Participatory farmers' selection of common bean varieties (Phaseolus vulgaris L.) under different production constraints

Citation:

Awio, Bruno, Katungi, Enid, Nkalubo, T. Stanley, Mukankusi, Clare, Malinga, Geoffrey Maxwell, Gibson, Paul, Rubaihayo, Patrick, Edema, Richard (2018). Participatory farmers' selection of common bean varieties (Phaseolus vulgaris L .) under different production constraints. Plant Breeding, 1-7 p.

Publisher's DOI:
http://doi.org/10.1111/pbr.12594

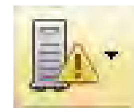
Access through CIAT Research Online:
http://hdl.handle.net/10568/92820

WILEY
Online Proofing System Instructions

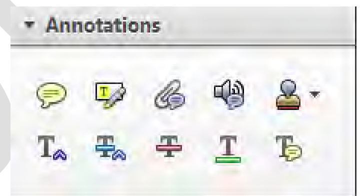
The Wiley Online Proofing System allows proof reviewers to review PDF proofs, mark corrections, respond to queries, upload replacement figures, and submit these changes directly from the locally saved PDF proof.

1. For the best experience reviewing your proof in the Wiley Online Proofing System ensure you are connected to the internet. This will allow the PDF proof to connect to the central Wiley Online Proofing System server. If you are connected to the Wiley Online Proofing System server you should see a green check mark icon above in the yellow banner.


Connected


Disconnected

2. Please review the article proof on the following pages and mark any corrections, changes, and query responses using the Annotation Tools outlined on the next 2 pages.



3. Save your proof corrections by clicking the "Publish Comments" button in the yellow banner above. Corrections don't have to be marked in one sitting. You can publish comments and log back in at a later time to add and publish more comments before you click the "Complete Proof Review" button below.

4. If you need to supply additional or replacement files bigger than 5 Megabytes (MB) do not attach them directly to the PDF Proof, please click the "Upload Files" button to upload files:

Upload files

Click Here

5. When your proof review is complete and all corrections have been published to the server by clicking the "Publish Comments" button, please click the "Complete Proof Review" button below:

IMPORTANT: Did you reply to all queries listed on the Author Query Form appearing before your proof?

IMPORTANT: Did you click the "Publish Comments" button to save all your corrections? Any unpublished comments will be lost.

IMPORTANT: Once you click "Complete Proof Review" you will not be able to add or publish additional corrections.

Complete Proof Review

Click Here

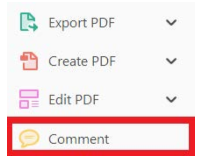
For technical questions about reviewing your proof contact OPS-Support@sps.co.in

USING e-ANNOTATION TOOLS FOR ELECTRONIC PROOF CORRECTION

Required software to e-Annotate PDFs: Adobe Acrobat Professional or Adobe Reader (version 11 or above). (Note that this document uses screenshots from Adobe Reader DC.)
The latest version of Acrobat Reader can be downloaded for free at: http://get.adobe.com/reader/

Once you have Acrobat Reader open on your computer, click on the Comment tab (right-hand panel or under the Tools menu).

This will open up a ribbon panel at the top of the document. Using a tool will place a comment in the right-hand panel. The tools you will use for annotating your proof are shown below:

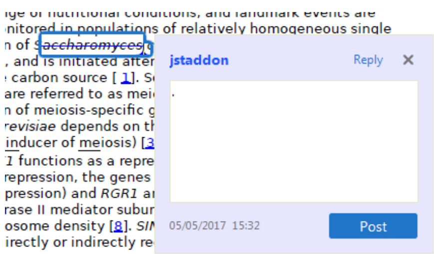


1. Replace (Ins) Tool – for replacing text.

Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it:

- Highlight a word or sentence.
- Click on .
- Type the replacement text into the blue box that appears.

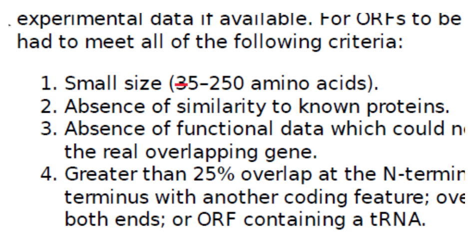


2. Strikethrough (Del) Tool – for deleting text.

Strikes a red line through text that is to be deleted.

How to use it:

- Highlight a word or sentence.
- Click on .
- The text will be struck out in red.

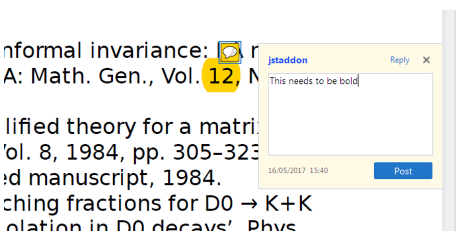


3. Commenting Tool – for highlighting a section to be changed to bold or italic or for general comments.

Use these 2 tools to highlight the text where a comment is then made.

How to use it:

- Click on .
- Click and drag over the text you need to highlight for the comment you will add.
- Click on .
- Click close to the text you just highlighted.
- Type any instructions regarding the text to be altered into the box that appears.

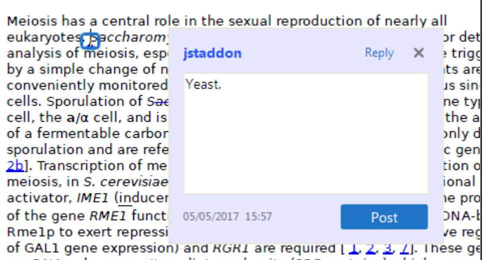


4. Insert Tool – for inserting missing text at specific points in the text.

Marks an insertion point in the text and opens up a text box where comments can be entered.

How to use it:

- Click on .
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the box that appears.



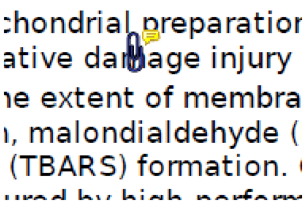
5. Attach File Tool – for inserting large amounts of text or replacement figures.

Inserts an icon linking to the attached file in the appropriate place in the text.

How to use it:

- Click on  .
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.

The attachment appears in the right-hand panel.

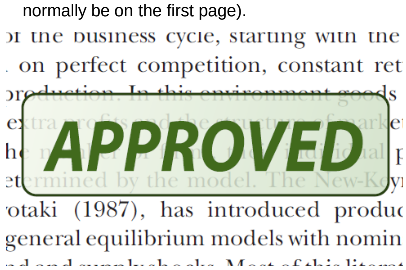


6. Add stamp Tool – for approving a proof if no corrections are required.

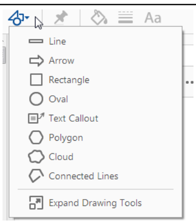
Inserts a selected stamp onto an appropriate place in the proof.

How to use it:

- Click on  .
- Select the stamp you want to use. (The Approved stamp is usually available directly in the menu that appears. Others are shown under *Dynamic*, *Sign Here*, *Standard Business*).
- Fill in any details and then click on the proof where you'd like the stamp to appear. (Where a proof is to be approved as it is, this would normally be on the first page).



Drawing tools available on comment ribbon

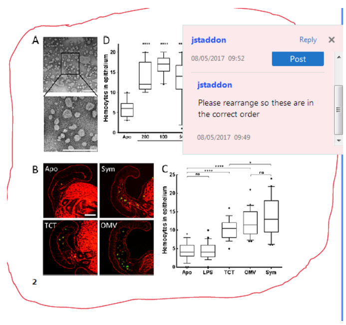


7. Drawing Markups Tools – for drawing shapes, lines, and freeform annotations on proofs and commenting on these marks.

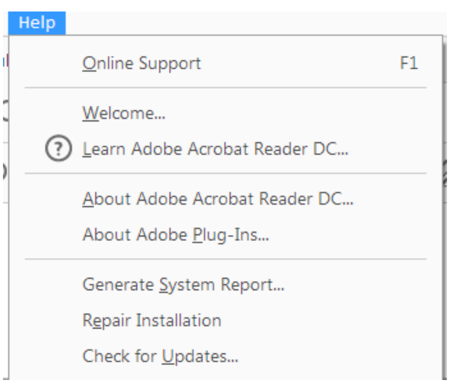
Allows shapes, lines, and freeform annotations to be drawn on proofs and for comments to be made on these marks.

How to use it:

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, right-click on shape and select *Open Pop-up Note*.
- Type any text in the red box that appears.



For further information on how to annotate proofs, click on the Help menu to reveal a list of further options:



Author Query Form

WILEY

Journal: PBR

Article: 12594

Dear Author,

During the copyediting of your manuscript the following queries arose.

Please refer to the query reference callout numbers in the page proofs and respond to each by marking the necessary comments using the PDF annotation tools.

Please remember illegible or unclear comments and corrections may delay publication.

Many thanks for your assistance.

AUTHOR: Please note that missing content in references have been updated where we have been able to match the missing elements without ambiguity against a standard citation database, to meet the reference style requirements of the journal. It is your responsibility to check and ensure that all listed references are complete and accurate.

Query reference	Query	Remarks
1	AUTHOR: As per journal style authority name (L.) is not allowed in the title. Please check and approve.	✓
2	AUTHOR: Please verify that the linked ORCID identifiers are correct for each author.	✓
3	AUTHOR: Please confirm that given names (red) and surnames/family names (green) have been identified correctly.	✓
4	AUTHOR: Please check that authors and their affiliations are correct.	✓
5	AUTHOR: The term "sub-counties" has been changed to "subcounties" throughout the article as per the Wiley house style guide. Kindly check.	✓
6	AUTHOR: Aseffa et al. 2005 has been changed to Assefa et al., 2014 so that this citation matches the Reference List. Please confirm that this is correct.	✓
7	AUTHOR: Please check and confirm the edits made in the sentence "The approach helps…varietal selection criteria"	
8	AUTHOR: Please provide an appropriate table footnote to explain the italics values and "***" in Table 3.	✓
9	AUTHOR: Please provide an appropriate table footnote to explain the bold values in Table 5.	✓
10	AUTHOR: De Ron et al. (2004) has not been included in the Reference List, please supply full publication details.	✓

Funding Info Query Form

Please confirm that the funding sponsor list below was correctly extracted from your article: that it includes all funders and that the text has been matched to the correct FundRef Registry organization names. If a name was not found in the FundRef registry, it may not be the canonical name form, it may be a program name rather than an organization name, or it may be an organization not yet included in FundRef Registry. If you know of another name form or a parent organization name for a “not found” item on this list below, please share that information.

FundRef name	**FundRef Organization Name**
Climate Change, Agriculture and Food Security (CCAFS)	

Received: 5 November 2017 | Accepted: 14 March 2018

DOI: 10.1111/pbr.12594

ORIGINAL ARTICLE

WILEY Plant Breeding

Participatory farmers' selection of common bean varieties (*Phaseolus vulgaris* L.) under different production constraints

Awio Bruno[1] | Enid Katungi[2] | Nkalubo T. Stanley[3] | Mukankusi Clare[2] | Malinga G. Maxwell[4,5] | Gibson Paul[1] | Rubaihayo Patrick[1] | Edema Richard[1]

[1]Department of Agricultural Production, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda

[2]International Centre for Tropical Agriculture (CIAT), Kampala, Uganda

[3]National Crops Resources Research Institute, Kampala, Uganda

[4]Department of Biology, Gulu University, Kampala, Uganda

[5]Department of Environmental and Biological Sciences, University of Eastern Finland, Joensuu, Finland

Correspondence
Awio Bruno, Department of Agricultural Production, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.
Email: awiobruno14@gmail.com.

Funding information
Climate Change, Agriculture and Food Security (CCAFS)

Communicated by: Wolfgang Link

Abstract

On-farm evaluation of 15 common bean varieties was undertaken with nine farmer groups under two fertilizer applications levels in four subcounties of Hoima and Rakai districts for two seasons to select farmers' desired and undesired varieties. Farmers' votes for acceptance and rejection of varieties at podding stage were converted to a preference index, and analysis of variance was conducted to examine differences in farmers' preference indices among subcounties and combined across subcounties, seasons, management and gender. Management had no-significant influence on the way farmers selected varieties in the subcounties. Choice of varieties varied significantly ($p \leq .001$) between seasons and gender in the different subcounties. Variety Masindi Yellow Long and Farmers' seed (Kaduli), and the introduced KATB1 were accepted by farmers due to their medium seed size, desired seed colour and potential of varietal adaptability to their farm conditions. Varieties NABE2, ROBA1 and RWR719 were deselected due to possession of traits less desired in the market. These results demonstrate the need for breeding programmes to involve diverse stakeholders in capturing the diverse traits preferences in varietal development process.

KEYWORDS

farmer evaluation, food security, grain legumes, participatory research

1 | INTRODUCTION

Common bean (*Phaseolus vulgaris*) is the most important legume grown by subsistence farmers in a range of farming systems in Africa either as a sole crop and or as an intercrop in banana, cassava and maize gardens. The grain yields under the varying systems are declining due to the farmers' continued use of landrace and old released varieties, declining soil fertility, drought, pest and diseases. Based on a survey conducted from 2003 to 2005, the share of improved varieties being grown by farmers was on the rise although this was still regarded as low with the estimated adoption rates of 31% in Uganda, 19% in Rwanda, 9.5% in Zambia and 45.8% in Tanzania, respectively (Muthoni & Andrade, 2015). The old varieties released earlier than 1996 were found to occupy over half of the share of improved varieties grown (Muthoni & Andrade, 2015) probably as a result of a combination of limited varietal promotion by research and extension services, and the lack of specific adaptation of the varieties to farmers' fields due to poor choice of environments for varietal evaluations before variety release. To increase the number of new varieties adopted and the scale of their production, there will be a need for farmers to participate in the selection of varieties that are adapted to their farm conditions and with consumption and market preferences.

Participatory variety selection (PVS) has been identified as a vital tool for enhancing variety adoption rates in farming communities (Assefa et al., 2014). The approach helps reduce the amount of time required to move varieties to the farmers' field and determine varieties that farmers want to grow, learn traits that farmers value and determine the gender differences in varietal selection criteria (Gridley, Jones, & Wopereis-pura, 2002). Studies show that varieties identified this way are quickly adopted and widely disseminated by farmers through the informal networks (Aw-Hassan, Mazid, & Salahieh, 2008) such as friends, neighbours and social groups within communities (Katungi, Edmeades, & Smale, 2008). In PVS trials, farmers are involved in the evaluation of released varieties or advanced promising lines from breeding pipelines. A number of successful implementation of this approach have been documented in Africa and Asia. For instance, the adoption of a range of crop varieties released in the 1990s achieved in Rwanda, Uganda, Kenya and Malawi has been attributed to farmers' participation (Weltzien, Smith, Meitzner, & Sperling, 2003). However, it is noted that in the farmers' selection, a single variety does not normally supply all the farmer's preferred traits, and thus, a combination of criteria is often employed by farmers in the actual selection of varieties. These combinations of desired traits may vary from individual to individual, gender groups and locations (Asfaw, Almekinders, Blair, & Struik, 2011) and may be affected by improvement in fertilizer management (Dereje et al., 2017).

Over the past years, the international centre for tropical agriculture (CIAT) and the bean national research programmes have developed improved bean varieties that have high nutritional values, are resistant to diseases and pests, and show high resilience to harsh growing conditions. These should provide farmers with diverse options required for adapting to the changing climatic condition. In Uganda, Hoima and Rakai districts experience contrasting climatic conditions that are typical of conditions in different agro-ecologies in the country. Hoima district is getting wetter and Rakai becoming drier (Förch, Kristjanson, Thornton, & Kiplimo, 2011). The soils in both districts are also degraded and fertility has continued to decline (Förch et al., 2011) and as such farmers in the districts have adjusted their farming systems to adapt their crop production to suit the conditions (Kyazze & Kristjanson, 2011; Mubiru & Kristjanson, 2012). Based on these backgrounds, a study was initiated to assess resident farmers' preferences on a given set of varieties with traits that are able to address production constraints such as drought, diseases, low soil fertility and nutrition. Our specific objectives were to identify farmers preferred varieties and to find out whether the selections of varieties can be affected by seasons and fertilizer management.

2 | MATERIALS AND METHODS

Farmer managed experimental field trials were set up in nine villages: five in Hoima and four in Rakai districts in Uganda where beans are commonly grown and form a major source of people's livelihoods (UBOS 2010). The trials were conducted in the two seasons of 2013 (March–June and August–December). Rakai district that is located in the Kagera Basin (south-western Uganda) receives annual rainfall in the range of 850–2,125 mm, which falls bimodally, peaking from March to May and October to November (Kimbugwe, 2013). However, declines in the amounts of rainfall and the number of rainy days in these months were reported by Mubiru et al. (2015). The mean annual temperature was 25°C, with a range of 15–27°C (Kimbugwe, 2013), and an increasing trend of about 0.5°C per year (Mubiru et al., 2015). On the other hand, Hoima district that is located in the Albertine Rift valley, central western Uganda, receives a mean annual rainfall of 1,270 mm with a range of 800–1,400 mm, during March to May and August to November. The district experiences increasing amounts of rains in January, March and August with declining trends in certain months (Mubiru et al., 2015). In these two districts, the studies were conducted in two villages per subcounty except in Kyabigambire subcounty in Hoima district where the experiments were in three villages (Table 1).

The trials were set up in a split plot design with two fertilizer application treatments (DAP and no DAP) as the main plots and 15 bean varieties as the subplots with two replications. The varieties included four Katumani bean varieties selected for drought tolerance, seven disease-resistant varieties, three farmer-preferred varieties and one variety with a high iron content (Table 2). DAP fertilizer of 150 kg was broadcasted in two of the four main plots measuring 40.5 × 7 m each. The replications for the management levels were laid side-by-side for ease of fertilizer application and farmer participation in the choice of variety. The fifteen varieties were sown in the subplots measuring 3 × 2 m within each main plot. Varieties were sown between 4 and 9 April 2013 in season 2013A and, from 12 to 15 August 2013 and 9 to 12 September 2013 in the season 2013B in Hoima and Rakai districts, at a spacing of 50 cm between rows and 10 cm between plants in a four-row plot. The experiments were hand weeded twice in the growing cycle, and the first and second weeding was carried out 3 weeks after planting and then before flowering, respectively, in 2013A and 2013B. The harvesting of the trials was performed from 25 to 28 June in 2013A and from 9 to 21 December in 2013B.

Farmers participated in selecting their preferred varieties at pod filling stage from the two outer blocks with DAP and no-DAP

TABLE 1 Villages and subcounties in Rakai and Hoima districts, Uganda where experimental field trials were conducted

District	Subcounty	Villages	Altitude (masl)	Average distance between sites (km)
Rakai	Lwanda	Kyengeza[a], Gosola[a]	1,177–1,243	8.5
	Kasali	Kalagala[a], Ninzi[a]	1,064–1,084	9.4
Hoima	Kiziranfumi	Mpalangasi, Kyakamese, Ngobi	1,202–1,241	7.0
	Kyabigambire	Butimba, Butyamba	1,202–1,241	7.0

[a]Sites selected by the Climate Change, Agriculture and Food Security (CCAFS) in 2010 as areas where innovations that are resilient to climate change could be evaluated and later transferred to locations with similar soil and climatic conditions (Förch et al., 2011).

TABLE 2 Common bean genotypes evaluated in Hoima and Rakai district in 2013A and 2013B of 2013

Genotype	Origin of seed	Year of release	Attributes
CAL 96	Uganda	1995	Popular variety, disease susceptible check
NABE 2	Uganda	1995	Drought tolerance, resistant to BCMVD
NABE 14	Uganda	2006	Resistance to root rot
NABE 15	Uganda	2010	Resistance to Bean anthracnose
NABE 17	Uganda	2010	Resistance to anthracnose, BCMVD, ALS
NABE 21	Uganda	2012	Resistance to anthracnose, BCMVD, ALS
Masindi Yellow Long	Uganda	Released	Farmer and consumer preferred
Farmers' seed	Uganda	Landrace	Farmer and consumer preferred
KAT B1	Kenya	1987	Drought tolerance (Escape mechanism)
KAT B9	Kenya	1998	Heat and drought tolerance
KATX 56	Kenya	1995	Drought tolerance
KATX 69	Kenya		Drought tolerance
CAL143	Malawi	1996	Resistance to angular leaf spot (ALS)
ROBA 1	TZ, DRC and Ethiopia		High iron, high yield & resistant to multiple stresses
RWR 719	Rwanda and Ethiopia	2003 and 90s	High yield, resistant to root rot and other diseases

Source: PABRA database (2014), BCMVD, bean common mosaic virus disease.

fertilizer management for ease of supervision by researchers during the voting process. A total of 164 and 174 farmers participated in 2013A and 2013B, respectively. Of these, 45 farmers were from Kasaali, 14 farmers were from Lwanda in Rakai district, and 46 farmers were from Kyabigambire and 59 farmers were from Kiziranfumbi subcounty in Hoima district in 2013A. The same farmers participated in selecting the varieties in 2013B, though with an increase in the number of participants more so in Lwanda subcounty. For farmers' selection of their preferred and/or best-performing bean varieties, each of the farmers was given two sets of three cards, each set with distinctive colours to make a total of six cards. The two distinct colours represent either acceptance or rejection of a particular variety, respectively. The cards of white and yellow colour were for voting for the best varieties, whereas blue and pink coloured cards were for choosing the least desired varieties by men and women, respectively. The farmers were guided through the voting process under the non-fertilized block, first to choose their three best varieties and thereafter the three least preferred varieties. On completion of voting under the non-fertilizer block, farmers were also led through the fertilizer management block to choose also their best and worst varieties. The farmers were unaware of the status of the treatments in each block. Focus group discussions were conducted, separately for men and women, at the end of the voting sessions to discuss the selection criteria the farmers used in the variety selection (voting) process and recorded.

2.1 | Data analysis

The sum of the votes for each of varieties selected by the farmers was evaluated separately for positive and negative votes under the two management levels in the nine villages. The preference index (PI) for each variety was calculated using the formula proposed by Ntare and Ndjeunga (2009). The analysis of variance was performed on the preference index using R-software (R Core Team, 2013) to determine the relative magnitude of the sources of variation towards the selection of the varieties by farmers. Each village in a subcounty was considered as a replicate for each of the management levels resulting in two replications in Kasaali, Kiziranfumbi and Lwanda and three replications in Kyabigambire subcounties. In the analysis, replication nested in a subcounty and season, management, subcounty, variety, gender and the associated interactions were considered as random factors and variety and management level as fixed factors. The significance of the main effects of variety and management, subcounty and seasons, and the interaction mean squares were tested at an alpha level of 0.05, with testing denominators chosen based on the contributions of the interaction effect to the variability (Table 2). The means were separated using Fishers' protected least significant difference (LSD) method.

3 | RESULTS

The selection of varieties by farmers was significantly ($p < .001$) different in the different seasons (Table 3). Similarly, highly significant ($p < .001$) interaction of subcounty-by-season-by-variety and subcounty-by-gender-by-variety were also found (Table 3). However, no-significant interaction in preference index between subcounty-by-management-by-variety interactions was registered ($p > .05$, Table 3).

3.1 | Variety-by-season

In the choices made by farmers, varieties Masindi Yellow Long, Farmers' seed and NABE 15 were the most preferred whereas varieties NABE 2, KAT B9, RWR 719 and ROAB1 were the least preferred varieties over the seasons (Table 4). Farmers showed a high preference for varieties KAT B1, KATX 69 and KATX 56 in 2013A but an intermediate preference in 2013B (Table 4). On the other hand, varieties CAL96, NABE 17 and CAL143 were most preferred in the 2013B than in 2013A (Table 4).

TABLE 3 Combined analysis of variance for preference index of selected bean varieties by farmers of Hoima and Rakai districts for two seasons of 2013. The minimum value of the preference index was −0.148, and the maximum was 0.159

N/O	Sources of variation	*df*	Mean squares	Testing term
1	Subcounty	3	3	5
2	Season	1	8	5
3	Management	1	46	6
4	Gender	1	2	8
5	Subcounty × season	3	65	11
6	Subcounty × Management	3	20	13
7	Season × Management	1	64	11
8	Subcounty × gender	3	11	12
9	Season × gender	1	52	12
10	Management × gender	1	1	13
11	Subcounty × season × Management	3	25	15
12	Subcounty × season × gender	3	41	15
13	Subcounty × Management × gender	3	35	15
14	Season × Management × gender	1	2	15
15	Subcounty × season × Management × gender	3	21	16
16	*Rep/(subcounty, season)*	*9*	*30*	*17*
17	*Rep/(subcounty, season) × Management*	*9*	*32*	*29*
18	Variety	14	11114	20
19	Subcounty × Variety	42	1462	20
20	Season × Variety	14	5927***	23
21	Management × Variety	14	445	24
22	Gender × Variety	14	724	26
23	Subcounty × season × Variety	42	1598***	29
24	Subcounty × Management × Variety	42	699	29
25	Season × Management × Variety	14	581	29
26	Subcounty × gender × Variety	42	1466***	29
27	Season × gender × Variety	14	374	29
28	Management × gender × Variety	14	382	29
29	Residual	674	658	

3.2 | Farmers' selection of bean varieties by subcounties and seasons

Masindi Yellow Long was the most preferred variety in both seasons in all subcounties except in Kasaali-Rakai and Lwanda-Rakai in 2013B (Table 5). Varieties KATX 56 in Kasaali-Rakai and KAT B1 and NABE 15 in Lwanda-Rakai, variety NABE 17 and Farmers' seed (Kaduli) in Kiziranfumbi-Hoima were the most preferred by farmers in both seasons. Besides those varieties, variety ROBA 1 in Kasaali-Rakai in 2013B, and variety KATX 69 in Kasaali-Rakai, and Kiziranfumbi-Hoima and Kyabigambire-Hoima in 2013A were most preferred. However, varieties RWR 719, NABE 2, ROBA 1 and NABE 14 were rejected in all subcounties in both 2013A and 2013B (Table 5).

3.3 | Farmers' selection of bean varieties by subcounties and gender groups

Masindi Yellow Long and Farmers' seed registered the highest preference index values in the selection by male and female farmers in all subcounties except in Kasaali-Rakai subcounty where Farmers' seed recorded the least preference index (Table 6). High preference index was registered for KAT B1 and NABE 15 in Lwanda-Rakai subcounty, varieties KAT B1 in Kiziranfumbi-Hoima, and KATX 69 and CAL 143 in Kyabigambire-Hoima by both gender group (Table 6).

3.4 | The criteria used by farmers for acceptance and rejection of the varieties

The choice of the varieties by the farmers was influenced by a range of factors. These included farmers' perceived varietal responses to drought, excessive rainfall and poor soils, maturity, yield, reaction to diseases and insect pests, taste, cooking time and cooking quality, and seed quality aspects (Tables S1a,b and S2a,b). The responses of farmers showed that varieties that were chosen as most preferred were not superior for all farmers' desired traits and also the varieties that were rejected carried some traits that farmers desired (Table S1a,b and S2a,b). The male farmers in Kalagala subcounty reported that some of their desired varieties were highly susceptible to weevil attack and are thus difficult to store for long (Table S2a,b). The selection criteria were also influenced by the availability or market demand for the varieties especially among men, whereas for the females, the selection criteria were associated with the cooking traits (Tables S1a,b and S2a,b).

4 | DISCUSSION

The farmers' preference index showed clear differences among the fifteen common bean varieties that aided in the selection of the most desired varieties. According to Ntare and Ndjeunga (2009), voting for the best and worst varieties by farmers can be associated with a high likelihood of varietal adoption and/or non-adoption. The direct farmers' participation in the actual selection of the varieties reveals more accurately the desired varietal preferences than either recording farmers rating or ranking for traits (Asfaw et al., 2011). This allowed for comparison of the performance for complex traits among the locally grown and modern varieties by breeders and farmers (Joshi & Witcombe, 1996). In our study, farmers were able to compare varieties for the supply for their desired traits attributes such as tolerance to drought, excessive rainfall and low soil fertility, seed quality traits, cooking quality, disease resistance and insect–pest resistance, and yield and yield component performance. Similar traits preference criteria have also been reported by Asfaw et al. (2011). The responses show that farmers were in search of varieties that could adapt to their soil, climatic and socio-economic environments.

The choice of the varieties by farmers was observed to be different between men and women in the different subcounties and between seasons in the different subcounties. Similar findings have been reported by Asfaw et al. (2011) when selecting among thirty-eight advanced drought-tolerant common bean genotypes. In their study, farmers in the different sites selected different sets of genotypes for their own farms. In our study, the difference in selection by gender might be due to differences in the combination of traits considered as most important by male and female farmers in different subcounties. The female farmers more so in Kasaali-Hoima subcounty were less driven by market demand as compared to the male farmers. The farmers showed a preference for the newly released bean varieties and the introduced Katumani varieties. Their preference could be associated with the desire for salient attributes the varieties possess. Katumani bean varieties were bred for drought tolerance, an attribute that was consistently mentioned by farmers during the focus group discussion in all farmer groups. Considering the different fertilizer management levels, the rankings of varieties were found to be similar in the different subcounties indicating that farmers' preference traits were not affected by management. The farmers were able to equally appraise the varieties for responses to improved management. The seed quality traits and the growth habits were probably the most important traits combinations used by farmers, and these were not influenced by improvement in management. The study by De Ron et al. (2004) showed that qualitative 10 traits are often highly heritable and therefore expressed in all environments.

Varieties Masindi Yellow Long, KAT B1 and Farmers' seed (Kaduli) were consistently selected by farmers in the different management and in the two seasons, and by both gender groups in the different subcounties indicating farmers' desire to continue growing those varieties. The combination of traits' that farmers

TABLE 4 Mean preference index and the associated rankings (*R*) of the 15 bean varieties evaluated by farmers in the 2013A and 2013B seasons across four subcounties of Hoima and Rakai districts

	Season			
Variety	2013A	*R*	2013B	*R*
Farmers seed	0.008	5	0.021	1
CAL96	−0.005	9	0.021	2
Masindi Yellow long	0.059	1	0.015	3
NABE 17	−0.001	8	0.014	4
CAL 143	−0.009	10	0.012	5
NABE 15	0.008	6	0.006	6
ROBA 1	−0.037	14	0.006	7
KAT X69	0.019	4	0.000	8
KAT B1	0.026	3	0.000	9
NABE 14	−0.017	11	−0.006	10
KATX 56	0.038	2	−0.010	11
RWR 719	−0.028	13	−0.016	12
NABE 21	0.003	7	−0.017	13
KAT B9	−0.019	12	−0.017	14
NABE 2	−0.042	15	−0.025	15
LSD	0.015		0.017	

TABLE 5 Mean preference index and the associated rankings of the 15 bean varieties evaluated by farmers in the four subcounties of Hoima and Rakai districts for 2013A and 2013B

	Kasaali				Lwanda				Kiziranfumbi				Kyabigambire			
Variety	2013A	*R*	2013B	*R*	2013A	*R*	2013B	*R*	2013A	*R*	2013B	*R*	2013A	*R*	2013B	*R*
KAT B1	0.051	**1**	−0.011	12	0.0182	**3**	0.0206	**4**	0.022	**5**	0.023	**5**	0.014	**4**	−0.021	13
Masindi Yellow Long	0.047	**2**	−0.004	9	0.0707	**1**	0.0012	8	0.052	**1**	0.044	**1**	0.066	**1**	0.0149	**5**
NABE 17	0.022	**3**	0.009	**4**	−0.024	12	0.0256	**3**	−0.015	11	0.033	**3**	0.005	7	−0.003	10
KATX 56	0.018	**4**	0.008	**5**	0.0646	**2**	−0.008	10	0.027	**4**	−0.019	11	0.048	**2**	−0.018	11
KAT X69	0.013	**5**	0.000	8	0.000	9	0.0039	7	0.030	**3**	−0.006	8	0.027	**3**	0.0035	8
Farmers seed	0.008	6	−0.009	11	0.0029	8	0.0363	**1**	0.031	**2**	0.039	**2**	−0.005	9	0.0205	**4**
NABE 15	0.007	7	0.006	7	0.0062	**5**	0.0201	**5**	0.012	6	0.008	7	0.007	6	−0.002	9
KAT B9	0.006	8	−0.007	10	0.0092	**4**	0.0093	6	−0.039	15	−0.012	9	−0.039	13	−0.043	15
CAL96	0.001	9	0.022	**1**	−0.006	10	0.0261	**2**	−0.018	12	0.028	**4**	0.000	8	0.0115	6
NABE 21	−0.008	10	0.016	**2**	0.006	6	−0.016	13	−0.002	7	−0.024	12	0.013	**5**	−0.037	14
NABE 14	−0.008	11	−0.023	15	0.0033	7	−0.015	12	−0.039	14	−0.027	13	−0.018	12	0.0257	**3**
CAL 143	−0.009	12	−0.02	14	−0.009	11	0.0008	9	−0.008	8	0.018	6	−0.010	10	0.0358	**1**
RWR 719	−0.038	13	−0.016	13	−0.058	15	−0.041	15	−0.011	9	−0.031	14	−0.017	11	0.0084	7
NABE 2	−0.05	14	0.006	6	−0.043	13	−0.036	14	−0.022	13	−0.055	15	−0.051	15	−0.02	12
ROBA 1	−0.054	15	0.013	**3**	−0.043	14	−0.015	11	−0.011	10	−0.018	10	−0.040	14	0.0306	**2**
LSD	0.033		Ns				0.034		0.023		0.032		0.032		0.031	

9 *R*, Rankings

TABLE 6 Mean preference index and the associated rankings of the 15 bean varieties evaluated by farmers in the four subcounties of Hoima and Rakai district aggregated by gender as averages across 2013A and 2013B

	Kasaali				Lwanda				Kiziranfumbi				Kyabigambire			
Variety	F	*R*	M	*R*	F		M	*R*	F	*R*	M	*R*	F		M	*R*
KAT B1	0.037	**1**	0.002	8	0.013	**5**	0.027	**3**	0.020	**3**	0.026	**3**	0.000	9	−0.009	13
KATX 56	0.031	**2**	−0.006	10	0.025	**1**	0.007	7	0.000	8	0.009	6	0.023	**2**	−0.001	9
Masindi Yellow Long	0.030	**3**	0.012	**5**	0.016	**3**	0.033	**1**	0.031	**2**	0.067	**1**	0.049	**1**	0.028	**1**
NABE 17	0.026	**4**	0.005	7	0.013	6	0.005	8	−0.005	9	0.023	**4**	−0.005	11	0.007	6
NABE 21	0.018	**5**	−0.011	12	−0.006	11	−0.011	12	0.002	7	−0.029	12	−0.021	13	−0.007	12
KAT X69	0.018	6	−0.005	9	0.004	9	0.001	9	0.016	**4**	0.008	7	0.019	**5**	0.008	**4**
KAT B9	0.006	7	−0.007	11	0.010	8	0.009	6	−0.012	11	−0.040	13	−0.049	14	−0.033	15
CAL96	0.004	8	0.020	**2**	0.012	7	0.019	**4**	−0.006	10	0.016	**5**	0.012	6	0.000	8
NABE 15	0.001	9	0.012	6	0.015	**4**	0.016	**5**	0.015	**5**	0.005	9	−0.003	10	0.007	**5**
NABE 2	−0.010	10	−0.035	15	−0.043	15	−0.034	14	−0.030	15	−0.047	15	−0.057	15	−0.010	14
ROBA 1	−0.015	11	−0.027	14	−0.031	13	−0.017	13	−0.015	12	−0.015	11	0.000	8	−0.004	11
Farmers seed	−0.016	12	0.016	**4**	0.022	**2**	0.028	**2**	0.037	**1**	0.033	**2**	0.020	**3**	−0.003	10
RWR 719	−0.027	13	−0.027	13	−0.041	14	−0.054	15	−0.028	14	−0.014	10	−0.019	12	0.014	**2**
CAL 143	−0.044	14	0.017	**3**	0.001	10	−0.006	10	0.004	6	0.006	8	0.020	**4**	0.011	**3**
NABE 14	−0.061	15	0.033	**1**	−0.008	12	−0.011	11	−0.025	13	−0.042	14	0.012	7	0.000	7
LSD	0.046		0.033		0.036		0.044		0.019		0.034		0.037		0.02	

F, Female, M, male and *R*, rankings.

looked for in these varieties was not affected by the differences in management and seasons. Farmers perceived these varieties as adapted to their farm conditions and have high market demand. The farmers acknowledged that the landrace (farmer seed, Kaduli) and Masindi Yellow Long offer less risk of crop failure even though they were average in grain yield (Awio et al., 2017). In the study, an aspect of seed colour, seed size and growth habit also contributed to the general acceptance of the varieties by the farmers. A case of interest was variety KAT B1, a drought-tolerant bean variety released in Kenya, having yellow seed coat colour which could have gained general acceptance from farmers due to its similarity to Masindi Yellow Long in terms of seed colour, size and also the possibility of it gaining high market demand. The preference for large seed beans is in line with a previous study conducted in eastern and south-western Uganda where farmers preferred largely seeded bean genotypes relative to the small-seeded ones (Mukankusi, 2008).

Varieties NABE 2, RWR 719 and ROBA 1 were least preferred by farmers in the different seasons and by both gender groups in the different subcounties because of their small seed sizes, late maturity and semi-climbing tendency. Farmers in the focus group discussion reported that these particular varieties could not combine well in their intercropping system and that the climbing tendency could affect management and harvesting of the companion crop. In addition, the seed size and colour had low market demand. One variety, NABE 2 having black seed coat colour was rejected by two third of the farmers. The low preference was associated with the anticipated poor culinary attributes such as "colour not attractive to the eye," "the taste not good and the soup looks bad," "sticky in the mouth," "colour not interesting," and thus, these contributes to it being lowly demanded in the market. In an earlier study by Asfaw et al. (2011), farmers also showed less preference for black seeded bean genotypes. However, these varieties are mostly high yielding and resistant to key diseases prevalent in bean growing areas (Asfaw et al., 2011; Awio et al., 2017). The rejection of these varieties could therefore be associated with lack of "the must-have farmer traits," and the farmers are often unwilling to sacrifice these traits for other traits in a variety.

Finally, the selection of RWR 719 among the most preferred by the male farmers in Kyabigambire-Hoima, and the preference of ROBA 1 in 2013B in Kasaali could be associated with the high yield attributes, less damage by storage pest, less seed required for planting and short cooking time. The varieties also showed resistance to the common diseases in the area, high pod load and highest grain yield in the villages. Generally, the low preference for varieties (NABE 2, RWR 719 and ROBA 1) by farmers was associated with lack of desired seed quality traits such as seed size and colour.

ACKNOWLEDGEMENTS

The study was funded by Climate Change, Agriculture and Food Security (CCAFS) and was implemented by CIAT, NARO—bean breeding programme and Makerere University. We thank the farmer groups of Hoima and Rakai district who participated in the management of the experiments and provided their opinions during the evaluation of the varieties.

CONFLICT OF INTEREST STATEMENTS

The authors declare that they are no conflicts regarding this publication.

AUTHORS' CONTRIBUTION

AB, EK, NTS, MC, GP and ER designed the field experiment; AB, EK, NTS and MC conducted the experiment; AB and MGM conducted the statistical analyses and drafted the manuscript. All authors contributed in the interpretation of the data and editing of the manuscript.

ORCID

Awio Bruno http://orcid.org/0000-0001-5269-9149
Mukankusi Clare http://orcid.org/0000-0001-7837-4545

REFERENCES

Asfaw, A., Almekinders, C. J., Blair, M. W., & Struik, P. C. (2011). Participatory approach in common bean (*Phaseolus vulgaris* L.) breeding for drought tolerance for southern Ethiopia. *Plant Breeding*, *131*, 125–134.

Assefa, T., Sperling, L., Dagne, B., Argaw, W., Tessema, D., & Beebe, S. (2014). Participatory plant breeding with traders and farmers white pea bean in Ethiopia. *The Journal of Agricultural Education and Extension*, *20*, 497–512. https://doi.org/10.1080/1389224X.2013.824385

Aw-Hassan, A., Mazid, A., & Salahieh, H. (2008). The role of informal farmer-to-farmer seed distribution in diffusion of new Barley varieties in Syria. *Experimental Agriculture*, *44*, 413–431.

Awio, B., Mukankusi, C., Nkalubo, S. T., Gibson, P., Maxwell, M. G., Rubaihayo, P., & Edema, R. (2017). Variety × Environment × Management interaction of diseases and yield in selected common bean varieties. *American Journal of Agronomy*, *109*, 1–13.

Dereje, G., Walelign, B., Giddisa, A., Hagos, A., Dabi, A., Dibaba, R., & Alemu, D. (2017). Participatory evaluation and determination of N and P fertiliser application rate on yield and yield components of Upland Rice (NERICA-4) at Bambasi District, Benishangul-Gumuz Regional State. *Advances in Crop Science and Technology*, *5*, 303.

Förch, W., Kristjanson, P., Thornton, P., & Kiplimo, J. (2011). *Initial sits in the CCAFS regions: Eastern Africa, West Africa and Indo-Gangetic PLAINS*, Version 2. Copenhagen, Denmark: Climate Change, Agriculture and Food Science.

Gridley, H. E., Jones, M. P, & Wopereis-pura, M. (2002). *Development of New Rice for Africa (NERICA) and participatory variety selection*. Bouaké, Côte d'Ivoire: West Africa Rice Development Association (WARDA).

Joshi, A., & Witcombe, J. R. (1996). Farmer participatory crop improvement. II. Participatory varietal selection, a case study in India. *Experimental Agriculture*, *32*, 461–477. https://doi.org/10.1017/S0014479700001538

Katungi, E., Edmeades, S., & Smale, M. (2008). Gender, social capital and information exchange in rural Uganda. *Journal of International Development*, *20*, 35–52. https://doi.org/10.1002/(ISSN)1099-1328

Kimbugwe, K. (2013). *Three year production sector development plan*. Kampala: Rakai District local government production and marketing department.

Kyazze, F.B, & Kristjanson, P. (2011). *Summary of baseline household survey results: Rakai district, south central Uganda*. Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security University of Copenhagen.

Mubiru, D.N, & Kristjanson, P. (2012). *Summary of baseline household survey results: Hoima district, west central Uganda*. Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security Copenhagen University.

Mubiru, D., Kyazze, F. B., Radeny, M., Zziwa, A., Lwasa, J., & Kinyang, J. (2015). *Climatic trends, risk perceptions and coping strategies of smallholder farmers in rural Uganda*. Working paper, Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security. 23 June 2015. Climate Change, Agriculture and Food Science. www.ccafs.cgiar.org (accessed 17 May 2017).

Mukankusi, C. M. (2008). *Improving resistance to Fusarium root rot (Fusarium solani (mart.) Sacc f.sp phaseoli (Burkholder) in common bean (Phaseolus vulgaris)*. Ph.D. Pietermaritzburg, South Africa: Kwazulu-Natal University.

Muthoni, R. A., & Andrade, R. (2015). The performance of bean improvement programmes in sub-Saharan Africa from the perspectives of varietal output and adoption. In T. S. Walker, & J. Alwang (Eds.), *Crop Improvement, adoption and impact of improved varieties in food crop in Sub-saharan Africa* (pp. 148–161). North Carolina and Virginia: CGIAR and CAB International. https://doi.org/10.1079/9781780644011.0000

Ntare, N., & Ndjeunga, J. (2009). *A Guide to participatory variety selection* (p. 28). Tropics. p: International Crops Research Institute for the Semi-Arid.

PABRA (2014). *PABRA Database*. Kampala, Uganda: Pan-Africa Bean Research Alliance. http://database.pabra-africa.org (13 Mar. 2015).

R Core Team. (2013). *R: A language and environment for statistical computing*. Vienna, Australia: R Foundation for Statistical Computing. URL http://www.R-project.org.

UBOS (2010). *Uganda Census of Agriculture 2008/2009*. Kampala: Ministry of Agriculture Animal Industry and Fishery (MAAIF).

Weltzien, R. E., Smith, M.S., Meitzner, L.S, & Sperling, L. (2003). *Technical and institutional issues in participatory plant breeding—From the perspective of formal plant breeding: A global analysis of issues, results, and current experiences* (p. 208). Cali, CO: CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation; Centro Internacional de Agricultura Tropical (CIAT). (PPB Monograph no. 1).

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Bruno A, Katungi E, Stanley NT, et al. Participatory farmers' selection of common bean varieties (*Phaseolus vulgaris* L.) under different production constraints. *Plant Breed*. 2018;00:1–7. https://doi.org/10.1111/pbr.12594