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Effectiveness of participatory breeding and variety selection for sorghum technology adoption in Zambia

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ABSTRACT

Participatory breeding and variety selection has been proposed as an effective way of disseminating improved technologies to farmers for social-economic benefits. As a result the Sorghum and Millets Improvement Programme (SMIP), of the Zambia Agriculture Research Institution (ZARI), in collaboration with the farming systems scientists at Mansa Research Station, in Luapula Province tested the effectiveness of this methodology. The effectiveness of this method was evaluated based on the number of farmers rating new improved agriculture technologies favourably and willing to adopt the improved technologies after being exposed to participatory breeding. An on-farm participatory sorghum variety demonstration trial was conducted during the 2011/2012 rainy season in Zambia, Milenge district, of the Luapula province. The trial consisted of 12 improved sorghum germplasm lines of which six were hybrids and six were varieties developed by SMIP. The germplasm was evaluated by the farmers, extension and research staff on farm. The germplasm was evaluated for its value for cultivation and use. The methodology that was used is called participatory breeding which is part of the broader concept of participatory rural extension and the Innovative Platform for Technology Adoption (IPTA) advocated by the Forum for Agriculture Research in Africa. The results of the methodology indicated that this methodology is effective if farmers are committed and good agriculture policies are in place. When farmers feel part of the developmental process, it is easier for them to adopt improved technologies.

Keywords: Sorghum, IPTA, participatory breeding, variety selection, technology adoption, value addition, markets, social-economic, policy.

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INTRODUCTION

The rural economy of Zambia is dependent on agriculture. Milenge district, like most of the rural districts in Zambia, is dependent on agriculture. Sorghum is one of the five major crops grown in the district. Other crops include maize, cassava, sweet potatoes and beans. Sorghum is one of the essential sources of income in the district and is grown by almost 80% of the population. The sorghum farming system plays an important role in the economy of Milenge district. The role that sorghum plays in this economy can be enhanced if strategies pursued to increase sorghum production and earnings from sorghum for farming households are enhanced (Larson et al., 2006; Pricilla, 2010).

Sorghum is one of the primary staple foods as well as an essential cash crop for small-holders. Since the agricultural sector in Milenge district is one of the keys to development and a major factor in poverty reduction, there was a need to investigate, gather and analyse the various relevant agronomic and socio-economic factors that influence the adoption of improved sorghum technologies using participatory breeding and variety selection.

Farmers in Milenge district grow sorghums landraces that are late maturing using the transplanting method. This method is usually labour intensive. However, this may not necessarily be a bad thing because the late maturing varieties also have a role to play in food security. Local sorghum varieties are low yielding (0.3 to 0.55 tons/ha) according to Hamukwala et al. (2010), 0.67 tones according to CSO (2010) and 0.844 tones according to Solomon and Nicholas (2013). In addition, Solomon and Nicholas reported that in 2011/2012 season only 0.68% of rural farmers in Luapula province grew sorghum while the national average was only 2.74%.

Sorghum local landraces take about six months to mature as compared to three months for the improved varieties. The improved sorghum varieties developed by the sorghum breeding programme can yield up to 8 tonnes per hector (Christiansen, 2008) and even more for sorghum hybrids. However, most small scale farmers are unable to produce this much. In unpublished reports by SMIP, it is reported that farmers can produce about 1.4 tons of sorghum per hector under poor management with no fertilizer using the improved varieties as a result there is now a paradigm shift to produce low input technologies for small-scale farmers.

As early as 1990, improved sorghum varieties were introduced in Milenge, but unfortunately they were not adopted by farmers (Chisi et al., 1997). Information on the actual factors that lead to the low adoption of the improved sorghum varieties is not very clear. However, one of the reasons cited for the low adoption of varieties by farmers is the linear approach to technology dissemination (Nkongolo et al., 2008; FARA, 2012; Salvatore, 2015). Another reason is that a great deal of farmers shun away from growing sorghum because of birds, which are a major pest in white grain sorghums (Russell, 2013). Therefore, there was a need to assess the performance and acceptability of these technologies by the farmers in Milenge district using participatory breeding and variety selection.

Participatory breeding and variety selection is part of a broader extension methodology called the Innovative Platform for Technology Adoption (IPTA), which has been encouraged by the Forum for Agriculture Research in Africa (FARA), as a useful tool for agriculture development. The IPTA concept is a non-linear model for technology development and adoption. It is a holistic model for technology development, dissemination and adoption. This methodology was tried to see its effectiveness in rural agriculture development.

The overall objective of this social-economic research was to investigate the agronomic and socio-economic factors affecting the adoption of sorghum improved varieties in Milenge district. The Specific objectives of this research were: (i) to evaluate the performance of the improved sorghum varieties, (ii) to evaluate the acceptability of improved sorghum varieties among farmers in Milenge, and (iii) assess the performance new variety against bird pests.

MATERIALS AND METHODS

The experimental design that was used for the trials was the Randomised Complete Block Design (RCBD) with four replications. Twelve improved sorghum germplasm lines were used. The first set of twelve sorghum entries was planted in an area called Kasepa. This was assigned to a local women organisation called "Tukosele Women Group". This was to ensure local participation and ownership of the technology adoption process. This trial had two replications. The second set of twelve sorghum entries was planted in two sites namely Kapalala and Sokontwe. The first replication was planted in Kapalala camp and the other replication was planted in Sokontwe camp.

Farmers were organized in groups. Discussions were held with farmers in which the objectives and monitoring indicators were discussed. The list of important factors that were observed and considered important by the farmers included: (i) Plant vigour (ii) Pest resistance (iii) Bird damage (iv) Plant height (v) Threshing ratio (vi) Grain yield (vii) Grain colour (viii) Storage pests (ix) Milling ability and (x) Taste.

Analysis of variance was used for variables such as yield, bird damage and threshing ratio. Differences within and between the means were tested using Duncan's Multiple Range Test. Three quantitative variables grain yield (kg/ha), bird damage (%) and threshing ratio (%) were analysed using Analysis of Variance (ANOVA) from the Statistical Package for the Social Sciences (SPSS), version 14.

To analyse farmers' visual assessment using scores, frequencies were used to profile their perception of the performance of the improved varieties. Pearson correlation was used for continuous variables. According to Vijay (1999), if even one of the variables is ordinal (ranked categorical) or non-normal, the "Pearson" method cannot be used. Instead "non-parametric" methods must be used.

RESULTS

Yield performance

The standard for comparing sorghum yield per hector under farmer conditions is 1 ton per hector. This is because the average yield of sorghum under farmer conditions in 2010 was reported as 1 ton per hector (CSO, 2010). Based on this information, any improved variety or hybrid giving less than 1.5 tones is considered to be a poor performer in terms of grain yield. (Table 1)

Bird damage

Bird damage was calculated as a percentage of the total number of plants attacked by birds (Table 2). Farmers assessed sorghum for bird damage by counting all sorghum plants that were attacked by birds and the total number of plants in a plot. Bird damage percentage was calculated as the number of plants attacked by birds divided by the number of sorghum plants in a plot area, multiplied by 100 (Table 3). The higher the number, the higher the bird damage.

Threshing ratio

Threshing ratio was calculated as grain weight divided by the head weight and multiplied by 100 (Table 4). The higher the ratio percentage, the more the grain that is recovered from the sorghum panicle. High ratios imply that more grain is recovered per panicle and hence post-harvest losses are minimized.

Table 1. Yield performance under farmer conditions.

Germplasm	Type of germplasm	Yield (kg/ha)
ELT1-16	Hybrid	833[a]
[FRAM x SDS3843]F6-5	Hybrid	1333[a]
SDS876-342 [OT] 8-2-1	Hybrid	1500[ab]
90CC655-1073-3	Hybrid	1667[ab]
ZSV-15	Variety	1833[ab]
ZSV-36R	Variety	3667[cb]
WP-13	Variety	3667[cb]
Kuyuma	Variety	4333[c]
ZSV-12	Variety	4500[c]
Sima	Variety	4667[c]
[ICSV112 x WSV187]15-1-1-1	Hybrid	5000[c]
[ICSV112 x SDS3136] 1-13-1	Hybrid	5833[c]

Ratios connected by the same letter are not significantly different at alpha = 0.05.

Table 2. Bird damage farmer rating scale.

Rating	Damage %	Damage Description
1	<20	No bird damage
2	21 - 40	Slight bird damage
3	41 - 60	Moderate bird damage
4	61 - 80	Severe bird damage
5	>80	Very severe bird damage

Table 3. Bird incidence as a percentage.

Germplasm	Type of germplasm	Bird incidence %
ELT1-16	Hybrid	1.0[a]
[FRAM x SDS3843]F6-5	Hybrid	2.0[ab]
SDS876-342 [OT] 8-2-1	Hybrid	18.4[abc]
90CC655-1073-3	Hybrid	27.8[abcd]
ZSV-15	Variety	34.2[abcd]
ZSV-36R	Variety	50.6[abcd]
WP-13	Variety	52.9[abcd]
Kuyuma	Variety	54.1[bcd]
ZSV-12	Variety	58.8[cd]
Sima	Variety	58.9[cd]
[ICSV112 x WSV187]15-1-1-1	Hybrid	59.8[cd]
[ICSV112 x SDS3136] 1-13-1	Hybrid	80.7[d]

Ratios connected by the same letter are not significantly different at alpha=0.05.

Grain yield vs. threshing ratio

Grain yield and threshing ratio were highly correlated with a correlation coefficient of 0.96 and confidence interval of 0.84 to 0.99 (Figure 1). The threshing ratio is a good indicator of yield and vice versa. If the threshing ratio is high the chances of recovering more grain is also high.

Plant vigour

The frequency of farmers rating seedling vigour of improved varieties compared to local varieties is shown in Figure 2. Of the 100 farmers interviewed, 79% rated the vigour as very good and only 4% rated the vigour as moderate.

Table 4. Threshing ratio reported as a percentage.

Germplasm	Type of germplasm	Threshing ratio (%)
ELT1-16	Hybrid	27.1[a]
[FRAM x SDS3843]F6-5	Hybrid	42.7[ab]
SDS876-342 [OT] 8-2-1	Hybrid	44.7[ab]
90CC655-1073-3	Hybrid	52.1[bc]
ZSV-15	Variety	55.0[bcd]
ZSV-36R	Variety	62.6[bcde]
WP-13	Variety	71.4[cde]
Kuyuma	Variety	73.2[cde]
ZSV-12	Variety	73.3[cde]
Sima	Variety	76.0[cde]
[ICSV112 x WSV187]15-1-1-1	Hybrid	79.6[de]
[ICSV112 x SDS3136] 1-13-1	Hybrid	81.0[e]

Ratios connected by the same letter are not significantly different at alpha=0.05.

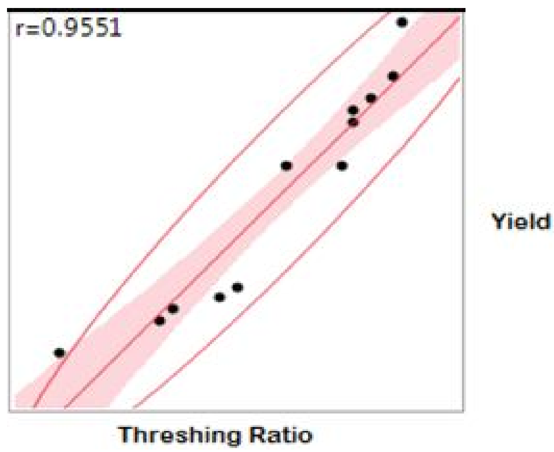

Figure 1. Yield vs. threshing ratio.

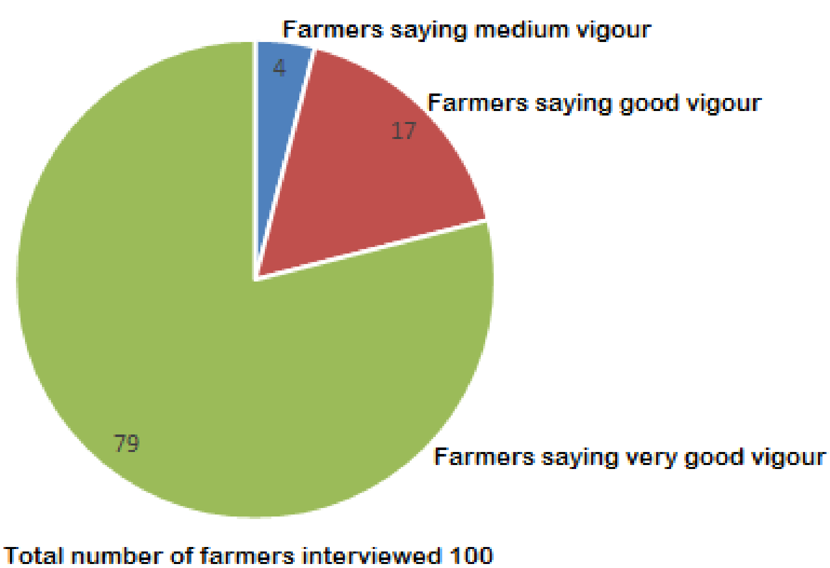

Figure 2. Farmers visual rating of plant vigour.

Table 5. Plant height farmer rating scale.

Rating	Height (cm)	Height description
1	<100	Too short
2	101 - 150	Short
3	151 - 200	Medium
4	201 - 250	Tall
5	>250	Very tall

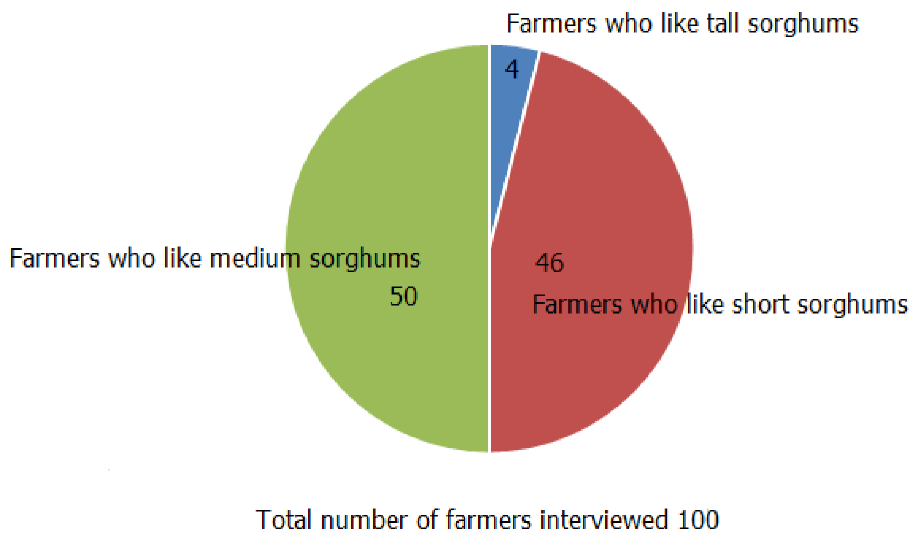

Figure 3. Plant height farmer scores.

Plant height

Plant height is an important trait for farmers because it affects how well they will harvest the crop. Plant height has implications on labour intensiveness. Farmers claim that sorghums that are about 1.5 m tall are easier to harvest and so this was an important factor to consider. Very short or very tall sorghums are considered undesirable at the time of harvest. According to the farmers very short sorghums posed a problem at harvesting due to constant bending which leads to backaches if the fields are large. Furthermore, other farmers claim that it is easier to do bird scaring in a field of sorghums that are shorter because they can easily see where birds are in the field. This makes perfect sense because tall sorghums will normally obscure the visibility of the field. On the other hand very tall sorghums take twice as much time to harvest because farmers have to cut the sorghum stem at two points to get to the panicle or they have to bend the sorghum plants to cut the panicle. A consensus rating of height by farmers is shown in Table 5.

The results in Figure 3 show that plant height of improved sorghum ranged from short to tall. The majority of improved varieties were neither too short nor very tall according to farmers. The pie-chart in Figure 3 shows the farmer preferences for plant height.

Grain colour

For grain sorghum grown for food, the most preferred colour by households is white 66%, then brown 25% and red is the least preferred 9%. Upon discussion, farmers admitted that grain colour is not an issue if sorghum is grown for sale. However for food purposes taste and texture were other attributes that needed further exploration. Due to the time limitation information on the shelf life of grain, milling quality and oganoleptic tests where not done but it is important to establish this information. The results for grain colour are as shown in Figure 4.

DISCUSSION

The significance of this study is that despite all the research efforts by SMIP, and since the inception of ZARI in 1953, the technology adoption rates have been very low (Chisi et al., 1997; Mukelabai et al., 2007). Some of

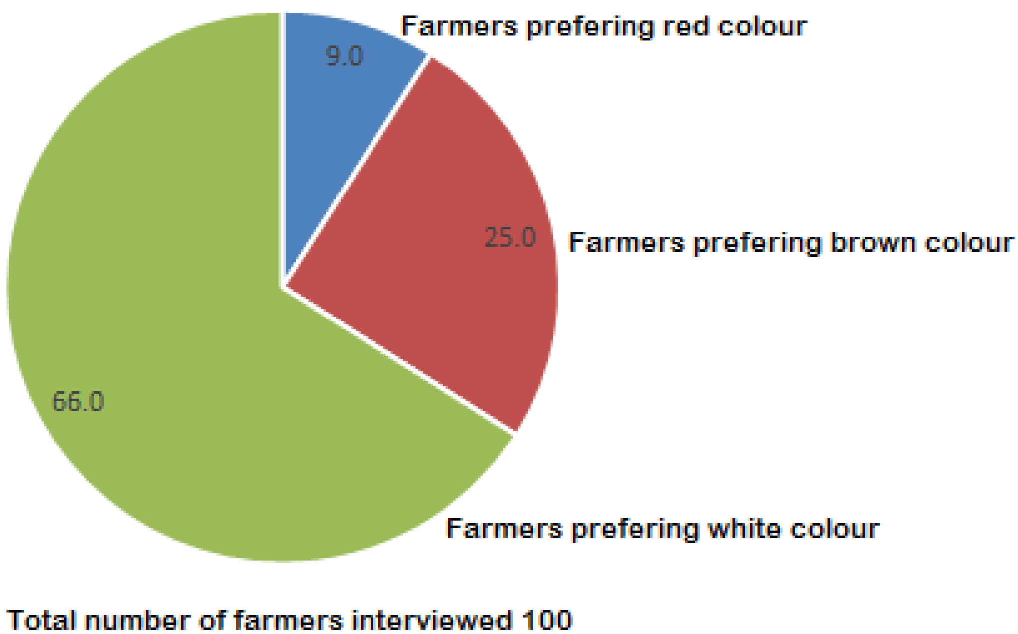

Figure 4. Grain colour preferences.

these reasons are not entirely due to the technology dissemination methods but also how these technologies were disseminated and the somewhat negative social perception of sorghum as a food crop (Monyo et al., 2001).

Generally, the improved varieties performed well in terms of agronomic and social-ecomical acceptance by farmers. The social-economic and agronomic evaluation indicate that the improved varieties can do better in Milenge unlike the myths that farmers have that the improved varieties can not do well. Some farmers in an area called Kasepa, claimed that the improved sorghum that they planted, the way they plant local sorghum, did very well. This is an indication that the improved varieties could fit well in the farming system of Milenge.

Of the two major reasons cited for low technology adoption, (i) linear technology dissermination, and (ii) bird pest problems, one of them was nullified as a cause for low technology adoption. The low adoption of improved varieties in Milenge could not be attributed to susceptibility of improved sorghum varieties to birds. Much as the improved sorghum varieties are suceptible to birds so are the local landraces. Besides that, sorghum is not the only crop affected by birds; rice, wheat and sunflower are equally affected by birds. In very severe situations even maize is attacked by birds and other wild animlas such as wathogs and monkeys.

Since the Sorghum Breeding Programme is very much aware that farmers are weary of farm inputs costs, pest problems such as birds and the market, the social economic-research included a new developed red sorghum variety called ZSV-36R, since this technology received sufficient merit by the farmers the programme recently released this low input variety in September 2013, through the Seed Certification and Control Institute of Zambia (SCCI), (SCCI, 2014). This variety is less suscetible to birds and has a market advantage because the industries are using it to make malt. So the farmers can switch to growing red sorghum and make an income. Farmers can then use the income to buy food. This is another form of food security.

Attitude and committiment by the farmers plays an important role as was the case in areas where the birds completely destroy sorghum. In Kasepa, the farmers showed comittiment and good attitude towards the improved varieties and good results were obtained. The lesson learned is that the use of the Inovative Platform for Technology Adoption works if there is commitment and importance attached to a crop. The Inovative Platform is a useful tool for bringing about rural agriculture development, but the following issues need to be resolved if it is to work properly.

Government funding and policies

Some policies need to be adjusted to prevent the exploitation of farmers by briefcase businessmen who buy grain at extremely low prices robbing the farmer of their profits. The Zambian bureau of standards could be more involved on the platform and ensure that farmers are given high quality inputs by agro-suppliers. Government could also prioritize funding to the agriculture sector. This could be brought about by creating awareness of the IPTA to facilitate buy in of decision makers. The funding system has to be reformed so that it can meet the demands of farmers at grass root level.

Information and communication

Information and communication need to be enhanced through consistent interactions among stakeholders and mainstreaming the IPTA on the day to day activities in all the institutions involved. Information sharing should be encouraged at all levels even though the cost of obtaining information is high. The short message sending (SMS) option on mobile phones should be explored more to foster easy access to information sharing. Mobile communication is emerging as a powerful tool in information and technology dissermination and media institutions should take advantage of this. However, community radio stations, Internet and information centres, farmer groups and cooperatives are still very important. The challenges to mobil communication is usually poor signals and network coverage in some parts of the country especially in rural areas.

Attitude change

This was considered a very important social attribute in agriculture development. Many people advocated for a change in attitude. This was echoed at all levels from farmers, Extension Officers, Researchers and indeed all stakeholders in the way that they do things.

Value addition and markets

These two were pointed out as probably the most important drivers in sorghum production. Markets and value chains are very critical, without markets farmers are not willing to grow anymore than they can consume. This is because surplus production will normally go to waste. Marketing and value chains is, therefore, an inportant componet of the the IPTA concept. More efforts need to be made to insure that all stake holders internalise the IPTA concept. The concept of the Innovative Platform needs to be widely disseminated.

Farming as a business

Small-scale farmers must look at farming as a business from which they can make full returns. They should analyse gross margins and wisely select crops that have low production costs but high returns.

CONCLUSION

Since participatory breeding and variety selection have been fairly successful; it should be utilised in technology dissermiation in order for farmers to enhance technology adoption. Additional efforts should include use of innovative technologies for social-economic development. Farmers do not only need food security but money to allow them access clean water, shelter, education and health (Pannella et al., 2013). Therefore, innovative ways of utilizing crops underutilised crops is a must. One of the ways this can be achieved is to promote value addition at both local and National level. Scientific research has revealed sorghum has a lot of nutritional value. For example, sorghum is beneficial for individuals with diabetes (Ciacci et al., 2007). Promoting sorghum as a food crop with health benefits and other uses can easily find use in urban markets in a processed form and farmers could earn incomes from crop sales (FARA, 2012).

Secondly the existing policy frame works can be enhanced and harnessed such as, Food Diversification (FD), Farmer Input Support Programme (FISP), Variety Registration (VR), Plant Breeders Rights (PBR), Plant Variety Protection (PVP), Farmers Rights (FR), Traditional Knowledge (TK), Intellectual Property Rights (IPR) and Geographical Indicators (GIs) to explore further how well these policies can help farmers. The financial policies in Zambia need include better funding mechanisms to micro-finance farmers because this is a key to national development so that farmers can invest in increased productivity, and production including invetsments in value addition and market access.

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