Participatory Approach to Variety Selection Using Soybean Production in Ghana as a Model

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Abstract

In the past, soybean varieties released in Ghana were selected primarily for grain yield potential, earliness, seed viability and low phosphorus tolerance. However, most of these varieties are not resistant to pod shattering, resulting in high grain losses. In order to identify traits farmers consider most important when deciding which soybean varieties to adopt, a participatory variety selection approach was used to evaluate varieties in two locations (Nyankpala and Wa) in the Guinea savanna zone of Ghana during the 2010 and 2011 cropping seasons. Twelve medium and 14 early maturing varieties were evaluated. Farmers' variety selection criteria and ranking did not differ across locations and gender groups. Additionally, four most preferred traits by farmer (grain yield, pod shattering, earliness and pods per plant) out of 12 traits were considered very important by farmers at both locations. In some instances, farmers' preference for the best varieties was not exactly in line with researchers' selection. Best four ranked varieties (TGx 1799-8F, TGx 1834-5E, TGx 1445-3E and TGx 1844-22E) were preferred by farmers because they possess positive attributes such as higher grain yields, resistance to pod shattering, numerically more pods per plant and enhanced ability to control *Striga hermonthica*. These varieties were later released as Suong-Pungun, Afayak, Songda and Favour, respectively for commercial production throughout Ghana. Consequently, soybean breeders should incorporate farmers' preferred traits in selecting varieties in the breeding process in order to increase likelihood of adoption of the varieties.

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the most important leguminous crops grown in a wide range of agro-ecological conditions. It is an important source of high quality and relatively inexpensive protein and oil, with approximately 35-40% protein and 18-20% oil (FAOSTAT, 2014). It also provides opportunities for enhancing household food and nutrition security due to its high protein content and also for increasing market-oriented production. Soybean is increasingly becoming an important cash crop in sub- Saharan Africa (SSA), owing to its wide range of uses as food, feed, and industrial raw material for cooking oil and animal feed especially in the poultry industry (MoFA, 2017).

Currently, domestic supply lags behind demand and the huge supply gap is often augmented through importation from other countries (MoFA 2017). This gap has a serious implication for the import bill of the government and the overall effect on the strength of the local currency. Nevertheless, Ghana can increase her domestic production and reduce the import bill, if farmers improve their productivity by adopting good agronomic practices (Mohammed *et al*., 2016; Avea *et al*., 2016). This provides the opportunity to improve food and nutrition security, improve the incomes of rural households and enhance soil fertility as well as other environmental benefits.

Increasing demand for soybean and its potential to contribute to smallholder farmer income has prompted both public and private organizations to promote its production and utilization in recent times (Avea *et al*., 2016; Osman el at., 2018). Despite these efforts, the average grain yield of 1.3 t ha^{-1} in Ghana is considerably lower than the potential yield of about 3.0 t ha^{-1} (MoFA, 2017). The low grain yield is attributed to lower capacity to adopt and use improved productivity enhancement technologies by farmers (MoFA, 2017; Raimi and Adeleke, 2017). One of the strategies to enhance the productivity of soybean in farmers' fields is through the development and utilization of improved soybean varieties accompanied by productivity enhancing technologies.

Soybean nodulates freely with native rhizobia strains and supply a large proportion of its nitrogen (N) requirement through biological N_2 fixation (BNF) without depleting soil N reserves. It contributes to soil fertility enhancement and reducing *Striga hermonthica* infestation on farmers' fields (Kanampiu *et al*., 2018). In order to meet the needs of smallholder farmers in SSA, the International Institute of Tropical Agriculture (IITA) in collaboration with National Agricultural Research Systems (NARS) in Ghana initiated comprehensive soybean trials in the early 1980s. This led to the release of some varieties for commercial production since 1985 (MoFA, 2019). These varieties were selected based on high grain yield, earliness, seed viability, low phosphorus tolerance, efficient natural nodulation without inoculation and wide adaptability to different agro-ecological zones (Chigeza *et al*., 2018). Nonetheless, most of the existing varieties are susceptible to pod shattering, resulting in higher grain yield loss.

Two existing varieties released in 2003 (Jenguma and Quarshie) are resistant to pod shattering. However, Jenguma is more popular and has higher grain yield than Quarshie. It covers around 40% of the area under soybean production in Ghana (Amanor-Boadu *et al*., 2015). The rest of the earlier released varieties are now grown only in small plots, and/or by a few farmers, or have been abandoned. Several factors may have accounted for the limited adoption of new varieties. First, breeders' selection criteria may not match the needs and preferences of farmers. In developing and selecting new varieties, breeders may discard many varieties because of traits considered undesirable to them; though these traits may be of interest to farmers (Getahun *et al*., 2016, Ojulong *et al*., 2017). As farmers are the ultimate beneficiaries of the varieties, there is the need to involve them in evaluating suitable varieties under their socio-economic and agro-ecological circumstances at very early or advanced stages of the breeding process.

According to Bellon (2002), participatory variety selection (PVS) is a breeding approach which provides a wide choice of varieties for farmers to evaluate in their own environment using their own resources for increasing production. This approach assumes that, varieties exist that are better than those currently grown, but which farmers have not had the opportunity to test, or adopt. The approach brings breeders, social scientists, farmers and agricultural extension officers together in a field setting in order to prioritize and target traits of importance. Thus, the emphasis in PVS approach is to enable farmers make their own analysis and decisions based on their perceptions and criteria. It also helps to identify and assess traits that are important to farmers and is especially successful in assessing "subjective traits" such as taste, aroma, appearance, texture, storage quality and other culinary qualities, which are difficult to measure quantitatively (Bellon, 2002). This approach helps to bridge the gap between breeders and farmers and also ensures that the new varieties satisfy farmers' preferences and suit their socioeconomic situation.

Developing varieties based on farmers' selection criteria was reported to enhance their productivity and dissemination among smallholder farmers. By employing PVS, a number of varieties were introduced and adopted in many countries, such as maize in Ghana and South Africa (Buah el at., 2013; Chimonyo *et al*., 2019), soybean in Kenya (Getahun *et al*., 2016), pearl millet in Nigeria (Angarawai *et al*., 2016) and finger millet in Ethiopia (Ojulong *et al*., 2017). Generally, any participatory research methodology should consider the importance of gender by including participants who play different roles within households, such as men, women, children and female heads of households (Kamara el at., 2018). Capturing the concerns of both men and women farmers is very important since soybean production involves gender specific roles (FAO, 2018). In the Guinea savanna agro-ecological zone of Ghana, soybean production is steadily increasing and many farmers depend on it as a cash crop. This study sought to understand farmers' soybean selection criteria, and to identify superior varieties based on combination of factors including farmers' selections and the use of agronomic yield data in two locations. Understanding farmers' selection criteria provides important information which improves focus when developing varieties that meet farmers' preferences in target agro-ecological zones, and also increases chances of acceptance and adoption.

Materials and Methods

Study Area

The study was conducted during the 2010 and 2011 cropping seasons (May to October) in Wa, (Latitude: 10º03'36.25" N Longitude: 2º30'35.6" W altitude: 305 m asl)) in Upper West Region and Nyankpala (Latitude: 09º 25'41" N Longitude: 00º58'42" W, altitude: 183 m asl) in Northern Region. Both sites are located in the Guinea savanna agro-ecological zone of Ghana (Figure 1). The zone has high potential for crop and livestock production and is characterized by a single growing

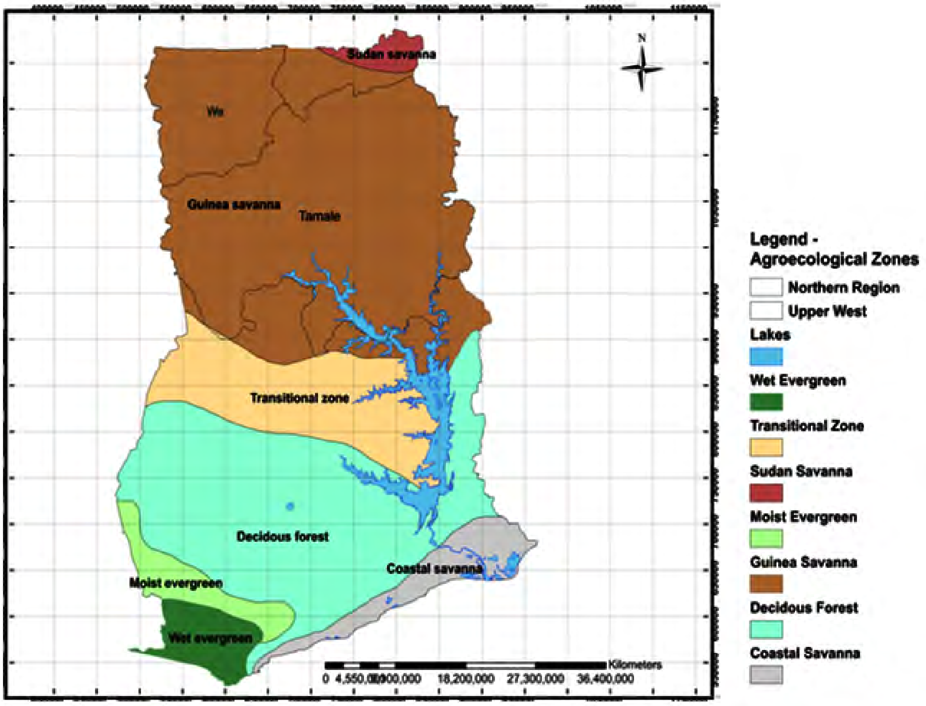

Figure 1. Map of Ghana showing agro-ecological zones

period (180–200 days), a unimodal rainfall pattern lasting from May to October with an erratic distribution pattern, with temperatures between 25°C to 40 °C and an annual mean precipitation of 1100 mm (MoFA, 2017). The Sudan savanna agro-ecological zone occupies the north-eastern part of Upper East Region. Essentially it has similar rainfall pattern as the Guinea savanna zone with an annual precipitation of about 1000 mm, but a shorter growing period (150-160 days). This zone is frequently subject to drought stress during cropping season and so extra-early and early maturing as well as drought tolerant crop varieties are preferred. Soybean is a relatively new crop in the two zones and its production is predominantly done under rain-fed conditions by smallholder farmers.

The growing season is followed by the Harmattan period, which occurs in late November and continues sometime until early February. This period is characterized by dry, dusty winds that blow across the Sahara Desert over West Africa into the Gulf of Guinea causing extremely hot, dry days, and cool nights. Relative humidity is between 70% and 90% in the rainy season but could be as low as 20% in the dry season (Ghana Statistical Service, 2014). Soils at both sites are generally sandy and poor in fertility with low water holding capacity.

Experimental Design and Field Management

A participatory Variety Selection, including a field experiment, were conducted on farmer fields in Nyankpala and Wa during the 2010 and 2011 cropping seasons. Based on willingness to participate in the study and through further consultation with agricultural extension officers, a single farmer was identified to host a yield trial at each location. The yield trials were established to facilitate data collection by the research team, including breeders and extension staff. At each location, one trial each of early (80-95 days to maturity) and medium maturing varieties (100-110 days to maturity) were planted. The early maturity group consisted of 14 varieties from IITA. The medium variety trial also comprised 12 varieties which included nine from IITA planted alongside three previously released varieties (Quarshie, Jenguma and Salintuya-I). Varieties that were in advanced stages of testing and performed well over the years were used for the study.

The experimental design was a randomized complete block with four replications per site. Each plot consisted of 6 rows, 5.0 m long. Both farmers and the research team participated in the management of the trials. At both locations, planting was done by hand, in rows, following current national research recommendations. Planting was done in Wa on 14th July, 2010 and 5th July, 2011. In Nyankpala, planting was done on 16th July, 2010 and 8th July, 2011. The planting distance was 75 cm between rows and 5 cm between plants with one seedling per stand resulting in a recommended plant population of 266,600 plants ha^{-1}. Plots were weeded twice with hoe at 3 and 6 weeks after planting (WAP). All fertilizers were band-applied at 5 cm depth and 5 cm from the plant, 10 days after planting at a rate of 25-60-30 kg ha^{-1} as N, P_2O_5 and K_2O, respectively. The sources of N, P_2O_5 and K_2O were Urea (46% N), triple super phosphate (TSP, 46% P_2O_5) and muriate of potash (KCl; 60% K^2O), respectively.

Ranking of preferred traits

The participation of farmers was voluntary and community-based. Farmers' Research

Groups (FRGs) were organized in each study community: in Wa, 16 women and 54 men, while in Nyankpala, 14 women and 36 men took part in the study. In the process of the field experimentation to identify important traits at different crop growth stages, farmers were segregated into gender groups. There was no attempt at balancing male and female participation since all farmers in the community where the experiment was carried out were encouraged to participate in the evaluation exercise. Farmers in each group joined in planting, cultivation and harvesting. Agricultural extension staff and researchers played a facilitation role during variety evaluation at flowering stage and during harvest. Evaluation at flowering stage generally considered the whole plant, while the evaluation at harvest considered the whole plant and grain characteristics. The overall importance of a selection criterion was computed based on the accumulative frequency of farmers mentioning it as being important across the two locations.

The criteria used by farmers in selecting suitable varieties depended on the existing constraints and opportunities. The farmers were requested to list and prioritize the traits they liked or disliked about the varieties. The traits were organized into lists and the farmers were requested to rank these traits on a scale of 1 to 3 (1 = very important, 2 = somewhat important, 3 = less important) to identify most preferred traits (criteria) for rating the varieties (De Groote *et al*., 2002).

Ranking of varieties

At physiological maturity, farmers from each site were invited to attend field days and also participate in selecting their preferred varieties from those that were planted in the trials. Farmers were divided by gender (Women, Men and both sexes) and each gender group subdivided into smaller groups consisting of 10-15 farmers. They were requested to rank the varieties based on the traits they had previously prioritized. For a better understanding of their preferences for the various varieties, farmers were also asked which varieties they would most likely adopt the following season. Varieties were ranked for each trait (for instance, yield, pod shattering resistance, disease resistance), and the actual selection was based on the average of all separate rankings. Scores from the different groups were averaged per gender, per farmer field and scores from the region averaged per group to give the scores per region. After harvest, data such as grain colour and size and threshability were taken and added to the pre-harvest data to form the final scores which were used for ranking the varieties with the one with the highest score being the best and the one with the lowest the least preferred.

Data Collection and Analysis

Data were taken by the research team during the course of the trial. These included days to flowering (days), plant height at maturity (cm), hundred seed weight (g) and grain yield (kg ha^{-1}). Grain yield was determined by harvesting all the 6 rows of each plot after physiological maturity when the first flush of pods was mature and dry. Similarly, fodder yield was based on all plants that were harvested from the 6 rows for each plot, sun dried to constant weight and calculated as kg ha^{-1}.

Quantitative data were subjected to an analysis of variance (ANOVA) with the Statistical Analysis System (SAS) for Windows 9.1 (SAS Institute Inc., Cary, NC) to establish varietal differences and interaction effects on crop development and yield. Fixed effects were varieties, while year, location and replication were treated as random effects. Varietal effects and all interactions were considered significant at $P \leq 0.05$. Where the ANOVA showed significant differences of variables between treatments, means were separated using Least Significant Difference (LSD) at the 5% level of probability. Descriptive statistics (simple percentages) were used to compare frequencies of respondents with respect to farmers' choice of variety and their perceptions on the varietal choice. These data were used to substantiate the farmer PVS data in the final scoring and selection.

Results

Early maturing variety trial

In both years, prolonged pre-season drought in June delayed planting until mid-July. This was followed by wet conditions which affected plant growth at both locations. At each location, year x variety interaction was not statistically significant ($P>0.05$) for any parameter, but year effect was significant. Therefore, data were not pooled across years and the main effects of variety are presented for each location and year because location x variety and location effects were significant.

The early varieties flowered and produced grains in about 85- 92 days. At Nyankpala in 2010, mean grain yield of the early varieties ranged from 675 kg ha^{-1} for TGx 1895-19F to 1908 kg ha^{-1} for TGx 1485-1D (Table 1). Grain yield ranged between 1000 kg ha^{-1} for TGx 1895-19F to 2621 kg ha^{-1} for TGx 1485-1D in 2011. On average, TGx 1485-1D tended to have the highest grain yield in both years although its mean yield across the two years was not significantly ($P>0.05$) greater than those of five other varieties (TGx 1799-8F, TGx 1831-32F, TGx 1831-32E, TGx 1843-3F and TGx1871-12E). The variety, TGx 1895-19F

TABLE 1
Mean grain yield of early maturing soybean varieties evaluated in Nyankpala and Wa in northern Ghana, 2010 and 2011

Genotype	Nyankpala		Wa	
	2010	2011	2010	2011
	Grain yield (kg ha^{-1})			
TGX 1805-5 E	1481	1478	1154	2063
TGX 1831-32 F	1638	2229	1579	1642
TGX 1843-3 F	1563	2475	769	1894
TGX 1799-8 F	1744	1969	1177	1663
TGX 1740-2 F	1348	1677	1454	2050
TGX 1805-8 F	952	1858	1458	2104
TGX 1789-7 F	1308	1592	1419	2348
TGX 1835-10 F	1469	1854	806	1883
TGX 1485-1 D	1908	2621	1390	2517
TGX 1895-19 F	675	1000	1256	840
TGX 1876-4 E	1602	1488	1010	1398
TGX 1871-12 E	1696	1998	685	1860
TGX 1831-32 E	1610	2244	627	1998
TGX 1895-49 F	1435	1827	1092	1925
LSD (0.05)	465	682	553.9	565
CV (%)	22	25	34.2	21

had the least grain yields in Nyankpala.

At Wa in 2010, mean grain yields of the early maturing varieties ranged from 627 kg ha^{-1} for TGx 1831-32E to 1579 kg ha^{-1} for TGx 1831-32F (Table 1). In 2011, mean grain yield ranged between 840 kg ha^{-1} for TGx 1895-19F to 2571 kg ha^{-1} for TGx 1485-1D. Across years, no significant differences P>0.05) were observed in grain yield among TGx 1485-1D and seven other varieties including TGx 1799-8F and TGx 1831-32F. The variety, TGx 1895-19F had the least grain production at both locations.

Medium maturing variety trial

The medium maturing varieties flowered and produced dry grains in about 110-115 days. Average grain yields of the medium varieties were relatively higher than those of the early maturing varieties across locations and years (Tables 1 and 2). At Nyankpala, grain yield ranged from 1174 kg ha^{-1} for Quarshie to 2153 kg ha^{-1} for TGx 1844-22E (Table 2). In 2011, mean grain yield ranged from 1477 kg ha^{-1} for TGx 1458-2E to 2404 kg ha^{-1} for Jenguma. It is noteworthy that both Quarshie and Jenguma were released by CSIR-SARI in 2003. Across years, grain yield in Nyankpala tended to be highest for Jenguma and TGx 1844-22E and least for Quarshie.

At Wa in 2010, grain yields of the medium varieties ranged from 1711 kg ha^{-1} for TGx 1838-10E to 2439 kg ha^{-1} for TGx 1846-5E (Table 2). Apart from TGx 1846-5E, all the other varieties had statistically similar (P>0.05) grain yields in 2010. Mean grain yields ranged between 2240 kg ha^{-1} for Quarshie to 3360 kg ha^{-1} for TGx 1844-22E in 2011. In the same year, mean grain yield of TGx 1844-22E was only significantly (P<0.05) higher than those of TGx 1834-5E, TGx 1445-3E and Quarshie. Overall, Quarshie had the least grain production at both locations.

Ranking of preferred traits

Across the two locations, a total of 120 farmers (comprising 90 men and 30 women) participated in the evaluation exercise. Most

TABLE 2

Mean grain yield of medium maturing soybean varieties evaluated in Nyankpala and Wa in northern Ghana, 2010 and 2011

Genotype	Nyankpala		Wa	
	2010	2011	2010	2011
	Grain yield (kg ha^{-1})			
TGX 1805-31F	1759	1950	2145	2904
TGX 1827-1E	1504	2060	2122	2900
TGX 1834-5E	1447	2144	1910	2404
TGX 1838-10E	1458	1946	1711	2796
TGX 1840-12E	1768	1829	2125	3154
TGX 1844-22E	2153	2038	2030	3360
TGX 1846-5E	1821	1977	2439	2986
TGX 1445-3E	1245	2371	2291	2402
TGX 1458-2E	1766	1477	2208	2708
Salintuya-I	1580	1927	1812	3244
Jenguma	1803	2404	2130	2752
Quarshie	1174	1606	1874	2240
LSD (0.05)	571	694	708	793
CV (%)	25.9	24	25.2	20

of the farmers have a long tradition (> 10 years) of growing soybean. The mean age of the participants was 32 years old with a range of 25 to 70. At both locations, farmers generated 12 traits with which they used to evaluate the varieties, with researchers only facilitating (Table 3). The traits were similar for both men and women famers. Across locations, traits desired by farmers, from the highest to the least preferred were: high yield, pod shattering resistance, earliness, number of pods per plant, biomass yield, grain colour, grain size, market demand, resistant to lodging, drought tolerance, pest and diseases resistance and plant height.

At each locations, only four traits were considered "very important" by more than 90% of the farmers in both locations (Table 3). More than 80% of farmers considered resistance to pod shattering to be a very important variety selection criterion. About 53% of the farmers rated drought tolerance as "very important". Overall, the selection criteria, in order of their importance, were high yield (89%), resistance to pod shattering 827%), earliness (67%) and number of pods per plant (58%). The remaining traits were either considered very important by only a few farmers or were related to other traits of importance. Large-sized grain, large number of leaves and tall plants were all related to high grain yield. Grain size is related to high yield and good marketability. Close to 32% of the farmers did not consider plant height to be a very important trait.

Ranking of varieties

Farmers' variety preferences and ranking were similar at the two locations. Among the early maturing varieties, TGx 1799-8F was ranked highest by most farmers, followed by TGx 1485-ID, TGx 1831-32F, TGx 1805-8F and TGx 1843-3F in that order (Table 4). However, researchers ranked them differently based on grain yield. Researchers ranked TGx 1485-1D first, followed by TGx 1831-32F, TGx 1843-3F, TGx 1789-7F and TGx 1799-8F in that order. The variety, TGx 1485-1D which was ranked 1st by researchers was rather ranked 2nd by farmers. Also farmers ranked TGx 1799-8F first but this variety was ranked 5th by researchers based on its grain yield. Nonetheless, researchers and farmers similarly ranked TGx 1895-19F the worst

TABLE 3

Average ratings of soybean variety trait importance by location and gender

Traits	Nyankpala		Wa		Location mean	
	Male	Female	Male	Female	Nyankpala	Wa
High yield	1.00	1.00	1.00	1.00	1.00	1.00
Resistance to shattering	1.00	1.00	1.00	1.00	1.00	1.00
Maturity period	1.00	1.00	1.00	1.00	1.00	1.00
Number of pods	1.02	1.04	1.03	1.05	1.03	1.04
Biomass/leaves	1.12	1.13	1.13	1.18	1.13	1.16
Seed colour	1.89	1.92	1.91	1.92	1.91	1.92
Grain size	2.11	2.19	2.12	2.10	2.15	2.11
Market demand	2.26	2.25	2.32	2.31	2.26	2.32
Resistance to lodging	2.34	2.33	2.35	2.36	2.34	2.36
Drought tolerance	1.00	1.00	2.79	2.69	1.00	2.74
Resistant to pest and diseases	2.89	2.89	2.88	2.87	2.89	2.88
Plant height	2.99	2.91	2.91	2.92	2.95	2.92

TABLE 4
Ranking of soybean varieties according to farmers and researchers impressions in order of importance

Early maturing varieties			Medium maturing varieties		
Variety	Farmers' Rank	Researchers Rank	Variety	Farmers' Rank	Researchers Rank
TGX 1799-8F	1	5	TGX 1844-22E	1	1
TGX 1485-1D	2	1	Jenguma	2	3
TGX 1831-32F	3	2	TGX 1834-5E	3	11
TGX 1805-8F	4	8	TGX 1846-5E	4	2
TGX 1843-3F	5	3	TGX 1805-31F	5	5
TGX 1789-7F	6	4	TGX 1840-12E	6	4
TGX 1740-2F	7	6	TGX 1827-1E	7	6
TGX 1831-32E	8	7	TGX 1445-3E	8	8
TGX 1805-5E	9	10	TGX 1458-2E	9	9
TGX 1871-12E	10	9	TGX 1838-5E	10	10
TGX 1835-10F	11	11	Quarshie	11	12
TGX 1876-4E	12	12	Salintuya-I	12	7
TGX 1895-49F	13	13			
TGX 1895-19F	14	14			

variety among the 14 early maturing varieties evaluated. Therefore, four new early varieties (TGx 1799-8F, TGx 1485-ID, TGx 1831-32F and TGx 1805-8F) showing positive attributes were accepted by farmers and TGx 1895-19 F was rejected by both farmers and researchers. Nevertheless, only TGx 1799-8F showed good resistance to pod shattering and also matured earlier than the other varieties.

Among the medium maturing varieties, TGx 1844-22E was ranked first by both researchers and farmers (Table 4). On the basis of grain yield, researchers ranked TGx 1846-5E second, followed by Jenguma, TGx 1840-12E and TGx 1805-31F in that order. Farmers rather ranked Jenguma, TGx 1834-5E and TGx 1846-5E second, third and fourth, respectively. TGx 1834-5E was ranked 3rd by farmers but researchers ranked it 11th. Both farmers and researchers equally ranked TGx 1805-31F, TGx 1445-3E, TGx 1458-2E and TGx 1838-5E, 5th 8th and 9th and 10th, respectively. The best four medium maturing varieties selected by farmers were TGx 1844-22E, Jenguma, TGx 1834-5E and TGx 1846-5E. Salintuya-1 was ranked 7th by researchers, but farmers

TABLE 5
Comparison of soybean varieties for important variety traits studied under PVS

Cultivar	Grain yield Potential (t ha^{-1})	Pod shattering (%)	Days to maturity (day)	1000-seed weigh(g)	Biomass/ leaves (t ha^{-1})	Seed colour	Plant height (cm)
TGX 1799-8F	1.5-1.8	5	85-92	17.7	1.2-1.4	cream	45-50
TGX 1805-8F	1.5-1.8	5	85-95	13.8	1.2-1.4	cream	45-50
TGX 1844-22E	2.5-3.5	5	116-120		3.0-4.5	cream	50-55
TGX 1834-5E	2.0-2.2	8	110-115	12.6	1.1-1.4	cream	45--55
TGX 1445-3E	1.8-2.2	20	110-120	12.3	1.4-2.4	cream	45--55
Jenguma	2.5-2.8	3	110-115	13.4	1.5-3.0	cream	50-55
Salintuya-I	2.2-2.8	>50	110-115	13.5	1.3-2.0	cream	45--55
Quarshie	2.0-2.4	15	110-115	12.7	1.3-2.0	cream	45-50

considered it the worst variety. Researchers, however, considered the variety, Quarshie as the worst performing variety in terms of grain yield, but it was also ranked 11th by farmers.

The preferred varieties were compared for six important traits: high grain yield, resistant to pod shattering, maturity period, biomass yield and grain colour and size (Table 5). The new varieties were compared to existing varieties grown by farmers. Both Salintuya-I and TGx 1445-5E are prone to pod shattering while the other varieties showed better resistance. Jenguma, and three other new varieties, TGx 1779-8F, TGx 1834-5E and TGx 1844-22E, showed good performance for grain yield and resistance to pod shattering and were therefore rated by farmers as the best varieties. In addition, the dual-purpose variety, TGx 1844-22E produced higher biomass and grain. Although TGx 1445-3E had lower yield, it is known to be efficacious for causing suicidal germination of *Striga hermonthica* seed and was therefore of interest to researchers.

Discussion

In general, production and utilization of soybean can contribute to improving soil fertility and reducing *Striga* infestation on farmers' fields (Kamara *et al*., 2018; Kanampiu *et al*., 2018). *Striga* is parasitic weed which is a major constraint to cereal production in Guinea and Sudan savannas of Ghana (Scheiterle *et al*., 2019). Kamara *et al*. (2018) noted that soybean is a cash crop and thus the adoption of improved varieties can increase rural incomes and employment opportunities especially for women farmers and the youth. Soybean production is essentially an effective climate-smart agriculture practice that conserves soil fertility for higher productivity of other major staple food crops for rural livelihood enhancement (Kamara *et al*., 2018; Kanampiu *et al*., 2018). Biological nitrogen fixation in soybean is economically and ecologically beneficial in the Guinea savanna zone, where soils are deficient in N and fertilizers are not accessible and affordable to resource-poor farmers, owing to their economic conditions.

The PVS approach allowed farmers to select their preferred varieties from a range of varieties. The observed field-based criteria used in the selection of varieties were similar to some extent across locations and gender groups, and had a combination of yield components (high grain yield, grain size, number of pods per plant) and adaptive traits (resistance to pod shattering, earliness to maturity, plant height, resistance to abiotic stresses such as drought and lodging). It is worth noting that the two locations are both situated in the Guinea savannah zone with similar climatic conditions.

Across gender and location, the four top ranked farmer preferred traits out of 12 traits used in evaluating the varieties were high grain yield, pod shattering resistance, earliness and number of pods per plant. It is notable that the farmer preferred traits could influence potential adoption of soybean varieties. Alternatively, adoption may be hindered for new varieties that lack any of those traits. The reason for farmers ranking grain yield highest is obviously because, their primary objective is to maximize their productivity. The high ranking of pod shattering resistance is in line with the findings of Antwi-Boasioko (2017), who identified pod shattering resistance as an important trait that is used to select soybean varieties by resource-poor farmers in the Guinea savannah zone. Pods normally shatter when ripe prior to harvesting, releasing the seeds, the rate and degree of shattering being varietal characteristics, and early or high shattering characteristics are detrimental in varieties harvested mechanically. A delay in harvesting can result in significant yield loss due to shattering. Generally, farmers run the risk of losing some of their harvest to shattering and so seek varieties that tend to shatter less to preserve their harvest.

Grain yield loss from pod shattering can result from pre-harvest loss from pod shattering that occurs in the field prior to harvest, and gathering losses that result from pods that shatter during harvest. Climatic conditions such as high temperatures, rapid temperature variations, low humidity, wetting and drying can contribute to pod shattering (Tukamuhabwa *et al*., 2002). When soybean is cultivated during the rainy season in the Guinea savanna zone, it matures towards the end of the season in October and pod shattering can be exacerbated by the dry Harmattan period in late November, particularly when harvest is delayed beyond maturity. Furthermore, drought, coupled with intense heat and low relative humidity coinciding with grain filling period can cause pod shattering even in resistant varieties. All these conditions are prevalent in the Guinea savanna zone during the dry season (November – March). Physical characteristics of the pods, including pod length, pod wall thickness and lignification of the cell along the suture lines of the pod valves influence resistance to shattering (Krisnawati and Adie *et al*., 2017).

Women play a vital role in crop production in Ghana. According to FAO (2018), rural women constitute about 58% of the agricultural labour force. Women farmers engage in all aspects of agricultural production including soybean production in Ghana (Mbanya, 2011). Thus, pod shattering may add more to the workload of women as they are the ones who will mop up any shattered grain by sweeping and collecting the mixture of grain and sand, then winnow to separate the grain from the sand. Consequently, there is the need for soybean breeders to develop and disseminate varieties that will lessen the burden on women in these farming communities.

According to Chigeza *et al*. (2019), rust resistance, maturity and grain yield were the major traits which formed the basis for releasing varieties in Tropical Legume I and II project countries in Africa, including Ghana between 2007 and 2012. They added that compared to the past decades, more traits may additionally determine overall suitability of a variety, hence selection criteria should be re-designed to meet the never-ending challenge of developing high yielding, stable and farmer preferred varieties. Farmers also mentioned biomass yield and grain size as important selection criteria, though they were not in the top four criteria in the locations that were investigated. Farmers prefer varieties with large-sized grains for trade and high market prices. Large-sized grain is also considered more useful in the preparation of feed for the poultry industry after the oil has been extracted (MoFA, 2017).

The early maturing varieties, TGx 1799-8F and TGx 1805-8F were ranged 1st and 2nd by farmers but researchers ranked them 5th and 8th in that order. The variety, TGx 1779-8F was chosen due to its earliness and therefore ranked highest. This is not surprising as the climate in the Guinea savanna zone is characterized by an erratic rainfall pattern, depicted by short rainy season, in-season and terminal drought. Early maturing varieties are more likely to escape drought and thus are more suited for the climate, helping farmers to adapt to the increasing threat of climate change. Also, an early variety is less risky to grow in areas with shorter rainy periods. With change in climate and expansion of soybean production into the drier savanna regions, abiotic stresses such as drought become more important. The variety, TGx 1485-1D was ranked first by researchers based on grain yield, while farmers ranked it second because it is susceptible to pod shattering and also matures relatively late compared with TGx 1779-8F. This suggest that farmers were not willing to trade-off pod shattering even though TGx 1485-1D possessed high grain yield. Additionally, it is apparent that farmers preferred early maturing varieties as their emphasis was more on earliness than high grain yield.

The medium maturing varieties, TGx 1844-22E and TGx 1834-5E showed good traits such as high grain yields and resistance to pod shattering that appealed to farmers and they therefore ranked them 1st and 3rd, respectively, but the research team ranked them 1th and 11th based on only grain yield data. It seems TGx 1844-22E was the most popular variety among the farmers in both locations. The outstanding characteristics of TGx 1844-22E included: high grain and fodder yields, resistant to pod shattering, high BNF capacity, good market value, weed suppression, human and livestock health and nutrition. TGx 1844-22E is adapted to the Guinea Savanna agro-ecological zone where both crop and livestock farming are practiced. Also, it has higher leaf output than any of the current commercial varieties in Ghana. The haulms of the plants and the dry pod walls are good sources of quality fodder for livestock. Likewise, TGx 1844-22E is preferred by many farmers because it smothers weeds, reduces the cost of weeding and has attractive seed colour. In other studies, TGx 1844-22E has also been shown to significantly fix higher amount of N, induce suicidal germination of *Striga* seed and also has high and better quality soymilk (Denwar, 2018). High soymilk yield and quality may help reduce food insecurity and malnutrition, especially in children, where protein deficiency among children is common because the average family cannot afford meat, fish or eggs.

The previously released variety, Jenguma meaning "sit and wait for me" in local language has been widely adopted by farmers in Ghana due to high grain yield and resistance to pod shattering (Amanor-Boadu *et al.*, 2015). This variety was ranked 2nd by farmers but researchers ranked it 3rd. The reverse was true for TGx 1846-5E. Although Salintuya-I which was released in 1985, had high grain and biomass production, it was rejected by farmers because it is prone to pod shattering. The research team ranked Salintuya-I seventh but farmers ranked it 12th (worst variety). Again, researchers considered the variety, Quarshie as the worst performing variety in terms of grain yield, but it was also ranked 11th by farmers because it shatters less. It is evident that in these specific instances, farmers' preferences for the best varieties, were not in exact agreement with researchers' selection. It appears smallholder farmers usually consider multiple traits to satisfy their diverse needs. Beside no single variety, of course, can meet all their needs.

Basically, the farmers' preferences of four early varieties (TGx 1835-10F, TGx 1876-4E, TGx1895-49F and TGx 1895-19F) and five medium varieties (TGx 1844-22E, TGx 1805-31F, TGx 1445-3E, TGx 1458-2E and TGx 1838-5E) coincided with the researchers' selection. According to Buah *et al*. (2013), farmer's preferences in some cases during PVS exercise often coincided with the breeders' selection as was the case with the similar order of ranking of these nine varieties by both researchers and farmers in this study.

In developing and selecting new varieties, breeders may discard many varieties because of traits considered undesirable to them; though these traits may be of interest to farmers (Getahun *et al*., 2016; Ojulong *et al*., 2017). As some of the criteria that were important for farmers at the two locations may not have been prioritised in formal soybean breeding programmes, results of this study point to the repeatedly emphasised need to involve farmers at the appropriate stages of variety development and testing in order to incorporate their preferences in selection of varieties in the breeding programme. This may increase likelihood of adoption of the varieties and also influence selection of traits in soybean breeding program in the future.

Results of the study showed that there is a desire by farmers to adopt their preferred improved varieties if they are available; they keep the popular variety for many years due to lack of options exacerbated by high prices for seed every season. Ceccarelli (2015) noted that plant breeders often develop improved varieties mostly based on their perspective and not much attention is given about the specific needs of the farmers in the target production areas, especially during early phases of selection process. The varieties are tested only at final stages on the farmers' fields for their suitability before their release. According to Ceccarelli (2015), research that does not involve farmers as active members in the early stages of the selection process faces the risk of developing technologies of little relevance and of low adoption

In this study, farmers were not given the opportunity to conduct sensory evaluation to rate their preferences for the organoleptic qualities of the varieties. It is possible that inclusion of organoleptic tests in the current study could have changed the observed ranking of varieties. Additionally, some of the important traits for farmers, such as high oil content, high and better quality soymilk production, high potential for N_2 fixation and ability to induce germination of *Striga* seed were not prioritized by farmers, but should be considered when developing or recommending soybean varieties.

Through the PVS process, farmers identified varieties with desired attributes such as high grain yield, resistance to pod shattering, suicidal germination of *Striga* seed as well as nutritional attributes. These findings corroborate with studies by Getahun *et al*., 2016 and Ojulong *et al*. 2017 who reported that PVS adds information on farmers' perceptions of plant and grain traits and ensures that new varieties satisfy their preferences and suit their socio-economic situations. Furthermore, PVS has been used in other parts of Africa to introduce, evaluate, release and promote various crop varieties for adoption (Buah el at., 2013; Getahun *et al*., 2016; Ojulong *et al*., 2017; Chimonyo *et al*., 2019). An important advantage of PVS is that the adoption of new varieties is much faster than under the formal system, in which farmers are confronted with only a very restricted range of varieties (Ceccarelli, 2015).

Generally, four preferred varieties (TGx 1799-8F, TGx 1445-3E, TGx 1834-5E and TGx 1844-22E) were ideal replacement for the existing commercial varieties. These varieties are superior in many traits compared to the existing varieties and their cultivation and use may increase farm level productivity, alleviate hunger and malnutrition and contribute to soil fertility improvement for end-users. Moreover, the production and utilization of these varieties could contribute to the nation achieving the Millennium Development Goal targets on reducing extreme poverty and hunger. Consequently, the National Variety Release and Registration Committee (NVRRC) later approved the release and registration of TGx 1799-8F, TGx 1445-3E, TGx 1834-5E and TGx 1844-22E as Suong-Pungun, Songda, Afayak and Favour, respectively. Major characteristics of the varieties were highlighted in their released and registration protocol (MoFA 2019). Although TGx 1445-3E had relatively low grain production and also prone to pod shattering, it was released and registered due to its enhanced ability to cause suicidal germination of *Striga* seeds. Moreover, Suong-Pungun is the only early maturing variety released in Ghana so far.

Farmers who participated in the PVS process and liked the varieties retained seed of some of the varieties from previous harvests of the trials for planting in the following season or to share with their colleagues. This is a clear indication that farmers are willing to adopt the varieties as they are convinced of their high grain yields and resistance to pod shattering. This obviously provides evidence that there is a desire by farmers to adopt improved varieties if they are available. This is in agreement with Getahun *et al*., 2016 who noted that increasing farmers' access to their preferred varieties would result in a faster rate of diffusion through farmer-to-farmer seed exchange, thus guaranteeing a further high adoption. The replacement of the existing varieties that are susceptible to pod shattering with these new pods shattering resistant varieties Jenguma, Suong-Pungun, Afayak and Favour boosted production by smallholder farmers who hitherto suffered significant yield losses due to late harvesting (MoFA, 2017). Following the release of these varieties, partnerships were established with seed companies and community seed producers associations to facilitate seed production and delivery to remote areas in order to increase availability and accessibility of seed of the varieties. This will contribute greatly towards the success of the Government's flagship programme, *Planting for Food and Jobs*.

Conclusion

Through the PVS approach, a broader choice of soybean varieties that matched farmer needs in adaptation and quality traits was offered for evaluation and farmers selected and adopted new varieties with a combination of improved agronomic traits, higher yield, and improved quality. Farmers' preferred variety selection criteria and ranking of varieties did not differ across locations and gender groups. This therefore did not necessitate extensive evaluation for adaptability and acceptability before recommending the varieties for release. In order of importance, farmers' preferred traits were high grain yield, pod shattering, maturity period and number of pods per plant. In this study, some selection criteria differed slightly between farmers and researchers. Across locations, the varieties preferred by farmers had high grain yields, pod shattering resistance, enhanced ability to control *Striga* and were broadly adapted to the Guinea savanna zone.The study demonstrated that multiple traits were used in variety selection, and there was no single variety that could meet all the requirements by farmers. Given the preference for pod shattering resistance, it might be worthwhile to improve soybean varieties for high and stable grain yields, pod shattering resistance and other quality traits that will be desired and accepted by farmers. Considering the local nature of the study, a macro-level study to cover other agro-ecological zones may be desirable for wider dissemination of results and to better guide the national soybean breeding efforts.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

Angarawai, I.I., Bukar, B., Olabanji, O.G., Iro, N., Haussmann, B.G., Weltzien, E.V., Gwadi, K.W., Gubio, T. and Yahaya, Y. (2016). Farmer participatory varietal selection in pearl millet: Experience across some states of Northern Nigeria. African *Journal of Agricultural Research*. **11**:1421-1425.

Amanor-Boadu, V., Zereyesus, Y., Ross, K., Ofori-Bah, A., Adams S., Asiedu-Dartey, J., Gutierrez, E., Hancock, A., Mzyece, A. and Slain, M. (2015). Agricultural Production Survey for the Northern Regions of Ghana: 2013-2014 Results. pp106.

Antwi-Boasiako, A. (2017). Screening of soybean (*Glycine max* (L.) Merrill) genotypes for resistance to lodging and pod shattering. *International Journal of Agronomy and Agricultural Research*. **10**: 1-8.

Avea, A.D., Zhu, J., Tian, X., Balezentis, T., Li, T., Rickaille, M. and Funsani, W. (2016). Do NGOs and development agencies contribute to sustainability of smallholder soybean farmers in Northern Ghana: A Stochastic Production Frontier Approach. Sustainability. **8**: 2-17.

Bellon, M.R. (2002). Analysis of the demand for characteristics by wealth and gender: a case study from Oaxaca, Mexico. In M.R. Bellon and J. Reeves (Eds). *Quantitative Analysis of Data from Participatory methods in Plant Breeding* (pp. 66-81). CYMMYT, Mexico, DF.

Buah, S.S.J., Kombiok, J.M., Kanton, R.A.L., Denwar, N.N., Haruna, A., Wiredu, A.N. and Abdulai, M.S. (2013). Participatory evaluation of drought tolerant maize varieties in the Guinea savanna of Ghana using mother and baby trial design. *Journal of Science and Technology*. **33**:75-83.

Ceccarelli, S. (2015). Efficiency of Plant Breeding. *Crop Science.* **55**:87–97.

Chimonyo, V. G. P., Mutengwa, C.S., Chiduza, C. and Tandzi, L.N. (2019). Participatory selection of maize genotypes in the Eastern Cape Province of South Africa. *South African Journal of Agricultural Extension*. **47**:103- 117.

Chigeza G., Boahen, S., Gedil, M., Agoyi,

E., Mushoriwa, H., Denwar, N., Gondwe, T., Tesfaye, A., Kamara, A., Alamu. O.E. and Chikoye, D. (2019). Public sector soybean (Glycine max) breeding: Advances in cultivar development in the African tropics. *Plant Breeding*. **138**:455-464.

De Groote, H., Siambi, M., Friesen, D. and Diallo, A. (2002). Identifying Farmers' Preferences for New Maize Varieties in Eastern Africa. In M.R. Bellon and J. Reeves (Eds). *Quantitative Analysis of Data from Participatory methods in Plant Breeding* (pp. 82-103). CYMMYT, Mexico, DF.

Denwar, N.N. (2018). Soybean Improvement Programme. *CSIR-SARI Annual Report*, pp 58-65.

FAOSTAT (2014). Retrieved from http://www.fao.org/faostat/en/#data/QC. Accessed on August 1st 2017.

FAO and ECOWAS Commission. (2018). National Gender Profile of Agriculture and Rural Livelihoods – Ghana. Country Gender Assessment Series, Accra. p80

Getahun A, Atnaf, M., Abady, S., Degu, T. and Dilnesaw, Z. (2016). Participatory variety selection of soybean (*Glycine max* (L.) Merrill) varieties under rain fed condition of Pawe District, North-Western Ethiopia. *International Journal of Applied Science and Mathematics*. **3**:40-43

Ghana Statistical Service (GSS). (2014). National Accounts Statistics. Final 2012 Gross Domestic Product & Revised 2013 Gross Domestic Product. Ghana, Accra. www.sta tsghana.gov.gh.

Kamara, A.Y., Kamai, N., Kanampiu, F., Kamsang, L., and Kamara, A.Y. (2018). Gender analysis of soybean adoption and impact. IITA, Ibadan, Nigeria. 57pp.

Kanampiu. F., Makumbi, D., Mageto, E., Omanya, G., Waruingi, S., Musyoka, P. and Ransom J. (2018) Assessment of Management Options on *Striga* Infestation and Maize Grain Yield in Kenya. *Weed Science*. **66**:516–524.

Krisnawati, A. and Adie, M.M. (2017) Variability on morphological characters associated with pod shattering resistance in soybean. *Biodiversitas*. **18**:73-77.

Mbanya, W. (2011). Assessment of the Constraints in Soybean Production: A Case of Northern Region. Ghana. *Journal of Developments in Sustainable Agriculture.* **6**:199-214.

Mohammed, S.A.R., Al-hassan, S. and Amegashie, D.P.K. (2016) Technical Efficiency of Soybean Farmers in the Northern Region of Ghana. *ADRRI Journal of Agriculture and Food Sciences.* **2:** 20-38.

Ojulong, H., Letayo, E., Sakwera, L., Ziwa, Mgonja, F., Sheunda, P., Kibuka, J., Otwani. D., Audi, P., Mgonja, M. and Manyasa, E. (2017). Participatory variety selection for enhanced promotion and adoption of improved finger millet varieties: A case for Singida and Iramba Districts in Central Tanzania H. *African Journal of Rural Development*, **2**:77-93.

Osman, A., Donkoh, S. A., Ayamga, M. and Ansah, I. G. K. (2018). Economic efficiency of soybean production in the Northern Region of Ghana. *Ghana Journal of Agricultural Economics and Agribusiness*. **1**:1-30

Raimi, A., Adeleke, R. Roopnarain, A. (2019). Soil fertility challenges and Biofertiliser as a viable alternative for increasing smallholder farmer crop productivity in sub-Saharan Africa, *Cogent Food Agriculture*. **3**: 1400933.

Scheiterle, L., Häring, V., Birner, R. and Bosch C. (2019). Soil, *Striga*, or subsidies?

Determinants of maize productivity in northern Ghana. *Agricultural Economics*. **50**:479-494.

Ministry of Food and Agriculture, MoFA. (2017). Agriculture in Ghana. Facts and Figures 2016. Statistics, Research and Information Directorate (SRID) of MoFA. Accra, Ghana.

Ministry of Food and Agriculture, MoFA, (2019). Catalogue of crop varieties released and registered in Ghana. Directorate of Crop Services of MoFA. Accra, Ghana

Tukamuhabwa, P., Dashiell, K., Rubaihayo, P. and Nabasiry, M. (2002). Determination of field yield loss and effect of environment on pod shattering in soybean. *African Crop Science Journal*. **10**:203-209