest on *RWR719*, *CAL143*, *ROBA1* and *NABE2*. Low severity of bean anthracnose on pods were observed for *CAL143*, *RWR719*, *ROBA1*, *NABE2*, N*ABE14*, *KATX69*, and *CAL96* and highest on *Masindi yellow* in Butyamba and *NABE17* in Malangasi, followed by *Masindi yellow* in Malangasi. Floury leaf spot was present in all sites and affected all bean varieties though severity varied depending on the site and the variety, being highest in Butimba and on *Masindi yellow*. The highest seventy was recorded on *KATB1* followed by *Masindi yellow* and *KATX56* in Butimba. It was lowest on *RWR719* and *NABE2* in Mpalangasi and *CAL96* in Butyamba. In the case of bean rust, severity ranged between 1 and 3.5, it was highest on *KATB9* followed by *KATB1* in Butyamba. Web blight was highest in Butimba on *Masindi yellow* and in Gosoola on *NABE2* and, *NABE1* in 2013a. There was also significant G x E interaction on diseases severity with the ranking of varieties differing in different environments.

3.2.3 Effect of fertilizer on variety performance

In general, use of fertilizer resulted in greater plant height, plant stand at podding, vigor, pod number (at podding and harvest), leaf area and yield. Average plant height, for instance, varied between 28.4 cm with no fertilizer to 32.9 cm with fertilizer (Table 11). The effect of DAP varied across the sites, probably due to differences in soil fertility. With DAP, plant height varied from 26.87 cm in Gosoola and 40;4 cm in Butimba, and with no DAP it varied between 22.7 cm in Ninzi and 35cm in Mpalangasi. On average, there was an increase of two pods per 10 plants when DAP fertilizer was used though there were no effects of DAP on pod number in Gosoola.

Table 11. Environment x Fertilizer interaction effects on plant height, plant vigor, and pod number at harvest and yield

Village	Plant height		Plant vigor		PNH		CW (kg/ha)	
	DAP	No DAP	DAP	No DAP	DAP	No DAP	DAP	No DAP
Gosola	26.8	23.1	3.0	2.2	4	4	144.7	157.0
Ninzi	29.1	22.7	3.5	2.9	5	4	303.6	313.3
Kyakamese	35.2	30.1	4.1	3.4	13	11	931.7	828.7
Mpalangasi	34.5	35.0	3.8	3.0	13	8	807.9	614.3
Butyamba	31.2	26.2	1.7	1.9	7	4	205.3	159.3
Butimba	40.4	33.2	3.8	3.9	13	12	631.3	647.3
Mean	**32.9**	**28.4**	**3.3**	**2.9**	**10**	**8**	**576.0**	**512.6**
SED	**1.3**	**1.3**	**0.2**	**0.2**	**0.9**	**0.9**	**47.4**	**47.4**
LSD	**2.7**	**2.7**	**0.4**	**0.4**	**1.7**	**1.7**	**93.6**	**93.6**
CV%	**15.9**	**18.4**	**21.5**	**24.7**	**33.6**	**43.0**	**31.9**	**35.8**

Fertilizer use appeared to result in higher disease levels in both crop seasons (Table 12), particularly for angular leaf spot, floury leaf spot, rust and common bacterial blight. This is odd as it is expected that healthier plants are able to resist diseases more than unhealthy plants. However, the effect of fertilizer on disease severity was also influenced by the environment. In Mpalangasi, for example, angular leaf spot severity was higher where no fertilizer was applied and compared to where fertilizer was applied unlike all the other districts where severity was higher where fertilizer was applied.

Table 12. Effect of the Environment x Fertilizer interaction on angular leaf spot on leaves and floury leaf spot

Village	Angular leaf spot on leaves				Floury leaf spot			
	Season 2013a		Season 2013b		Season 2013a		Season 2013b	
	DAP	No DAP	DAP	No DAP	DAP	No DAP	DAP	No DAP
Gosola	2.7	2.4	3.3	3.3	3.2	1.9	1.9	1.9
Ninzi	3.1	2.7	4.0	4.0	3.7	3.0	3.8	3.3
Kyakamese	2.0	1.9	2.5	2.4	2.1	1.7	2.4	2.2
Mpalangasi	1.8	2.2	3.0	3.4	2.3	1.1	2.7	3.1
Butyamba	3.4	2.5	2.7	2.5	2.4	2.1	3.4	3.3
Butimba	3.2	2.5	2.9	2.5	2.3	2.4	3.0	2.4
Mean	**2.7**	**2.4**	**3.3**	**3.12**	**2.7**	**2.0**	**2.9**	**2.7**
SED (p=0.05)	**0.2**		**0.19**		**0.2**		**0.19**	
CV%	**23.5**		**22.1**				**26.1**	

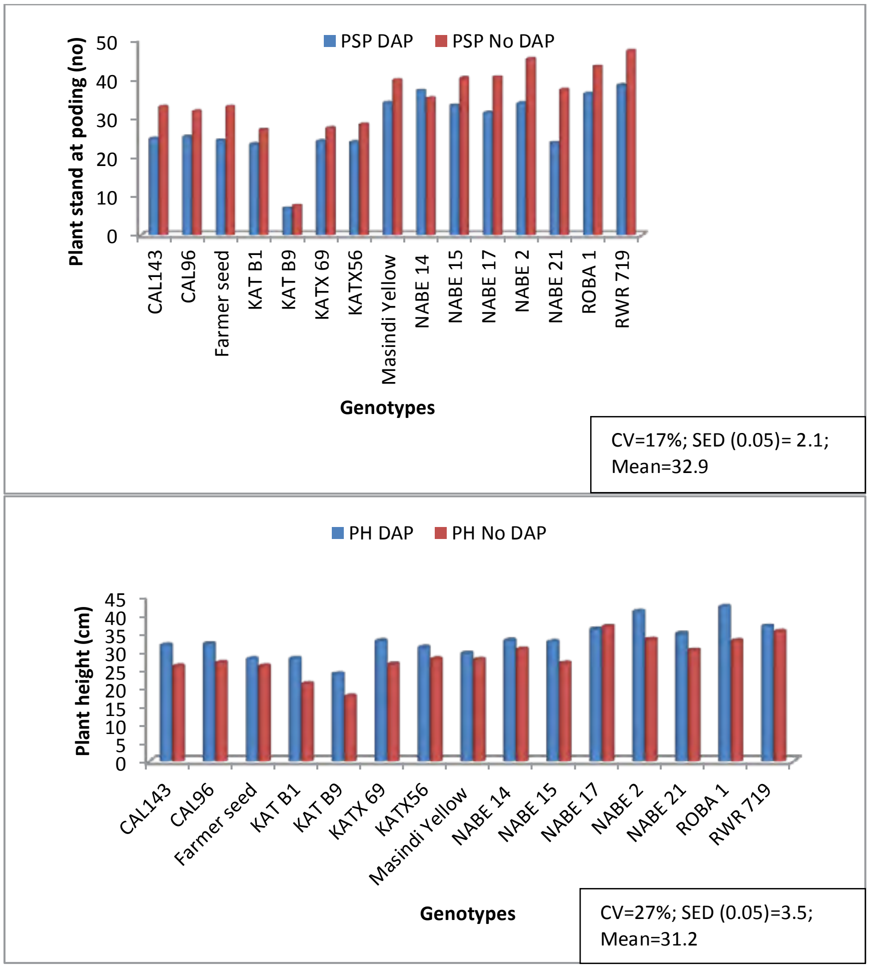
The study also showed that, the responses of the 15 bean varieties differed significantly in the two fertilizer levels for plant height, plant stand at podding and the occurring diseases (Figure 3). In terms of plant height, the effects positively affected growth for all the varieties. Statistically, *NABE2*, *ROBA1*, *RWR719*, and *NABE17* were taller and equal in height, followed by *NABE21*, *NABE15*, *NABE14*, Masindi yellow, *KATX56*, *KATX69*, and *CAL96* (Table 13). The least in height growth were *KATB9*, *KATB1* and Farmers' seed.

Table 13. Mean squares for yield in six locations - single site analysis

SOV	Kyakamese		Butimba		Mpalangasi		Butyamba		Ninzi		Gosola	
	TY	CY	TY	CY	TY	CY	TY	CY	TY	CY	TY	CY
Seasons	ns	ns	**	**	**	**	**	**	ns	ns	**	**
Fertilizer	**	**	*	*	**	**	**	**	ns	ns	ns	ns
Varieties	ns	*	ns	ns	**	**	ns	ns	ns	ns	ns	ns
S x F	ns	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns
V x S	**	**	ns	ns	*	*	ns	ns	**	**	ns	ns
V x F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
V x S x F	ns	ns	ns	ns	ns	*	ns	ns	**	**	ns	ns

TY – total yield, CY – clean yield; S=season, F=fertiliser, V=variety*, ** and ***=significant at, 0.01, 0.001 and 0.0001; ns-not significant at p=0.05

Figure 3. Effect of fertilizer application on plant height and plant stand at podding



3.2.4 Yield performance across two seasons in different environments

Yield is the most important trait breeders and farmers consider in selecting promising varieties, with the study examining how the 15 varieties performed across 12 different environments. Based on single site analysis (Table 13), there were significant differences between the two seasons (2013a and b) in total and clean yield at all the sites with the exception of Ninzi and Kyakamese. Fertilizer application had significant effects on yield in all locations, except in Ninzi and Gosola. Yield was significantly different between the 15 varieties in Kyakamese and Mplalangasi only. However, the yield of the 15 varieties was not significantly affected by DAP fertilizer though varieties behaved significantly different between the two seasons in Kyakamese, Mpalangasi and Ninzi. Signficant V x S x F were only observed in Mpalangasi and Ninzi.

In conducting the G x E analysis, we considered application of DAP fertilizer as a factor of the environment and hence analysed the plots that received fertilizer as unique environments. This implies we analysed 12 environments[1].

Results of the multi-site analysis indicated that the 15 varieties, six locations, the two seasons and the two fertilizer regimes significantly affected yield (p<0.001) (Table 14). Yield performance of the varieties varied with season, location and the interaction of location and season, indicating significant Variety x Environmental (G x E) effects on yield.

Table 14. G x E interaction on yield performance of 15 varieties across five locations, two seasons (2013 a and b) and two fertilizer regimes

Source	DF	Mean squares		
		TY (kg/ha)	CY (kg/ha)	PNH
Variety	14	ns	*	***
Location	5	***	***	***
Season	1	*	***	***
Fertilizer	1	***	***	***
Variety x Location	70	ns	Ns	ns
Variety x Season	14	***	***	**
Location x Season	5	***	***	***
Variety x Fertilizer	14	ns	Ns	ns
Location x Fertilizer	5	***	***	***
Season x Fertilizer	1	ns	Ns	ns
Variety x Location x Season	70	*	**	ns
Variety x Location x Fertilizer	70	ns	Ns	ns
Variety x Season x Fertilizer	14	ns	Ns	ns
Location x Season x Fertilizer	5	ns	Ns	ns
Variety x Location x Season x Fertilizer	69	ns	Ns	ns

In general, application of DAP in Kyakamese recorded the highest total and clean yield, ranging between 2163-3772 kg/ha and 1777-3468 kg/ha, respectively. This was followed closely by Butimba with DAP (Table 12). Ninzi recorded the lowest yield with and without DAP among the 12 scenarios of 635-1510 kg/ha for total yield and 517 and 1333 kg/ha for clean yield (Table 15).

[1] All the six sites (Kyakamese, Butimba, Mpalangasi, Butyamba, Gosola, Ninzi) with DAP; and a replication of the six sites no DAP.

Tabe 15. Yield performance of 12 environments across two seasons (2013a and b)

Environment	Total yield (kg/ha)				Clean yield (kg/ha)			
	Mean	Median	Min	Max	Mean	Median	Min	Max
With DAP fertilizer								
Kyakamese	2721	2717	2163	3772	2372	2209	1777	3468
Butimba	2345	2300	1708	3418	1851	1806	1241	2629
Mpalangasi	2319	2225	1550	3825	1884	1791	1192	3329
Butyamba	2153	2111	1498	3189	1758	1744	1308	2331
Gosola	1753	1731	1100	2366	1573	1678	487	2148
Ninzi	1131	1130	743	1538	968	949	675.5	1319
With no DAP fertilizer								
Kyakamese	2234	2191	1705	2863	1931	1924	1377	2595
Butimba	1932	1813	1578	3176	1510	1353	1155	2452
Gosola	1769	1716	1127	2410	1648	1607	1052	2346
Mpalangasi	1407	1410	843	1937	1204	1227	734	1857
Butyamba	1279	1332	519	1910	1065	1064	311	1723
Ninzi	993	941	635	1510	857	813	517.2	1333

3.2.5 Genotype by environment (G xE) interaction effects to capture the effects of climate variability on variety performance

Based on the Finlay Wilkinson model (FW), G x E was not significant and accounted for only 7.9% of the G x E for total yield and 7.7% for clean yield, hence was not adequate to explain the observed G x E. In general, *RWR719* variety had the highest yield while *KATB1* recorded the lowest yield. Based on the computed sensitivities (b), the *KATX69* variety (with an average yield of 1862 kg/ha), and *NABE15* (with average yield of 1690 kg/ha) were the most stable varieties for both total and clean yield. Among the 15 varieties, *CAL143* had the lowest sensitivity implying that it is very sensitive to environmental changes but is a high performer in poor environments. The *ROBA1* variety had the highest sensitivity implying that is was very unstable, but a high performer in good environments. Based on the seasons, 2013b proved to be a better season with most of the varieties performing better, with the exception of *KATB9*, *KATX56* and Masindi Yellow (data not shown). To further explain the yield performance of the varieties, stability, superiority, static stability and Wrike's ecovalance were computed. Based on variety superiority, *NABE2* combined high performance with consistency with regards to yield while the performance of *KATB1* and *NABE14* were not consistent. Based on static stability, *CAL143* variety was the most stable with regards to total and clean yield, while *RWR719* was the least stable based on the magnitude of the stabilities (Table 16). Based on the Wricke's ecovalence, *NABE17* and Masindi Yellow varieties were the most stable with respect to changing environments while variety *RWR719* was least stable. In summary, *NABE2* was the most superior variety, with *CAL143*, *NABE17* and Masindi Yellow being the most stable varieties, while *RWR719*, *KATB1* and *NABE15* were the least stable.

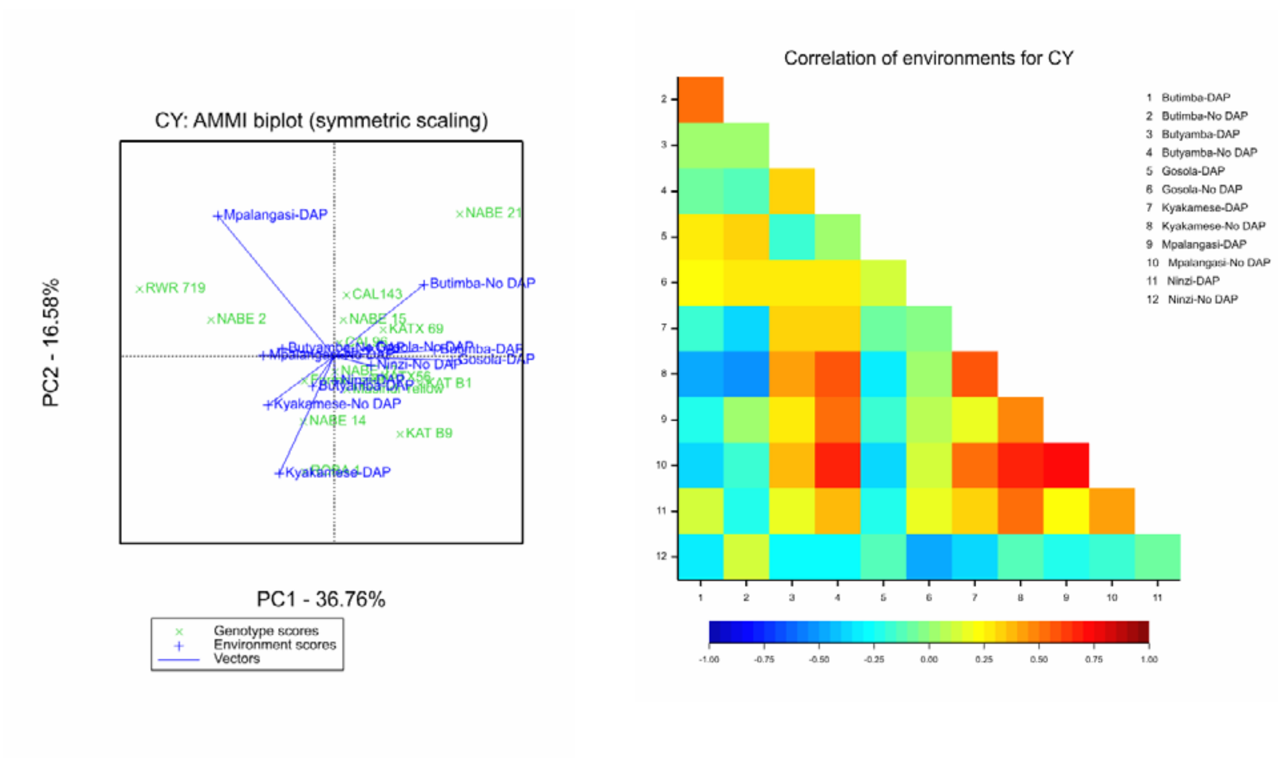
Table 16. Yield performance estimates and stability of 15 bean varieties across 12 environments

Variety	Mean total yield (kg/ha)	Mean clean yield (kg/ha	Sensitivities (*b*)		Stability superiority measure coefficients		Static stability measure coefficients		Wricke's ecovalence stability coefficients	
			TY (kg/ha)	CY(kg/ha)	TY (kg/ha)	CY(kg/ha)	TY (kg/ha)	CY(kg/ha)	TY (kg/ha)	CY(kg/ha)
CAL143	1827	1510	**0.5782**	**0.5369**	495,208	402,998	**172,160**	**113,311**	1,326,005	1,058,510
CAL96	1803	1539	1.0690	1.0210	417,778	348,438	382,239	262,882	520,341	534,396
Farmer seed	1926	1546	1.1824	1.1410	381,675	342,320	554,064	319,126	1,732,394	660,310
KATB1	**1516**	**1318**	0.9068	1.0226	**800,896**	581,177	362,918	308,678	1,279,882	980,714
KATB9	1813	1335	1.2653	1.0395	471,128	584,726	581,379	330,107	1,409,976	1,142,141
KATX69	1862	1608	**1.0029**	**0.9879**	401,048	325,585	431,681	295,147	1,458,384	981,578
KATX56	1913	1646	0.8549	0.9606	395,592	280,674	282,394	241,846	741,783	551,682
Masindi Yellow	1906	1690	0.9204	0.9650	378,620	266,262	291,011	240,815	**452,760**	567,370
NABE14	1687	1340	0.7472	0.6567	633,174	**614,718**	255,797	228,717	1,201,643	1,816,926
NABE15	1690	1477	**0.9972**	**0.9975**	557,417	398,251	378,028	267,804	899,628	684,138
NABE17	1746	1522	0.8480	0.9034	526,792	381,583	253,216	208,331	492,315	**468,106**
NABE2	**2075**	**1855**	1.0294	1.1597	**313,987**	**187,464**	479,307	442,153	1,862,226	1,993,763
NABE21	1949	1567	1.0599	0.8796	372,389	391,408	662,917	414,897	3,541,024	2,715,643
ROBA1	1923	1692	**1.3063**	**1.4563**	365,612	260,585	578,865	504,810	1,152,411	1,297,497
RWR719	1908	1630	1.2199	1.2529	448,393	327,080	**805,801**	**646,610**	**4,266,820**	**3,840,336**

The AMMI model was explored to assess its superiority in explaining the observed G x E. Based on AMMI model, G x E was significant (at $p<0.05$) and the model explained 51% of the observed G x E with IPCA 1 explaining 33% and IPCA 2 explaining 18% for total yield. In the case of clean yield the AMMI model explained 53% (IPCA 1 =36% and IPCA 2 =16%) of the observed G x E and was thus more superior to FW model in explaining the observed G x E.

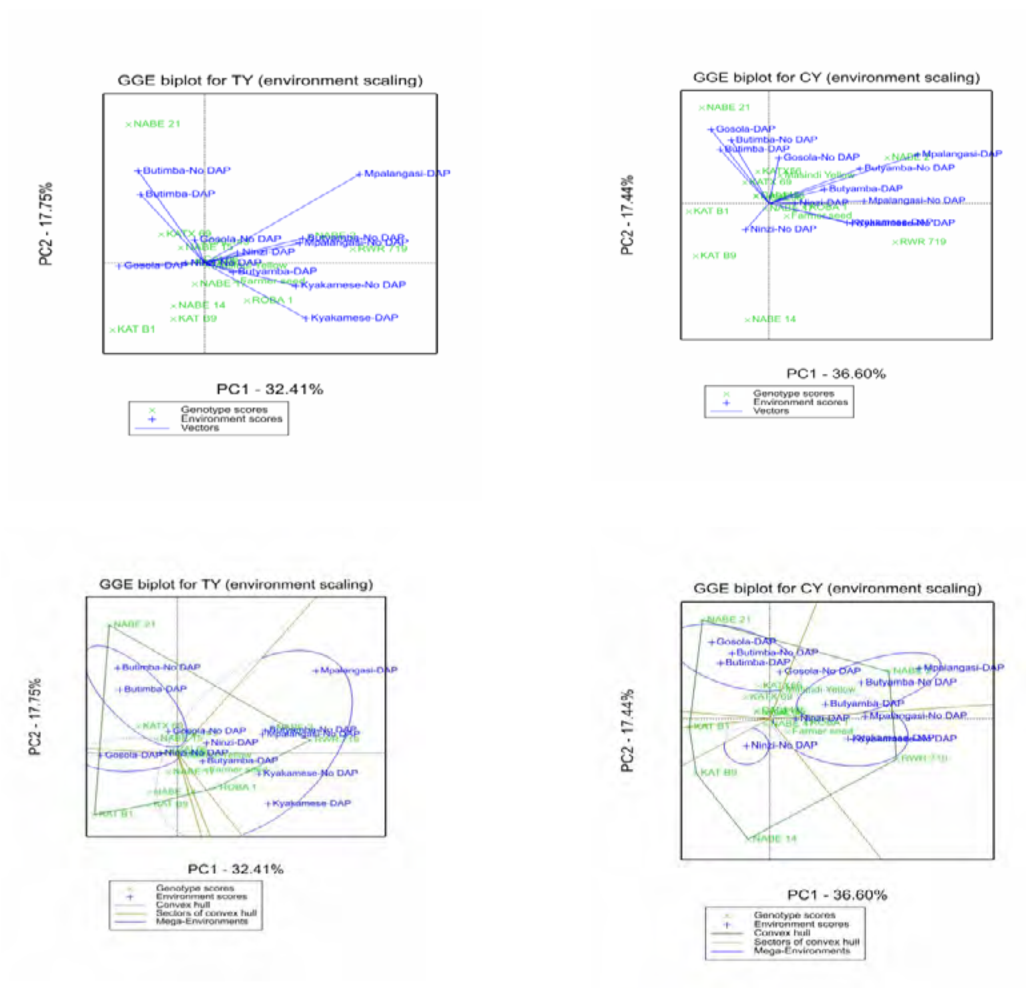
The AMMI biplots and correlation matrices showed that Mpalangasi with DAP environment had the largest genetic variance (Figure 4), implying that there were no significant differences ($p=0.05$) among the 15 varieties with respect to yield. Ninzi with DAP on the other hand had the lowest genetic variance implying that yield performance of the 15 varieties differed significantly in this environment (Figure 4). Mpalangai and Kyakamese were highly correlated environments while Butimba and Kyakamese were negatively correlated. The environments Butyamba with or without DAP, Gosola with and without DAP, Mpalangasi without DAP, were the best in discriminating between varieties as they had PCA 1 values close to zero.

Figure 4. AMMI biplots and correlation matrices for clean yield (kg/ha) for 15 bean varieties in 12 environments



As shown in the plots below (Figure 5), the GGE analysis grouped the 12 environments into three and four main mega environments based on total and clean yield, respectively. For total yield mega environment A included Butyamba with and without DAP, Kyakamese with and without DAP, Mpalangasi with and without DAP, and Ninzi with DAP; the second mega environment B included Gosola with and without DAP, and Ninzi no DAP; the third mega environment C included Butimba with and without DAP. For clean yield there were four mega environments and included environment D - Butyamba with and without DAP, and Mpalangasi with DAP; environment E - Butyamba with DAP, Mpalangansi without DAP, Kyakamese with and without DAP, and Ninzi with DAP; environment F- Ninzi without DAP; and mega environment G - Gosola with and without DAP, Butimba with and without DAP. Butyamba with DAP was fitted into two environments. The ordering of the environments into mega environments implies similarities between them, and similar technologies can be promoted in these environments.

Figure 5. GGE biplots for clean yield (Kg/ha) for 15 bean varieties in 12 environments



With respect to total yield, the GGE plots indicate that *RWR719* variety performed best in mega environments A, while *KATB1* had the best in the mega environment B, and *NABE21* performed best in environment C. With respect to clean yield, the best performing variety in mega environment D was *NABE2*, *RWR719* was the best performing variety in mega environment E *NABE14* was the best performing variety in mega environment F, while *NABE21* performed best in mega environment G. Overall, the best performing varieties were *NABE2*, *RWR719*, *NABE21* and *NABE14*.

3.2.6 Variety performance in baby trials

A total of 45 farmers were selected by different farmer groups to host baby trials out of which 26 (58%) were female. All farmers established baby trials comprising of three varieties apart from only four farmers. Appendix 5 shows treated varieties in different ways that affected the yield. Table 17 shows the yield from the baby trials. Comparing these yields with those obtained in the mother gardens (Table 15), shows very high differences with the on-farm yields being much lower. Although farmers were given almost equal amounts of seed (150gm), expected to cover a planting area of 12-15 square meters depending on size of the seed, lots of variation were observed in baby fields sizes established. For the same amount of seed, farmers established varying baby trial fields, sizes ranging between 5-43 square metres among farmers in Hoima and 9-101 square metres in Rakai. On average, the spacing used by farmers in Hoima was closer to the recommended spacing and as a result, had better yield performance (Table 17).

Use of improper spacing is still a big challenge in as far as closing the yield gap is concerned. We observed that farmers also used varying planting methods which included intercropping, planting 2-3 seeds per hole instead one and the use of chop and planting method. All these led to either low or higher seed rate, resulting into poor land utilization and low yields. Also, in many cases farmers used different agronomic methods, some of which were poor while other methods they used were good. For the baby trials, farmers who used better agronomic practices had better yields, and were in some cases better than even the mother garden, for example, the yields obtained from Kakindu and Kyamalera baby trials in Hoima in 2013a (Table 17). The baby trials that were established in Hoima had better land utilisation rates than those in Rakai and thus had better yields. In general, farmers in Hoima tended to be more market oriented compared to farmers in Rakai, hence better management practices were observed in baby trials in Hoima. Similarly, relatively high average crop yields were observed in market oriented systems compared to low crop yields in subsistence oriented systems (Affholder et al. 2013).

Table 17. Yields and area planted from the baby trials in Hoima and Rakai in season 2013a

Variety	Hoima								Rakai							
	Yield (kg/ha)				Area planted (m^2)				Yield (kg/ha)				Area planted (m^2)			
	But	Mpa	Kya	Bya	But	Mpa	Kya	Bya	Aga	Kye	Gos	Kwe	Aga	Kyea	Gos	Kwe
NABE15	3	1,860	1,595	545	36	13	13	17	34	137	943	03	23	81	11	15
NABE2 (MCM 1015)	151	237	192		23	19	10	-	45	324		26	40	37	-	31
Farmer seed	69	-	-	852	14	-		05	12	-	540	04	16	-	13	19
RWR719	-	-	246	619		-	22	07	-	-	458	03	09	-	52	35
Masindi Yellow long	10	295	326	253	8	08	09	24	03	566	02	67	24	44	20	25
NABE17	257	-	748	317	8	-	09	22	8	356	221	12	13	28	09	16
ROBA1	4	372	750	2	43	19	16	42	20	-	393	274	24	-	25	25
KATX56	149	400	1,261	388	07	10	07	16	07	260	10	12	11	44	5	16
KATB1	1,684	321	833	-	05	06	05	-	-	232	03	44	15	30	18	12
KATB9	-	245	490	36	-	08	08	14	02	-	03	04	24	-	15	12
KATX69	-	2,555	578	335	-	09	16	18	-	188	163	05	16	43	49	22
NABE14 (RWR 2075)	4	175	299	18	43	11	08	27	35	317	470	90	14	49	13	23
CAL143	-	505	190	74	-	16	11	32	-	-	238	246	11	-	34	16
CAL96 (K132)	201	-	71	414	20	-	16	10	67	-	-	01	29	-	-	36
NABE21	233	1,826	76	285	17	10	20	28	28	221	-	-	101	54	-	-
Mean	**251**	**799**	**547**	**318**	**21**	**12**	**12**	**20**	**24**	**289**	**287**	**57**	**25**	**46**	**22**	**22**

Where: But =Butimba, Mpa=Mpalangasi, Kya=Kyakamese, Bya=Butyamba, Aga= Agaliawamu, Kye= Kyengeza, Gos= Gosola, Kwe= Kwewayo;
-=missing data,

3.3 Gender disaggregated analysis of farmer participatory bean variety selection and heterogeneity under conditions of climatic variability

3.3.1 Participatory variety selection in mother trials

The results of the weighted ranking of varieties are presented in Table 18 and Appendix 5. For the two seasons in 2013 (a and b), a total of 2293 votes were cast to select the three most preferred varieties and three worst varieties, with each variety having a potential threshold of 383 votes if selected by every farmer. The number of cards received by each variety in shown in Table 18 (column 1), including the percentage of the potential threshold number received by the variety (column 2). None of the varieties received half of threshold votes, implying a significant variability in farmers' preferences and trade-offs. Masindi Yellow long received the highest number of votes (41%), followed by *NABE2* (36.5%), while *RWR719* and *ROBA1* were third with nearly the same number of votes (one-third).

Table 18. Weighted ranking of varieties across the two seasons in 2013

Bean variety	Number of votes received	Percent of the total votes available	Percent of the received votes that are positive	Weighted ranking
Masindi Yellow long	157	41.0	92.4	0.38
Farmer seed	105	27.4	77.1	0.21
KATX56	99	25.9	64.7	0.17
KATB1	92	24.0	68.5	0.16
NABE15	92	24.0	60.9	0.15
KATX69	63	16.5	76.2	0.13
CAL143	82	21.4	57.3	0.12
NABE 17	80	20.9	56.3	0.12
ROBA1	127	33.2	30.7	0.10
RWR719	129	33.7	28.7	0.10
CAL96 (K132)	48	12.5	58.3	0.07
NABE14	108	28.2	24.1	0.07
KATB9	86	22.5	24.4	0.05
NABE2	140	36.6	14.3	0.05
NABE21	55	14.4	18.2	0.03

Results of the weighted ranking for each variety in two seasons, shows that Masindi Yellow long emerged the top most preferred variety, followed by farmer seed variety. Three varieties (i.e. *KATX56*, *NABE15* and *KATB1*) were ranked nearly the same. Masindi Yellow was ranked highly in both seasons, characterized by different weather conditions. The first season was characterized by limited rainfall with an early cessation, while rainfall in the second was adequate though with a delayed onset. This means that Masindi Yellow long is a well-adapted variety as perceived by farmers under variable climatic conditions. Similarly, the preference for farmer seed remained stable across the two seasons, a reflection of the fact that farmers had tested and confirmed it is adapted to their environment. Varieties from KARI Katumani (i.e. *KATX56*, *KATX69*) were ranked second and third in season 2013a (under low rainfall conditions), while they were outperformed by other varieties in season 2013b (i.e. adequate amounts of rainfall). Other varieties such as *CAL143* and *ROBA1* were ranked highly in season 2013b but did not do well in season 2013a, which explains why they dropped out in the cross season analysis.

The results are consistent with the literature (e.g. Sperling et al. 1993), where the most important positive traits that influenced farmers' ranking decision included yield, tolerance to weather fluctuations, early maturity, and suitability for intercrop. Yield was mostly assessed by the number of pods per plant, seeds per pod, pod filling ability and germination. Resistance for pests and diseases were assessed through plant architecture, a firm ground stand and attractive clean pods. Similar proxy traits for yield and pest and disease damage were reported by Asfaw et al. (2011). Since most of the varieties had acceptable post-harvest traits such as seed colour or grain sizes, they remained implicit on the list of traits used as criteria to rank varieties. The negative attributes of the varieties that recorded high positive votes were also reported and included undesirable colour but with good taste (by a woman in Butimba village, Hoima) and generally low yielding, and others low yielding under harsh conditions of low nutrient soils, drought and excessive rainfall. This showed the ability of the farmers to make selection even though the variety does not have all the desirable attributes (World Bank 1994). However, information from farmers involved in the baby trials on the importance of each trait (Table 19), revealed that marketability attributes ranked highest, and are more important to farmers than agronomic attributes. This is not surprising since bean has increasingly become an important source of household income; with nearly every farmer selling a proportion of the bean harvest.

Using weighted ranking, we also identified the least preferred varieties. Table 18 shows that while *NABE2* (*MCM1015*) received the second highest number of votes, most of these were negative, ranking it as the second worst variety, after *NABE21*. The ranking for both varieties was low in both seasons, suggesting farmers have systematically rejected the varieties irrespective of the climatic conditions. The most frequently cited reasons for low preference were poor marketability (manifested in poor colour that was black, small seeded), less adapted to drought conditions, and losses leaves quickly which means low yield. Attributes such as late maturing were also mentioned as less preferred but appreciated by some farmers "because if it is late maturing, the variety is good for staggered planting".

3.3.2 Socio economic evaluation of varieties in baby trials

The characteristics of the farmers who participated in baby trials were similar to those who participated in mother trials in many respects (not presented here due to limited space)—household size, education and scale of bean production. However, most of the plots allocated to baby trials were intercropped with maize, banana and other crops, with almost no external inputs like fertilizers, organic manure or pesticides applied.

Farmers participating in the baby trials were asked to rank different bean variety traits on a scale of 1 (less important) to 5 (extremely important). The results show that farmers prefer a wide range of common bean attributes that include marketability (demonstrated by grain size and colour, grain price), early maturing, yield, taste, cooking time, drought tolerant and uniform maturity, in order of importance. This reflects the wide range of production constraints faced by farmers in these study sites and the importance for varietal adaptation. Of these traits, four are agronomic, while the others relate to consumption attributes (Table 19).

Variety traits that seem less important included pest or disease tolerance, storability, nutritional value and palatability of beans. Regarding the gender differences in tagging importance to specific traits, there were no significant differences between men and women farmers with the exception of disease and drought tolerance, where women tagged more importance to these traits than men (Table 19.).

While significant investments have been directed to bio-fortification of beans, farmers attach low importance to the nutritional value of these traits, perhaps because there is a knowledge gap.

Table 19. Importance of bean variety traits to farmers and gender heterogeneity

Trait	Not important	Somehow important	Important	Very important	Extremely important	Average score	Gender differences
Marketability	7.1	7.1	2.4	47.6	35.7	4.0	ns
Grain price	7.1	4.8	14.3	42.9	31.0	4.0	ns
Early maturity	7.1	4.8	21.4	47.6	19.1	3. 7	ns
Yield	4.8	7.1	19.1	59.5	9.5	3.6	ns
Taste	14.3	2.4	28.6	38.1	16. 7	3.4	ns
Cooking time	14.3	9.5	19.1	40.5	16. 7	3.4	ns
Grain size	14.3	11.9	21.4	42.9	9.5	3.2	ns
Drought	11.9	11.9	33.3	40.5	2.4	3.1	*
Uniform maturity	16.7	14.3	23.8	38.1	7.1	3.1	ns
Grain colour	19.1	14.3	23.8	33.3	9.5	3.0	ns
Disease tolerance	21.4	9.5	31.0	31.0	7.1	2.9	*
Storability	31.0	14.3	28.6	16.7	9.5	2.6	ns
Nutritional value	35.7	11.9	26.2	16.7	2.4	2.3	ns
Leaf palatability	52.4	11.9	14.3	14.3	2.4	2.0	ns

3.3.3 Evaluation of varieties according to the most important traits

Farmers were asked to rate each variety according to the selected production and consumption traits. Results show that farmers perceived varieties as different in their levels of the most important traits preferred by households. Since the number of varieties given to each farmer was limited to three and the number of baby trials was few, all the varieties were assessed in combination to compare with locally grown varieties. The analysis showed that the varieties that were being evaluated had 45.2% chances of being ranked higher than a locally grown variety, consistent with the results from the mother trial that Masindi yellow and farmer seed were ranked as the best varieties.

3.3.4 Sources of heterogeneities in farmer variety preferences

Based on the Kruskal Wallis one-way analysis of variance by ranks, we found variation in the relative importance for two traits—drought tolerance and diseases resistance—between men and women farmers. More women were likely than men to attach higher importance to these traits. While men tend to be more market oriented, the results show both men and women farmers attached equal importance on market related traits, implying that research to adapt bean to climate change might benefit women more than men. The partial correlation results show variation among farmer voting of varieties that is correlated with the socioeconomic characteristics. In particular, there was variation in preferred varieties across sites, with farmers in Hoima likely to select Masindi Yellow and farmers' seed, while those in Rakai had higher preference for *NABE15* and *KATB1* (Table 20). This indicates that market-oriented farmers tend to be slower in adopting new varieties in the face of climate change compared to the subsistence farmers, until they are fully convinced of the market for the new variety and would rather invest in management. Masindi Yellow also received more positive preference from farmers with poor soils, while farmers with soils of good fertility tended to go for *KATB1,* while farmers with soils of average fertility preferred *KATX56*. This indicates the ease of adopting new varieties when there are no risks and the cautiousness in more risky environments. Finally, there was no correlation between variety preference and other household characteristics such as education level, landholding, and family size.

Table 20. Partial correlation of farmer socioeconomic characteristics and variety preference

Variable	NABE15	Masindi Yellow	Farmer seed	KATX56	KATB1
Age of participant	-0.229*	0.119	-0.036	-0.217*	-0.074
Gender of participant (1= female)	-0.218*	-0.178**	-0.106	0.291***	0.017
Number of household members	0.201*	-0.030	0.0319	0.0274	0.072
Years of formal education	0.120	0.037	-0.012	-0.123	0.098
Dummy=1 if soil fertility rate average	0.036	0.042	-0.170	0.199*	-0.229**
Dummy=1 if soil fertility rate poor	-0.012	0.174**	-0.145	0.123	-0.126
Landholding (ha)	0.002	-0.037	0.040	0.066	0.166
Area allocated to bean (ha)	-0.064	-0.034	0.093	0.091	-0.189*
District (1=Hoima)	-0.240**	0.294***	0.214**	-0.139	-0.204*

3.4 Comparing farmers and breeders criteria

The study shows that breeders and farmers look out for similar traits and in most cases end up with the same results. However, a few discrepancies do exist (Table 21 and 22). For instance, yield was the major driver to assess superiority of a variety by the breeders. Breeders believe that all the other traits such as disease resistance, pod number, plant height all contribute to yield. For farmers, other traits such as marketability were important for their selection. Marketability of a variety is based on size and colour of the seed. For example, even though *NABE2* performs highly with respect to disease resistance and yield, its preference among farmers is low because of its black seed colour. However, farmers perceive *NABE2* to be a superior variety in times of harsh climatic conditions due to its high yield. For the breeders, the best performing varieties were *NABE2*, *RWR719*, *NABE2*, *CAL143* and *NABE14*, while for the farmers the best varieties included Masindi Yellow, Farmer seed, *KATX56* and *KATB1* (Table 21 and 22). However, it is important to note that with the inclusion of PVS in breeding, breeders tend to merge the farmers and their own selections in recommending varieties for release and as such showing the power of PVS.

Table 21. Preference matrix for bean selection by researchers, female and male farmers in Hoima in 2013 (a and b) in nine villages

Researcher ranking	1	RWR719									RWR719			RWR719		
	2		NABE2												NABE2	
	3			NABE14								NABE14		NABE14		
	4				ROBA1						ROBA1	ROBA1				
	5					CAL143		CAL143		CAL143						
	6						CAL96		CAL 96							
	7			KATX69	KATX69			KATX69								
	8						NABE15		NABE15							
	9									NABE21			NABE21			
	10					NABE17				NABE17	NABE17					
	11				KATX56			KATX56				KATX56				
	12		FS										FS			
	13													KATB9		KATB9
	14	Masindi													Masindi	
	15			KATB1		KATB1										KATB1
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Farmers of Hoima (male and females') ranking														

Blue coloured cell = genotype rank by male farmers, plain = genotype rank by female farmers, Diagonal cells (green coloured cells) = genotypes ranking by researcher, Red colour = coincidence of the female and male farmers in ranking of a genotype, FS = Farmers' seed, Masindi = Masindi Yellow Long

NB: The horizontal distance between entries in a row depicts the difference in ranking by the different groups

Table 22. Preference matrix for bean selection by researcher, female and male farmers in Rakai in 2013 (a and b) in nine villages

Researcher ranking	1	RWR719												RWR719		RWR719
	2		NABE2										NABE2		NABE2	
	3			NABE14						NABE14					NABE14	
	4				ROBA1							ROBA1		ROBA1		
	5					CAL143					CAL143					CAL143
	6				CAL96		CAL96				CAL96					
	7							KATX 69					KATX69			
	8						NABE15		NABE15							
	9						NABE21		NABE21	NABE21						
	10				NABE17	NABE17					NABE17					
	11	KATX56										KATX56				
	12			FS						FS			FS			
	13					KATB9		KATB9						KATB9		
	14	Masindi		Masindi											Masindi	
	15		KATB1													KATB1
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Farmers of Rakai (male and females') ranking														

Blue coloured cell = genotype rank by male farmers, plain = genotype rank by female farmers, Diagonal cells (green coloured cells) = genotypes ranking by researcher, Red colour = coincidence of the female and male farmers in ranking of a genotype

NB: The horizontal distance between entries in a row depicts the difference in ranking by the different groups

4. Conclusions

Use of genetic resources is one of the options for small scale farmers in Africa to respond to climate variability and change. Common bean is key to reducing poverty and improving food security, providing an inexpensive source of protein for rural and urban households in Eastern and Southern Africa. Common bean production, however, is greatly affected by several challenges including drought, excessive rain, flooding, heat, and cold temperatures, pests and diseases. These challenges are predicted to increase with climate variability and change. This study evaluated different varieties of common beans with farmers in two sites in Uganda in order to establish the factors influencing bean productivity, learn about farmers' preferences and selection criteria, including heterogeneity among different social classes and gender under the prevailing climatic conditions.

A number of bean varieties were evaluated and included local landraces, farmer variety, varieties officially released in Uganda, and new germ plasm. Parameters used to assess the performance of each bean variety included days to 50% flowering, days to maturity, plant height, number of pods per plant, disease incidence and severity, and total and clean yield. The results clearly highlight differences in climate and weather patterns, edaphic factors and crop management practices within very small geographical areas (e.g. within a village), implying the need for farmers to have access to a widely adapted bean variety or a diverse range of bean varieties in order to address the effects of different factors. The results also show significant differences in agronomic parameters, disease resistance and yield among the varieties over the different environments.

Five mega environments characterized by similarities in clean yield performance were identified. No single bean variety performed best in more than one mega environment, indicating the specificity of the bean varieties to particular environmental factors. One variety (*NABE2)* performed well in all environments indicating that it was the most widely adaptable among the bean varieties. However, the grain of this variety is small and black in colour—characteristics that are not preferred by farmers. Some of the varieties, notably, *CAL143*, *NABE17* and Masindi yellow were stable—consistently performed well or performed poorly across the environments—indicating that the environment differences did not affect their performance and are unlikely to respond significantly to changes in management practices or environmental factors. In general, the improved bean varieties significantly outperformed the local varieties. However, the local landrace (Masindi yellow) was relatively stable and a good performer across all the sites proving to be widely adapted even though it was very susceptible to occurring diseases.

Use of improper spacing emerged as a major challenge in closing the common bean yield gap, with farmers usage of different planting methods leading to either low or higher seed rates and thus resulting into poor land utilization and low yields. Land utilisation was tagged towards market availability, with market oriented farmers having better land utilisation. Marketability (based on seed size and colour), yield and adaptability were the main factors influencing farmer selection of a particular bean variety. Other factors influencing farmer's selection included climate-related traits, with women more likely to attach higher importance to these traits compared to men. The results indicate high acceptability of some few promising bean varieties that can be promoted to a wider community, increasing the stock of bean varieties available to farmers for coping with climate variability. Also, farmers are not homogenous and some varieties though not popular were attractive to some individual farmers. Heterogeneity in farmer preferences between and within locations is a useful lesson for breeders and calls for scaling out evaluation of varieties in more locations to ensure that varieties are exposed to all categories of farmers.

The farmers' variety was ranked higher by farmers than many new varieties and is an important lesson for breeders working to enhance the adaptation of crop varieties to climate change. In addition to developing new ones, such varieties should be collected and also evaluated in new locations with similar conditions. Despite climate variability and hence risks, bean farmers demonstrate high preferences for marketability of their beans, implying that the magnitude of allowable trade-offs between market and adaptability are small. Hence enhancing the agronomic performance and adaptation to climate change will have to be addressed simultaneously with market needs. Another consideration is the production environment such as soil quality that dictates which varieties are suitable.

Some key lessons emerged from this study. First, there is need to promote marketing of the varieties preferred by the farmers as a means to improve their incomes. This could involve linking farmers to new markets, training in bean marketing or business, and exposure to innovative ways of increasing production to sustain markets. Second, nutrition related projects are needed to expose the benefits of beans and legumes in general as nutritious crops. Third, a strong seed system targeting the best performing varieties in the different environments is necessary, including linking the farmers to the existing markets. Fourth, an approach that encompasses farming systems in comparison to a single component in addressing climate change needs to be adopted in the PABRA network activities. Lastly, scaling out of the activities of this project to more sites in Uganda as well as in other countries in the East and Central Africa region, by testing a range of diverse bean varieties and crop management technologies under different environments and social economic contexts, utilising the CCAFS analogue sites tool to identify promising packages that farmers can adopt.

Appendices

Appendix 1. Soil nutrient and physical status of farmers trial plots in Phase I (2012a)

District	Sub county	Group name	Depth (cm)	PH	OM%	N%	P (ppm)	Ca (ppm)	Mg (ppm)	K (ppm)	Sand%	Clay%	Silt%	Textural Class
Hoima	Kyabagambire	Akumurukire	15	6.5	3.7	0.21	39.14	3810	724.7	925.22	66.4	24.32	9.28	Sandy Clay loam
Hoima	Kyabagambire	Akumurukire	30	6	5.2	0.24	trace	4250	786.9	330.82	22.4	60.32	17.28	clay
Hoima	Kiziranfumbi	Katweyambe	15	5	6	0.28	2.73	2327	647.5	150.88	38.4	40.32	21.28	clay
Hoima	Kiziranfumbi	Katweyambe	30	4.7	4.4	0.22	6.91	1814	466.4	126.36	38.4	44.32	17.28	clay
Hoima	Kiziranfumbi	Butimba	15	5.7	6.5	0.3	7.48	2288	678.4	184.2	58.4	28.32	13.28	Sandy Clay loam
Hoima	Kiziranfumbi	Butimba	30	5.3	4.2	0.2	1.73	4186	517.7	90	58.4	30.32	11.28	Sandy Clay loam
Hoima	Kyabagambire	Kyamalera	15	6	5.8	0.27	7.05	4045	705.7	568.28	48.4	34.32	17.28	Sandy Clay loam
Hoima	Kyabagambire	Kyamalera	30	5.4	4.6	0.22	2.01	2753	709.5	291.64	40.4	40.32	19.28	clay
Hoima	Kyabagambire	Kakindo	15	5.5	6.4	0.31	3.88	4792	806.7	208.72	44.4	40.32	15.28	clay
Hoima	Kyabagambire	Kakindo	30	5.4	6	0.27	1.58	1349	732.2	142.68	44.4	35.04	20.56	clay loam
Rakai	Kasaali	Kwewayo	15	5.7	3.1	0.18	17.84	3765	408.8	98.36	56.4	30.32	13.28	Sandy Clay loam
Rakai	Kasaali	Kwewayo	30	5.6	2.9	0.18	7.19	1515	330.4	63.2	62.4	20.32	17.28	Sandy Clay loam
Rakai	Lwanda	Twezimbe	15	5	6.9	0.32	20.86	1145	341.1	256.22	20.4	37.04	42.56	clay loam
Rakai	Lwanda	Twezimbe	30	4.6	7	0.31	11.22	3007	364.8	215.18	18.4	37.04	44.56	Silty clay loam
Rakai	Kasaali	Agaali awamu	15	5.7	6.3	0.28	1.73	3353	826	521.96	24.4	49.04	26.56	clay
Rakai	Kasaali	Agaali awamu	30	6.3	3.4	0.18	25.05	3592	489.6	726.02	62.4	23.04	14.56	Sandy Clay loam
Rakai	Lwanda	Kiyovu		5.7	5.1	0.26	54.39	3625	629.9	177.78	48.4	27.04	25.56	Sandy Clay loam
Critical values				5.2	3	0.2	<90	350	100	150				
Sufficient levels				5.2-7	6	0.3	90-230	2000	600	500				

Appendix 2. Soil nutrient levels for trial sites (2013a)

District	Sub-county	Group name	Depth (cm)	PH	OM%	N%	P (ppm)	Ca (ppm)	Mg (ppm)	K (ppm)	Sand %	Clay%	Silt%	Textural Class
Hoima	Kyabigambire	Kakindo	0-15	5.9	10.1	0.41	20.02	2639.22	716.90	374.48	45.7	29.0	25.3	Sandy clay loam
Hoima	Kyabigambire	Kakindo	15-30	5.5	8.8	0.38	4.06	2622.77	538.98	376.16	43.7	33.0	23.3	Sandy clay loam
Hoima	Kyabigambire	Akumlikire	0-15	5.7	6.7	0.30	1.47	1849.43	542.21	255.78	41.7	37.0	21.3	Clay loam
Hoima	Kyabigambire	Akumlikire	15-30	5.6	8.4	0.35	1.06	1405.17	474.27	156.70	39.7	41.0	19.3	Clay
Hoima	Kyabigambire	Kyamalera	0-15	5.6	6.2	0.28	4.20	2754.40	691.02	471.04	47.7	31.0	21.3	Sandy clay loam
Hoima	Kyabigambire	Kyamalera	15-30	5.4	6.4	0.31	0.65	2227.88	603.68	374.20	47.7	35.0	17.3	Sandy loam
Hoima	Kiziranfumbi	Butimba	0-15	5.7	7.2	0.34	53.02	2524.05	616.61	337.24	47.7	27.0	25.3	Sandy clay loam
Hoima	Kiziranfumbi	Butimba	15-30	5.5	7.3	0.31	28.75	1783.61	519.57	296.10	53.7	27.0	19.3	Sandy clay loam
Hoima	Kiziranfumbi	Butyamba	0-15	5.4	6.3	0.28	2.56	2392.42	687.79	209.04	47.7	35.0	17.3	Sandy clay
Hoima	Kiziranfumbi	Butyamba	15-30	5.3	3.8	0.18	3.52	1668.44	629.55	116.94	49.7	37.0	13.3	Sandy clay
Rakai	Kasali	Agaliawamu	0-15	5.5	4.8	0.22	8.56	1092.55	215.46	158.66	71.7	21.0	7.3	Sandy clay loam
Rakai	Kasali	Agaliawamu	15-30	5.5	3.4	0.20	2.70	993.82	173.41	103.24	67.7	21.0	11.3	Sandy clay loam
Rakai	Lwanda	Twezimbe	0-15	5.7	5.6	0.26	1.61	2326.59	606.91	154.46	29.7	33.0	37.3	Sandy clay laom
Rakai	Lwanda	Twezimbe	15-30	5.6	6.9	0.31	0.79	2112.70	435.44	113.04	29.7	33.0	37.3	Sandy clay loam
Rakai	Lwanda	Kiyovu	0-15	5.6	7.4	0.35	52.07	2277.24	490.45	197.28	57.7	23.0	19.3	Sandy clay loam
Rakai	Lwanda	Kiyovu	15-30	5.5	7.4	0.35	73.89	2260.78	419.28	83.36	57.7	25.0	17.3	Sandy clay loam
Rakai	Lwanda	Kwewayo	0-15	5.2	6.1	0.27	3.65	1454.53	503.39	10.02	59.7	21.0	19.3	Sandy clay loam
Rakai	Lwanda	Kwewayo	15-30	5.3	4.4	0.23	1.47	1635.52	412.80	2.74	59.7	23.0	17.3	Sandy clay loam
Critical values				5.2	3.0	0.2	<90	350	100	150				
Sufficient values				5.2-7.0	6.0	0.3	90-230	2000	600	500				

Appendix 3. Soil nutrient levels for trial sites (2013b)

District	Sub-county	Name of group	Depth (cm)	PH	OM%	N%	P (ppm)	Ca (ppm)	Mg (ppm)	K (ppm)	Sand%	Clay%	Silt%	Textual class
Hoima	Kiziranfumbi	Butimba	0-15	5.8	4.5	0.22	4.16	2131.4	793.4	46.8	53.1	33.6	13.3	Sandy clay loam
Hoima	Kiziranfumbi	Butimba	15-30	6.2	3.9	0.20	7.84	2801.7	1116.0	144.7	53.1	31.6	15.3	Sandy clay loam
Hoima	Kyabigambire	Kyamaleera	0-15	6.1	4.8	0.25	5.21	3119.5	1061.0	159.4	47.1	35.6	17.3	Sandy clay
Hoima	Kyabigambire	Kyamaleera	15-30	5.9	5.4	0.25	3.63	2852.6	1018.0	83.5	45.1	39.6	15.3	Sandy clay
Hoima	Kyabigambire	Kakindo + DAP	0-15	7.0	3.7	0.20	75.74	3966.2	1107.0	313.7	41.1	39.6	19.3	Clay loam
Hoima	Kyabigambire	Kakindo + DAP	15-30	6.8	5.0	0.24	53.89	3870.1	1133.0	265.1	47.1	41.6	11.3	Clay
Hoima	Kyabigambire	Akumulire	0-15	6.7	8.2	0.35	27.58	3495.7	991.6	276.4	41.1	39.6	19.3	Clay loam
Hoima	Kyabigambire	Akumulire	15-30	6.8	8.7	0.40	11.92	3047.1	866.9	207.1	41.1	39.6	19.3	Clay laom
Hoima	Kyabigambire	Kyamaleera + DAP	0-15	6.1	6.7	0.30	5.74	2989.4	1062.0	99.8	47.1	35.6	17.3	Sandy clay
Hoima	Kyabigambire	Kyamaleera + DAP	15-30	6.0	5.5	0.26	3.24	2639.9	1034.0	57.5	49.1	39.6	11.3	Sandy clay
Hoima	Kiziranfumbi	Butyamba	0-15	5.6	5.4	0.25	4.42	1764.3	991.7	44.7	49.1	35.6	15.3	Sandy clay
Hoima	Kiziranfumbi	Butyamba	15-30	5.4	4.9	0.22	16.26	3504.7	1053.0	84.5	47.1	39.6	13.3	Sandy clay
Hoima	Kyabigambire	Kakindo - DAP	0-15	6.5	6.8	0.31	2.84	1534.1	853.3	35.2	49.1	39.6	11.3	Sandy clay
Hoima	Kyabigambire	Kakindo -DAP	15-30	6.5	7.7	0.34	28.76	3644.4	1072.0	103.5	47.1	35.6	17.3	Sandy clay
Rakai	Lwanda	Kyengeza	0-15	6.5	4.4	0.22	23.20	3399.2	989.9	123.8	59.7	21.0	19.3	Sandy clay loam
Rakai	Lwanda	Kyengeza	15-30	6.6	4.4	0.23	17.00	3357.5	966.4	75.1	59.7	23.0	17.3	Sandy clay loam
Rakai	Kasali	Agaliawamu	0-15	5.9	2.5	0.15	15.90	1014.5	331.3	51.1	71.7	21.0	7.3	Sandy clay loam
Rakai	Kasali	Agaliawamu	15-30	5.8	2.1	0.14	23.30	929.3	288.2	20.1	67.7	21.0	11.3	Sandy clay loam
Rakai	Lwanda	Kwewayo	0-15	13.1	4.4	0.23	18.00	2188.5	821.1	76.1	57.7	23.0	19.3	Sandy clay loam
Rakai	Lwanda	Kwewayo	15-30	5.9	3.3	0.18	21.70	1962.0	662.5	35.9	57.7	25.0	17.3	Sandy clay loam
Rakai	Lwanda	Kiyovu	0-15	5.8	4.6	0.24	15.60	2221.8	778.9	131.1	67.7	21.0	11.3	Sandy clay loam
Rakai	Lwanda	Kiyovu	15-30	5.4	2.9	0.16	16.40	1345.9	470.2	76.0	57.7	27.0	15.3	Sandy clay loam
Critical values				5.2	3.0	0.2	<90	350	100	150				
Sufficient values				5.2-7.0	6.0	0.3	90-230	2000	600	500				

Appendix 4.Classification of mehlich 3 extractable nutrients

	P	K	Ca	Mg
Very low	<45	<55	<330	<17
Low	45-90	55-95	330-655	17-46
Medium	90-230	95-150	655-1640	46-87
High	230-310	150-300	1640-3280	87-145
Very high	>310	>300	>3280	>145

Source: *Soil and Plant Analytical Laboratories, NARL*

Appendix 5. Weighted ranking of varieties across the two seasons

	Season 1				Season 2			
Variety	# votes received	% of the total votes available	% of positive votes received	weighted score1	# votes received	% of the total votes available	% of positive votes received	weighted score2
Masindi Yellow long	113	61.4	96.5	0.59	44	22.1	81.8	0.18
KATX56	63	34.2	85.7	0.29	36	18.1	27.8	0.05
KATX69	52	28.3	84.6	0.24	11	5.5	36.4	0.02
Farmer seed	52	28.3	78.9	0.22	53	26.6	75.5	0.20
NABE15	52	28.3	73.1	0.21	40	20.1	45.0	0.09
KATB1	47	25.5	70.2	0.18	45	22.6	66.7	0.15
RWR719	64	34.8	23.4	0.08	65	32.7	33.9	0.11
NABE17	28	15.3	46.4	0.07	52	26.1	61.5	0.16
NABE14 (RWR 2075)	63	34.4	12.7	0.04	45	22.6	40.0	0.09
NABE2 (MCM 1015)	73	39.7	9.6	0.04	67	33.7	19.4	0.07
KATB9	38	20.7	18.4	0.04	48	24.1	29.2	0.07
NABE21	18	9.8	33.3	0.03	37	18.6	10.8	0.02
ROBA1	70	38.0	7.1	0.03	57	28.6	59.7	0.17
CAL143	24	13.0	12.5	0.02	58	29.2	75.9	0.22
CAL96 (K132)	22	12.0	13.6	0.02	26	13.1	96.2	0.13

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