Participatory rural appraisal to identify farmer-preferred soybean traits in Ghana

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Abstract

Soybean pod shattering remains an important constraint in soybean cultivation causing yield loss up to 100%. The objective of this study was to identify the varieties as well as the plant and grain traits of soybean preferred by farmers. A survey was conducted in three northern (Northern, Upper east and west) regions of Ghana. A total of 192 farmers were reached and individual farmers were interviewed using structured questionnaire. The data collected was coded using a statistical software. Descriptive analyses were used to summarize the data into means, percentages and tabulations. Kendall Coefficient of Concordance procedure was implemented to ascertain the level of agreement among farmer preferred soybean traits. The study revealed that, despite the existence of pod shattering resistant varieties, many farmers still grow pod shattering susceptible varieties. They preferred these varieties because they were high yielding (Salintuya-I), early maturing (Sounpungun), and a trap crop for striga (Songda). Majority of farmers (98%) ranked yield (3.79), big seed size (4.03) and non-shattering (4.08) as the most important traits (Kendall's W=0.379 P=00.00) across all regions. In addition, early maturing (4.45) and medium maturing varieties (4.45) were also ranked as important traits by all respondents. Therefore, breeding programmes should aim to develop varieties, taking into consideration farmer preferred traits to increase varietal adoption.

Keywords: Pod shattering, ranking, farmer preferred trait, resistance, susceptibility

Introduction

Soybean (*Glycine max*) is an important leguminous crop. It is an annual, erect and bushy plant, which has the potential to grow in a wide range of ecological conditions (Ministry of Food and Agriculture, MoFA, 2010; Mishra et al., 2024). The grain contains 40% edible oil and 20% protein together with vitamins, minerals and essential amino acid, hence, serve as an essential commodity beneficial to human, poultry and livestock (Plahar, 2006). Plant breeders develop new crop varieties at on-stations trials and often consider agronomic traits like yield, 50% flowering date, height, flower colour as important traits. Nonetheless, farmers desired traits like yield, resistance to shattering, earliness and big seed size are often not included in conventional plant breeding programmes (Singh et al., 2014).

As a result, there is a mismatched of desired traits between scientist and farmers as well as yield differences between farmer-managed and controlled on-station fields (Mishra et al., 2014). Hence, low adoption of new varieties by farmers due to the marginalization of these farmer traits during varietal development. According to Daudi et al., (2018) the use of participatory plant breeding will justify the inclusion of farmer preferred traits and increase adoption rate of improved varieties. Participatory techniques served as an important and effective tool to collect information on significant plant traits for breeding programmes (Witcombe et al., 2005).

The initiation of participatory plant breeding involves the elicitation of farmer knowledge

on desirable traits of crops they cultivate (Walker, 2008). The success of this will enable the screening and selection of diverse parental material for crosses. These are most likely to result in progenies that segregate well for farmer desirable traits in their ecologies (Abady et al., 2019). The use of farmer preferred and other marketable cultivar traits will increase their choice with high chances of adoption (Ribeiro et al., 2017). Participatory Rural Appraisal (PRA) seeks to address farmers' perception on production limitations, selection of varieties and trait preference (Abady et al., 2019). It is also an effective formulation procedures meant to improve clients' lives (Singh Mahra et al., 2015).

Previous studies used different PRA procedures for collecting data including transect walk, matrix scoring and ranking. These procedures are quick in gathering and using information to solve socioeconomic problems of the clients (Richards, 2014; Singh Mahra et al., 2015; Alam, 2012). Other uses of PRA were geared towards solving soybean market channels in smallholder technical performance (Dogbe et al., 2013), soybean utilization training to women (Yvonne Price , 2011) and evaluation of superior soybean genotypes for adaptation to different environment (Moses, 2012). There should therefore be a resolution between farmers and scientist to accept common economic traits beneficial to farmers. This will guarantee high adoption rate by farmers. The main objective of this study was to identify major plant and grain traits of soybean preferred by farmers in Ghana. The success of this will increase varietal adoption rate and guide for future breeding programmes. Specific objectives were to: Identify farmer soybean production systems and constraints, assess farmer perception on shattering traits and identify farmer current preferred traits in new soybean varieties.

Review of farmer-preferred crop traits

Participatory Varietal Evaluations (PVEs) empower breeders to have a deeper understanding of farmer preferred traits that are relevant to farmers, for planning of breeding objectives (Klauck, 2020). The use of participatory approach aid breeders' conception about their client's knowledge, experiences, constraints, needs and varietal trait preferences in crop improvement. Considerable information about the farming systems, agro-eco logical and socio-economic settings under which farmers work and their production goals are important to initiate any crop improvement program (Buah et al., 2018) and (Lammerts van Bueren et al., 2002). Besides, consideration of the trait physical appearance is ideal to the farmers and other stakeholders in the value chain in defining product profiles needed to develop new varieties and therefore offers great potential for adoption. Crop varietal adoption is an intricate situation and new varieties developed are less likely to be adopted if it does not address farmer preferences (Klauck, 2020) and (Sall et al., 2000). Besides, low adoption rate of new varieties is attributed to the lack of adequacy between farmers' expectations and breeding programs' priorities (Thiele et al., 2021) and (Marenya et al., 2022)

Many studies revealed that, low adoption rate of improved varieties is due to inadequate farmers' outlooks and breeding programs' priorities (Ndeko, 2022), (Kimathi et al., 2021) Also, lack of efficient breeding procedure that combines farmer preferred traits in new varieties results in low performance and adoption rates by farmers especially in marginal environments (Dawson et al., 2008). For effective adoption rate, increase in yield, income, or nutritional values, the use of any cultivar development methodology must appreciate farmer preferred traits. It is important to note that, farmers are well aware of their cultivar needs and that they prioritize these traits depending on the social-economic and environmental conditions prevailing in their precise ecology (Piñeiro et al., 2020) and (Bottrell & Schoenly, 2018).

Therefore, effective breeding procedures must be follow to develop new soybean varieties that considers farmer trait preferences and other end-users (Witcombe et al., 2005). A close collaboration for interaction between

scientist, farmers and other stakeholders should be done to identify farmer preferred traits.

Material and Methods

Study area

The survey was carried out in the Northern, Upper East and Upper West regions of Ghana during the year 2019 and 2020 cropping seasons. Twelve (12) districts made up of 4 districts from each region as well as 48 communities made up of 4 communities from each district were randomly selected as in Figure 1. A total number of 192 soybean farmers were purposively selected through random sampling approach and were interviewed using semi-structured questionnaires in their local languages. In each community, 4 farmers made up of 2 men and 2 women were used as in (Table 1). Geographically, the Northern and Upper West regions are in the Guinea savannah agro-ecology while the Upper East Region is in the Sudan agro-ecology. Information on the environmental characteristics of the regions are presented in Table 2.

Rainfall regime is unimodal across all regions with erratic distribution pattern starting from early April to October/November across the Guinea and the Sudan Savannahs. (Salifu et al., 2017). Besides, minimum temperature and soil types were 15°C and sandy loam to gravely sandy across the three regions. Mean annual precipitation is 1100mm and 1000mm for Guinea and Sudan Agro-ecological zones

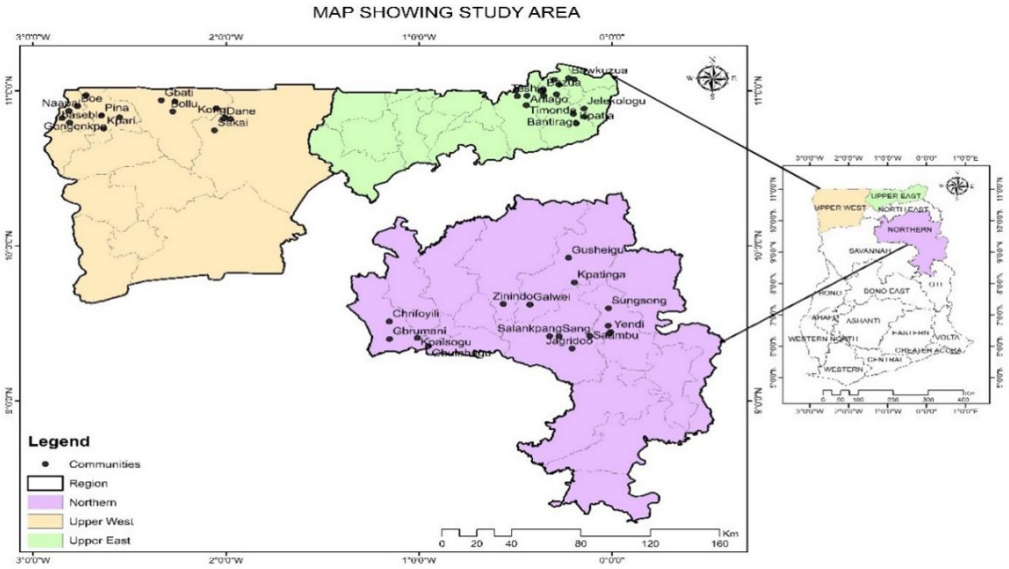

Figure 1 Regions, districts and communities of the study area

TABLE 1

Locations and number of farmers involved in the survey

Region	District	Communities	Male	Female
Northern	Tolon	Kpalsogu, Chrifoyilii, Gbrumani and Gbulahagu	8	8
	Gushegu	Gushegu, Kpatinga, Zinindo and Galwei	8	8
	Mion	Salankpang, Jagridoo, Saambu and Sang	8	8
	Yendi	Yendi, Tusani, Gundogu and Sunsong	8	8
Upper East	Bawku Municipal	Bawkuzua, Musiga, Zawse and Kpalwega	8	8
	Binduri	Bazua, Nafikoliga, Gayoko and Komnab	8	8
	Bawku west (Zebila)	Kubongo, Aniago, Teshie and Timonde	8	8
	Garu	Jelekologu, Bantirago, Kpatia and Parinboko	8	8
Upper West	Sisala East (Tumu)	Challo, Kong, Dane and Sakai	8	8
	Nandom	Boe, Gengenkpe, Naapal and Baseble	8	8
	Lambusie	Samoa, Pina, Kpari and Billaw	8	8
	Sisala West (Gwolu)	Kwala, Silibele, Bollu and Gbati	8	8

TABLE 2
Environmental conditions of the survey area

Regions	Agro-Ecology	Latitude	Longitude	Soil type	Temp (Mini)	Temp (Maxi)	Rel. Hum	Rainfall Amount	Rainfall Regime
Northern	Guinea Savannah	10° 39' 0" N	2° 35' 30" W	Sandy loam to gravely sandy	18°C	40°C	20 - 95%	1100mm	Unimodal
Upper East	Sudan Savannah	11° 9' 30" N	1°34' 30" W	Sandy loam to gravely sandy	15°C	43°C	10 - 90%	1000mm	Unimodal
Upper West	Guinea Savannah	11° 0' 0" N	3° 0' 0" W	Sandy loam to gravely sandy	15°C	42°C	18 - 95%	1100mm	Unimodal

respectively (MoFA, 2018-2021).
Despite the potential features of the zones to grow food crops and livestock, low soil fertility especially with sandy soils is a major constraint coupled with drought especially in the Sudan zone during the beginning of the season.

Experimental and Questionnaires Design, Sampling and Data collection
Sampling of soybean farmers for the interview was done using purposive sampling procedure. A semi-structured questionnaire was developed and administered face-to-face to farmers. Primary data was elicited on soybean production, constraints and farmer-preferred traits from the selected farmers. The questionnaire also captured farmer demographic information, soybean production and varieties of soybean cultivated. Others were sources of the seeds, constraints in production, harvesting times and plant and seeds traits preferred. Besides, farmers were asked about their knowledge of soybean shattering and management practices they used to overcome pod shattering. Farmers' preferred soybean traits were evaluated and graded using a score of 1 (most important), 2 (important), 3 (moderately important), 4 (less important) and 5 (not important).

Data analysis
Both quantitative and qualitative data were coded and subjected to analyses by means of descriptive and cross-tabulation procedures using a statistical software. Descriptive analyses were used to summarize the data into means and percentages and tables were constructed out of them. Besides, data on farmer- preferred soybean traits were analyzed using Kendall Concordance Analysis. The total rank score computed was used to calculate the coefficient of concordance (W) which measures the degree of agreement among the respondents in the rankings.
The coefficient of concordance was estimated using the relation as determined and previously used by Kopa & Tichy (2012) and Marozzi (2014).

$$W = \frac{12\left[\sum T^2 - \frac{(\sum T)^2}{n}\right]}{nm^2(n^2-1)} \qquad (1)$$

Where in the above formulae: T = Sum of rank of factors being ranked, m = number of respondents (farmers), n = number of factors being ranked and W = coefficient of concordance.
The Coefficient of Concordance (W) was tested for significance in terms of the F distribution. The F-ratio is given by

$$F = \frac{(m-1)\times(1-W)}{(1-W)} \qquad (2)$$

With numerator and denominator degrees of freedom being

$$(n-1)-\left(\tfrac{2}{m}\right) \text{ and } m-1\left[(n-1)-2/m\right]$$

respectively.
Finally, the null and alternative hypotheses were stated as;
H_0 There was no agreement between the respondents on the ranking of the factors
H_1 There was an agreement between the respondents on the ranking of the factors.

Results

Socio-demographic characteristics of the respondents
The socio-demographic characteristics of the respondents reported a total of 192 farmers

TABLE 3
General information on Socio-demographic characteristics of the respondents

Characteristics	Respondent in Northern Region			Respondent in Upper East Region			Respondent in Upper West Region		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
Age of farmer									
Greater than 50 years	15.3	14.4	29.7	09.5	01.6	11.1	21.1	06.7	27.8
Less than 50 years	37.6	32.7	70.3	35.6	57.2	91.8	37.8	41.4	72.2
Stakeholder in soybean									
Farmer	51.6	48.4	100.0	43.7	56.3	100.0	51.6	48.4	100
Educational level									
No education	14.00	29.00	43.00	24.00	19.00	43.00	14.00	31.00	45.00
Nonformal	10.10	07.70	17.80	13.10	11.70	24.80	07.10	10.70	17.80
Primary	04.10	08.70	12.80	03.10	06.70	09.80	03.10	09.70	12.80
JHS	05.10	06.00	11.10	02.10	04.00	06.10	03.10	09.00	12.10
SHS	14.10	03.20	17.30	10.10	07.20	17.30	11.10	01.20	12.30
Tertiary	00.00	00.00	00.00	00.00	00.00	00.00	02.00	00.00	02.00
Why do you grow soybean									
For consumption	0.00	01.6	01.6	0.00	01.6	01.6	1.6	3.1	04.7
Processing	06.3	15.5	21.8	06.3	15.6	21.9	1.6	4.7	06.3
For domestic market	37.5	39.1	76.6	37.4	39.1	76.5	48.4	40.6	89.0
Years of cultivating soybean									
2 – 10 years	14.0	01.60	15.6	20.7	24.3	45.0	01.60	09.5	11.0
10 – 20 years	31.2	47.0	78.2	23.6	31.4	55.0	50.0	39.1	89.0
20 – 28 years	06.20	00.00	06.20	00.00	00.00	00.00	00.00	00.00	00.00

of which 96 (50%) were male and 96 (50%) were female across the three regions. This suggested a complete gender balance in the study as in Table 3. Majority of the farmers (78%) were less than 50 years across all the regions whilest the least percent (23%) were more than 50 years. This means many farmers interviewed were into their productive years. All the respondents across the 3 regions were farmers of soybean. Soybean is considered as a cash crop, so majority of the farmers (90%) grow soybean for the domestic market. A smaller to the least proportion of farmers (6%) and (5%) grows it for consumption and processing respectively. Majority of the farmers (44%) have not gotten formal education, resulting in low level of literacy across the three regions. However, about 20% had nonformal education, 12% primary, 10% Junior high, 16% senior high was reported across all regions and 2% tertiary was revealed in Upper West region only.

Many of the farmers (74%) have experience in soybean cultivation, as they have been cultivating soybeans for the past 20 years. Few farmers were into soybean production for the past 10 years (16%) and fewer farmers (6%) for the past 28 years. Hence, these farmers with such experience would be able to expand their farms if new technologies or varieties are introduced to them using their preferred traits. The low level of literacy influenced the role Agricultural Extension Agents (AEA) played in explaining and interpreting the questionnaires during the survey. Besides, research service providers and other change agents need to communicate to respondence in these communities in their local languages. On the other hand, the educated respondence were important in information gathering pertaining to farmers' priority, needs and constraints. They also served as facilitators and Trainer of Trainees (ToT) that will help and positively influence the introduction of new technologies in their respective communities.

Farmer experience in soybean cultivation

The cultural practices used by farmers in soybean cultivation has been spelled out in Table 4.0. A greater proportion of men (48.40%) and women (31.80%) in Northern Region cultivate soybean more than those in

TABLE 4
Practices used by farmers in soybeans cultivation

Characteristics	Northern Region			Upper East Region			Upper West Region		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
Who grow soybean									
Men	25.00	23.40	48.40	00.00	00.00	00.00	01.50	00.00	01.50
Women	12.50	18.80	31.30	00.00	00.00	00.00	07.90	09.50	17.50
Both	10.90	09.40	20.30	45.30	54.70	100.0	33.30	47.60	81.00
Cropping systems									
Sole	41.40	47.60	89.00	39.10	45.30	84.40	38.10	47.60	85.70
Intercrop	04.20	06.80	11.00	06.30	09.30	15.60	04.80	09.50	14.30
Seed bed preparation									
Tractor	43.80	46.90	90.60	00.00	00.00	00.00	36.50	52.40	88.90
Donkey	01.60	01.60	03.20	40.30	54.70	95.00	00.00	00.00	00.00
Hoe	03.10	03.10	06.20	05.00	00.00	05.00	06.30	04.80	11.10
Seed bed type									
Flat	46.80	43.50	90.30	00.00	00.00	00.00	42.90	55.60	98.40
Ridges	01.60	08.10	09.70	45.30	54.70	100.0	00.00	01.60	01.60
Time of planting									
June	37.50	34.40	71.90	42.20	54.70	96.90	17.50	23.80	41.30
July	10.90	14.10	25.00	03.10	00.00	03.10	25.40	33.30	58.70
August	00.00	03.10	03.10	00.00	00.00	00.00	00.00	00.00	00.00
10 – 20 years	31.2	47.0	78.2	23.6	31.4	55.0	50.0	39.1	89.0
20 – 28 years	06.20	00.00	06.20	00.00	00.00	00.00	00.00	00.00	00.00

Upper East and West regions. The majority of both men and women in Upper East (100%) and West (81%) regions produce soybean more than men and women (20.3%) in the Northern Region. The introduction of soybean cultivation has been integrated by farmers into many cropping systems. The majority (85%) of farmers practice soybean sole cropping especially in the Northern Region. About 15% of farmers practice soybean intercropping with maize, groundnut and sorghum especially in Upper East and West regions. Land preparation in soybean cultivation is an important practice for good seed emergency. A greater portion of the farmers in the Northern (90%) and Upper West (100%) regions used tractor plough for land preparation. Farmers in the Upper East Region (95%) used donkey plough for land preparation. About 5-11% of farmers across all the regions used hoe for land preparation. Most farmers in Northern (90.30%) and Upper West (98.40%) regions planted on the flat, while farmers in Upper East Region (100%) planted on ridges. Many farmers in the Northern (72%) and Upper East (97%) regions as well as some farmers in the Upper West Region (41%) plant soybean in June when soil moisture is stabilized. However, the majority of farmers in the Upper West Region (59%) plant in July.

Soybean varieties commonly grown by farmers

Soybean varieties grown by farmers do not differ so much from one location to another as revealed in Fig. 2. The only differences are differences in names of similar varieties and the average unit of land assigned to each variety in each region. Ten soybean varieties were commonly found to be cultivated across all the three regions. These varieties were: Jenguma, Salintuya-I, Favour, White soybean, Soungpungun, Afayak, Songda, Red Soybean, Local and Agric. In all the regions, all the pod shattering-resistant varieties (Jenguma, Favour and Afayak) were grown. But in addition to these varieties, many of the farmers (52%) still cultivate susceptible-to-pod-shattering varieties such as Salintuya-I,

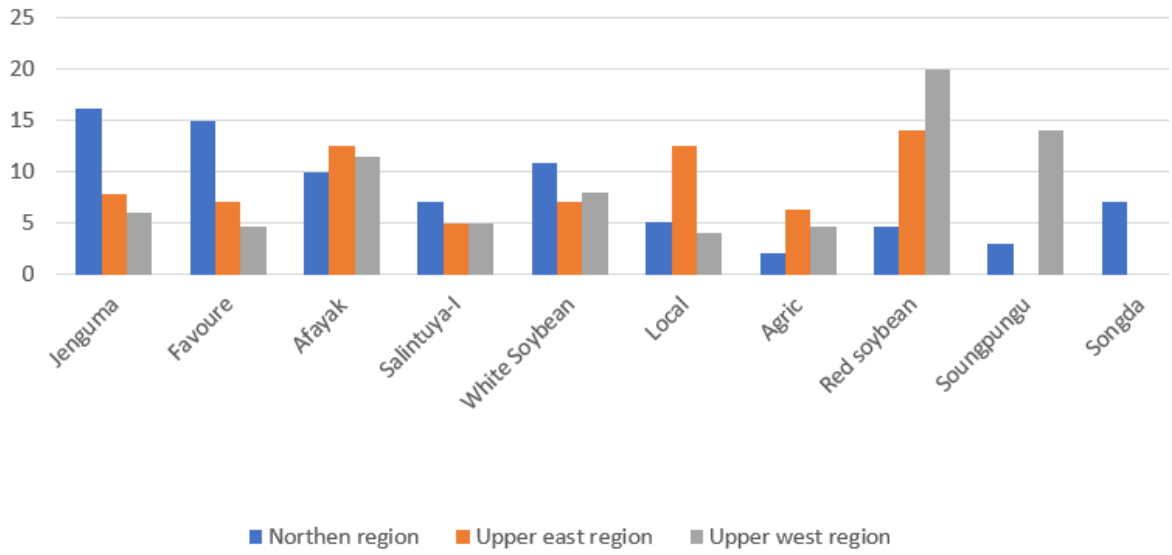

Figure 2 Common soybean varieties grown by farmers at the various ecologies across Northern Ghana

Songda and Soungpungun. A high proportion of farmers (88%) preferred elite but pod shattering varieties because of desired traits associated with these varieties. These traits were: early maturity (Sounpungun), high yielding (Salintuya-I) and a trap crop for striga control (Songda).

Commercial farmers and seed growers (20%) with targeted customers and markets grow more of Jenguma, Favour and Afayak. Only Variety Songda was cultivated in Tolon and some parts of Gushegu districts of Northern region. Sounpungun grew largely in Upper West region than the other two regions.

Reclassification of farmer cultivated varieties

Soybean seeds grown by farmers were sampled as germplasm during the survey. After comparing the seeds and plant phenotypes to the existing varieties released by CSIR – SARI and cultivated by farmers, it was revealed that, The Agric soybean variety cultivated by farmers and resistant to pod shattering referred to Jenguma, Favour and Afayak across all locations as in Fig. 3.0. On the contrary, the local varieties refer to all susceptible-to- pod-shattering varieties (Salintuya-I, Songda and Sounpungun) cultivated by farmers. The red soybean variety was described by farmers of Upper West region using the colour of the Soungpungun seed kernel which is brown in colour. Besides, farmers in Northern and some farmers in Upper East region referred to red variety as Afayak because of the wine colour the plant exhibit when matured and dried. The white variety cultivated by farmers referred to Salintuya-I and Favour, described by farmers as gray using the plant features after maturity

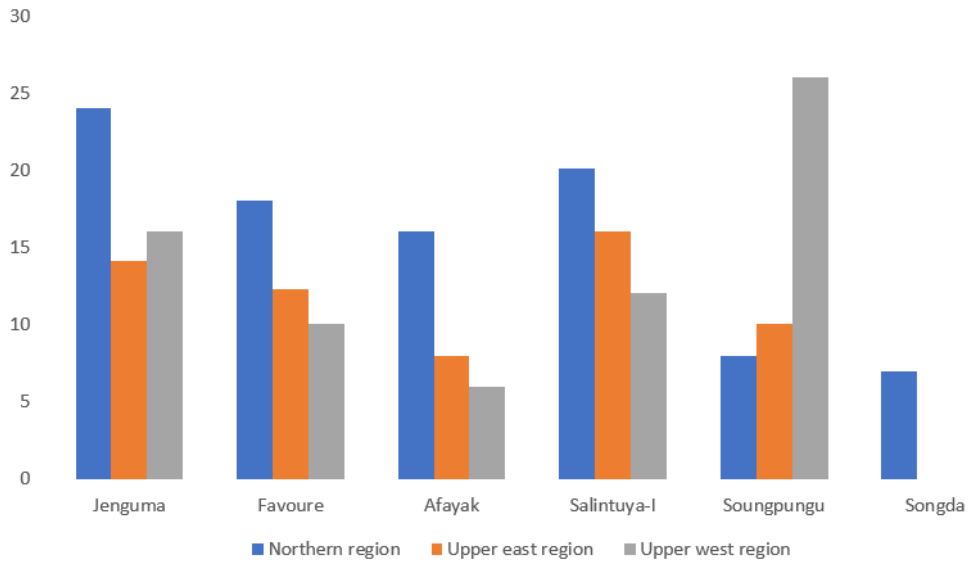

Figure 3 Reclassification of common soybean varieties grown by farmers

TABLE 5
Farmer preference of elite but susceptible soybean varieties

S/N	Variety	Days to maturity	Yield (kg) per hectare	Reasons for preference
1	Salintuya -I	118	1800kg/ha	Medium maturing with high yielding
2	Sounpungun	90	1350kg/ha	Early maturing with substantial yield
3	Songda	110	1500kg/ha	Medium maturing with striga control

and dried across the three regions.

Farmer preference of susceptible varieties over current resistant varieties

Many farmers cultivate susceptible to shattering varieties because most of their seed sources are obtained informally through inheritance, aided from parents or borrowed from colleague farmers. Besides, they were high yielding with a potential yield of 1.8 t/ha as presented in table 5.

These varieties also fall within early to medium maturity period. Sounpungun is early maturing across the 3 regions, but mostly cultivated in the Upper West Region. Besides, Songda was resistant to Striga (*Striga gesnerioides*). This made it fit well in the cropping systems that existed before and after the introduction of soybean varieties. Only few farmers (8%) patronized the Agric varieties (Jenguma, Favour and Afayak because they were expensive with a kilogram ranging from GHC 5 – 10. Besides affordability, access to resistant varieties was limited since most seed sellers were found in district or regional capitals.

Farmer seed system

Many soybean farmers start cultivating soybeans using seeds from their parents or aided seeds from colleagues' farmers. The study revealed in fig. 4. that about 65% of the farmers across the three regions save seeds from their previous harvest for the next farming season. Besides, 28% acquired their preferred varietal seeds from colleague farmers through exchange, borrowing or buying, 15% of the farmers buy from the market and 7% buy from the Ministry of Food and Agriculture or approved certified seed sellers.

Soybean production constraints

Soybean production has a lot of constraints as revealed in table 6. Biotic constraints that were mentioned by farmers at the vegetative phase, but said to be very negligible, were leaf miners and grasshoppers. During land, seed bed preparation and planting stages, common constraints that farmers faced were low soil moisture (12.30%), unavailability of improve seed (51.60%) and tractor services (36%)) for the Northern Region. Unavailability of

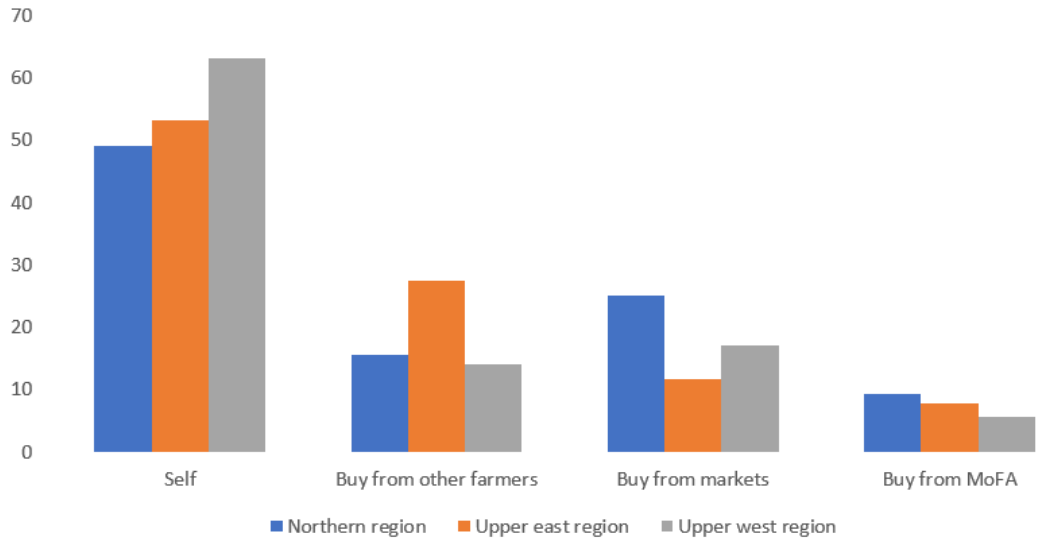

Figure 4 Farmer sources of planting soybean seeds

TABLE 6
Soybean production constraints faced by farmers

Characteristics	Northern region		Upper East region		Upper West Region	
	Male	Female	Male	Female	Male	Female
Land preparation and planting						
Unavailability of tractors	76.9	23.1	0	0	60.9	39.1
Unavailability of bullocks	0	0	72.4	27.6	0	0
Low soil moisture	81.6	18.4	75.5	24.5	90.8	9.2
Lack of improved seeds	89.3	10.7	75	25	78	22
Unavailability of labour	92.6	7.4	0	0	0	0
Initial capital	0	0	0	0	40	60
Lack of arable lands	0	0	0	0	0	0
Harvesting						
Dry hard soil	60.2	39.8	0	0	0	0
Time for harvest of food crops	77.4	22.6	97.6	2.4	60.2	39.8
Pod Shattering	89	11	52	48	84.7	15.3
Bush fires	66.7	33.3	0	0	0	0
Animal destruction	70	30	48	52	50	50
Bruised palm	0	0	41	59	73.8	26.2
Uprooting, gathering and threshing	0	0	0	0	0	0
Unavailability of labour	0	0	91.6	8.4	53.7	46.3

donkey ploughs (12.30%), unavailability of improved seed (42.20%) and low soil moisture (45%) for the Upper East Region. Lack of initial capital (20%), unavailability of improve seeds (54%), tractor services (10.3%) and low soil moisture (15%) for the Upper West Region. The major challenges associated with harvesting were; soybean pod shattering (50.50%), animal destruction (22%), bush fires (7%), time spent harvesting other food crops (10.30%) and hard dried grounds during uprooting (10.20%)) for the Northern Region, animal destruction (68.20%) and soybean pod shattering (26%)) for the Upper East Region. Pod shattering (55.90%), unavailability of labour (6.79%), time used for harvesting food crops (10.70%) and bruised palm (6.10%)) for the Upper West Region.

Farmer perception of soybean pod shattering as a constraint

Most soybean crops start physiological maturity in October. The majority of farmers in the Upper East (65.60%), Upper West (81.30%) and small (9%) number of farmers in Northern Region harvest their early maturing soybean varieties in October, respectively. Many farmers (62.40%) in the Northern Region and some farmers in the Upper East (34.40%) and West (14.10%) regions harvest their medium maturing varieties in November. Late harvesting of some varieties was done in December in the Northern Region (28.80) and by some farmers in the Upper West region (4.70%). A greater proportion of farmers in the Northern (62.80%), Upper East (57.50%) and Upper West (61.20%) regions revealed that, at maturity, most soybean plants and their pods turned brown, gray and wine with the leaves intact. Nonetheless, a smaller proportion of farmers in these regions reported that some plant varieties and their pods will turn brown, gray and wine but the leaves will drop. Almost all the farmers in the Northern (96.40%), Upper East (98.40%) and Upper West (93.80%) regions observed soybean seeds on the ground during harvesting indicating pod shattering (95%) at maturity among the varieties cultivated as shown in Table 7.

Many farmers across the three regions said that the observation of seed on field is pod shattering. Soybean pod shattering (67%) is an explosion of the pod and spreading of the seed. Accordingly, there is no control measure

TABLE 7
Farmer perception of soybean harvesting and pod shattering

Characteristics	Northern Region			Upper East Region			Upper West Region		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
When is soybean matured									
October	05.4	3.40	8.80	31.30	34.30	65.60	46.90	34.40	81.30
November	32.7	29.70	62.40	12.50	21.90	34.40	01.60	12.50	14.10
December	19.4	09.40	28.80	00.00	00.00	00.00	03.10	01.60	04.70
Plant morphological at maturity									
Brown with or without bush leaves	30.0	22.70	44.00	25.30	20.20	45.50	21.00	25.20	43.20
Gray with or without bushy leaves	17.6	19.60	37.20	20.40	16.10	42.50	19.90	12.90	31.80
Wine with or without bushy leaves	11.1	07.70	18.80	08.00	10.00	18.00	12.00	09.00	23.00
Pod morphological at maturity									
Brown	32.5	38.70	71.20	18.40	41.90	60.30	44.00	41.40	85.40
Gray	12.1	04.70	16.80	15.30	08.40	23.70	01.60	03.00	.04. 0
Wine	7.0	05.00	12.00	10.00	06.00	16.00	06.00	04.00	10.00
Weather condition at harvesting									
Sunny and harmattan	42.1	42.2	84.3	35.9	51.4	87.3	44.3	45.6	89.9
Windy and harmattan	09.4	06.3	15.7	7.90	4.7	12.6	8.3	2.9	11.2
Observe seed on the ground at harvest									
Yes	48.0	48.4	96.4	42.1	56.3	98.4	50.0	43.8	93.8
No	3.6	0	3.6	1.6	0	1.6	1.60	4.6	6.2
Have you heard of pod shattering									
Yes	48.4	48.4	96.8	42.2	54.70	96.9	46.9	43.8	90.7
No	3.2	0	3.2	1.5	1.60	3.1	4.6	4.7	9.3
Describe pod shattering									
Breaking of pods and scattering of seeds	3.1	8.0	11.1	6.3	07.90	14.2	7.80	17.7	25.5
Explosions of pods and spread of seeds.	42.9	28.0	70.9	26.6	35.90	65.5	38.0	26.0	64.0
Cracking of pods and dispersal of seeds	6.0	12.0	18.0	9.4	10.90	20.3	8.90	1.6	10.5
Do you control soybean shattering									
Yes	5.7	8.8	14.5	5.6	4.40	10.0	6.50	6.5	13.0
No	46.1	39.4	85.5	38.1	51.9	90.0	45.9	41.1	87.0
How do you control pod shattering									
Early harvesting	8.0	1.1	9.1	7.0	4.0	11.0	4.0	1.5	5.5
No control	61.80	28.1	89.9	55.0	34.0	89.0	52.2	42.30	94.5

(91.40%) to pod shattering, but some farmers indicated that, early harvesting (8.60%) is the only way susceptibility to pod shattering varieties were managed.

Farmer ranking of preferred traits

A greater proportion of the farmers (98%) ranked yield (3.79), big seed size (4.03) and non-shattering (4.08) as the most important yield component traits (Kendall's W=0.379 P=00.00) as shown in table 8. Other important traits ranked by many of the farmers were; early (4.45) and medium (4.45) maturing varieties for Upper East, Upper West and Northern region, respectively. Besides, genotypes with stem branching (4.83), leaf types (5.05) and plant height (6.16) traits were considered less important by the respondent. Nonetheless, the

TABLE 8
Ranked of farmers preferred traits

Soybean traits	Mean ranked	Rank
Number of seeds per pod	3.79	1
Big seed size	4.03	2
Non-shattering	4.08	3
Maturity period (early and medium)	4.45	4
Stem branch	4.83	5
Leaf types	5.05	6
Plant height	6.16	7
Matured pod colour	7.71	8
Seed coat luster	8.04	9
Seed colour	8.86	10
Flower colour	9.01	11
N	**192**	
Kendall's Wa	**0.481**	
P<0.05	**0.000**	

Note: The smallest rank indicates the most important trait

following traits; mature pod colour (7.71), seed coat luster 8.04), seed colour (8.86) and flower colour (9.01) were not considered as important traits since they were ranked with higher values and their effects on the plant do not contribute to seed yield and shattering. Ultimately, genotypes develop with these preferred traits will reduce seed loss and increase yield.

Development of new varieties

Satisfying farmer's needs with new varieties is very important. Thus, farmer varieties that are elite but susceptible to shattering must be rebred to be high yielding, early to medium maturing, striga resistant as well as resistant to pod shattering. Many farmers (99%) preferred a variety that has pods with many seeds and (56%) bigger seed sizes as presented in table 9. Many seeds per pod and bigger seed size are deemed important yield component for high-yielding varieties. A large proportion of the farmers prefer varieties which matured early (60.5%) for the Upper East and West regions and medium (61.2%) maturing varieties for most farmers in the Northern Region of Ghana. Farmers across the study area generally preferred a variety with tall plants (68.2%) and branched stem (94.3%) with broad leaves (76%) characters. These features were much appreciated and fit well into their current cropping systems. However, flower colour, mature pod colour and seed coat luster were not so much preferred by farmers across locations.

Farmers readiness to pay for newly developed varieties with their preferred traits

The majority of farmers know the advantages of resistant varieties. Even though there are some resistant varieties in the system, farmers still wish to have and are willing to pay good prices for varieties developed for their preferred plant traits. Accordingly, farmers' soybean production unit areas will increase when their preferred traits-varieties are developed.

Only few farmers (8%) patronized improved varieties (Jenguma, Favour and Afayak) because it was expensive with a kilogram selling at GHC 8.00 (US$ 1.62), (Thus, US$1.00=GHC 4.95) (Alex Antwi, 2021). Besides affordability, access to resistant varieties was limited since most seed sellers were found in district or regional capitals. Currently, certified soybean seed prices keep on fluctuating even with the Government of Ghana's subsidy on crop seeds and inputs under the planting for food and jobs programme. However, many farmers were willing to pay

TABLE 9
Respondent's preferred soybean traits

Soybean trait	Description	Northern region	Upper east region	Upper west region	Pooled
Seeds size	Small	6.0	1.5	6.2	4.7
	Medium	25.0	43.8	50.0	39.6
	Big	69.0	54.7	43.8	55.7
Maturity period	Early	35.4	54.0	67.2	53.0
	Medium	61.2	46.0	32.8	46.0
	Late	3.4	0	0	1.0
Plant height	Tall	87.5	45.3	71.9	68.2
	Short	12.5	54.7	28.1	31.8
Stem	Branched	100	84.4	98.4	94.3
	Unbranched	0	15.6	1.6	5.70
Leaf type	Broad	93.8	53.1	81.2	76.0
	Narrow	6.2	46.9	18.8	24.0
Flower colour	Pink	55.0	57.8	56.2	56.4
	white	45.0	42.2	43.8	43.6
Mature pod colour	Deep brown	52.0	53.0	46.0	50.8
	Light brown	48.0	46.0	54.0	49.2
Pod shattering	Shattering	6.3	0	0	2.10
	Non-shattering	93.8	100	100	97.90
Seeds per pod	Two	3.1	0	0	01.00
	Three	96.9	100	100	99.00
Seed coat luster	Shinny	46.9	29.7	50	42.20
	Dull	53.1	70.3	50	57.80
Seed coat colour	Yellow	71.9	68.8	62.5	67.70
	Light yellow	12.5	31.2	37.5	27.10
	Tan (Gray)	15.6	0	0	5.20

a minimum of GHC 4.00 and a maximum of GHC 6.00 per kilogramme of improved certified seed of their preferred traits varieties.

Discussions

Participatory Rural Appraisal (PRA) is a useful technique that seeks to address farmers' perception concerning their production limitations, selection of varieties and trait preference (Singh Mahra et al., 2015).

The current study revealed farmer perception on soybean production, constraints, preferred varieties and traits, pod shattering and how it was managed. There is a complete gender balance in soybean production with majority of the farmers in the active age (less than 50

years) bracket. This means majority of the farmers are in their productive ages, therefore, adoption of new technologies/varieties for the improvement of their livelihoods would be high (Manyong et al., 2005).

Soybean has gained multiple-purpose production in each household. It is a cash crop, but has now become popular for its job creation and employment among the youth and the women (Dugje et al., 2018). Women are the key players in soybean processing.

They buy their grains from farmers, traders or from the market. The grains are processed into useful and healthy products like soya kebabs, soymilk, dawadawa, flour for porridge, soymilk and soy cake.

In commercial farms and seed growing fields, soybean is grown as a sole crop for preferred varieties. On smallholder farmer fields, different varieties are grown for diversity purpose or intercropped with maize, millet, groundnut and sorghum especially in the Upper East and Upper West regions.

Farmers reap other benefits from cultivating soybeans as a rotational crop, fixing of atmospheric nitrogen, usage as a fodder for animal feed and incorporation of dead leaves into the soil after maturity.

The adoption of soybean has enabled farmers to address two important production constraints, thus low soil fertility and striga infestation (Buah et al., 2020). Land tenure system in Northern Ghana is purely traditional. Thus, land is owned by clans, families and landlords from the traditional homes. Though men have more access to land than women in northern Ghana and the country as a whole (Bambangi & Abubakari, 2014), hence, acquisition of land for crop production and for that matter soybean cultivation is relatively easy making both sexes to be enrolled into soybean cultivation. There is no tenancy agreement, but initial bowl of kola and token of money, or part of the farm harvest is given to the landlord for appreciation ((Kunbun-Naa Yiri II, 2006).

Though the rainfall starts in April/May (Kumi et al., 2023), soybean cultivation and planting start in June and July for farmers in Northern, Upper East and West regions, respectfully. During this time, soil moisture conditions are stabilized and suitable for seed bed preparation and planting. Both men and women play an important role in soybean cultivation (Mbanya, 2011). Planting, uprooting, gathering, threshing, bagging and transportation of soybean grain from farm to the house are production activities carried out by both men and women. Winnowing and sometimes threshing is done by women alone. Land preparation, seed bed preparation, weeding is and used to be done by men only but with the intervention of tractors, bullock ploughs, hired labour and herbicides, these husbandry practices become cash-dependent and not gender sensitive.

Soybean varieties used by farmers are developed from pure line cultivars (Kaga et al., 2012). These cultivars are self-pollinated with a low level of natural crossing ranging from 0.5% between plants of nearby rows to 1% within plants of the same rows. It has a genetic structure of homogeneous and homozygous, hence narrow genetic base. Therefore, soybean grains produced by farmers can be used as seed when selected and bulked after threshing to be stored under room temperature for the following year. (Mbanya, 2011).

Through this informal seed system, farmers are able to spread desirable seed from one farmer to another and from one community to the other every year for replanting (Ayenan et al., 2017). The used of the informal seed system enables majority of soybean farmers to easily start soybean cultivation because, they inherited seeds from parents, family members and colleagues with few of them purchasing seed (Mula & Sarker, 2013). Improved resistance to shattering varieties were not readily available and could be acquired at the price farmers described as exorbitant at district or regional capitals. This made farmers to continue to prefer and cultivate varieties that were susceptible to pod shattering (MoFA, 2019). Harvesting for most crops is done almost at the same time, hence the quest for labour is high. For the farmer, the only dependable source of labour is the family labour (Sylvester and Chinkonda, 2012).

Farmer's priority in harvesting start with the food crops, before cash crops like soybean. For soybean to be harvested later, all the pods would have shattered leaving no grain to be harvested. In an attempt to prevent seed loss and increase farmers' total production at maturity, soybean farmers ranked and selected preferred traits that a newly developed variety) should have including many seeds per pod, big seed size (high yielding), resistant to shattering and medium to early maturing. These rankings were similar to that of (Buah et al., 2020).

Conclusions

The survey conducted revealed that soybean is an important economic crop for farmers in northern Ghana. The rainfall regimes together with fluctuating humidity and temperatures presented a good and healthy ecological potential for soybean production and expansion. Production is influenced by demographic conditions (gender, education and previous farming experiences), and biotic and abiotic constraints. The majority of the farmers revealed that soybean pod shattering was a problem and could cause yield loss of up to 100% if harvesting is delayed. A greater majority of the farmers ranked yield, big seed size, and non-shattering as the most important attribute of their preferred varieties. Other important preferred traits ranked by many of the farmers were; early and medium maturing varieties for the Upper East and Upper West as well as Northern regions, respectively. All farmers across the three regions expressed their willingness to pay a premium price for new variety that contained their preferred trait. Hence, the incorporation of farmer-preferred traits by crop improvement programmes will produce climate-smart varieties. This calls for hybridization or screening for resistance to pod shattering genotypes to be set up. These breeding programmes will produce and evaluate new soybean varieties with incorporated farmers preferred traits for wide scale adoption.

Author contribution statement

Sayibu Alhassan; Richard Akromah; Francis Kusi; Alexander Wireko Kena: Conceived and designed the experiments; Sayibu Alhassan; Performed the experiments; Wrote the paper.
Sayibu Alhassan; Desmond Sunday Adogoba; Bashiru Haruna: Analyzed and interpreted the data. Sayibu Alhassan; Haruna Kendey Ali; Sulemana Abdul Somed; Alaafia Daniel Ayawini; facilitated, materials, analysis tools and data. All authors reviewed and approved of the final manuscript.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request
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References

Abady, S., Shimelis, H., & Janila, P. (2019). Farmers ' perceived constraints to groundnut production , their variety choice and preferred traits in eastern Ethiopia : implications for drought- tolerance breeding. *Journal of Crop Improvement*, **33(4)**, 505–521. https://doi.org/10.1080/15427528.2019.1625836

Alam, A. (2012). Role of Participatory Rural Appraisal in Community Development (A Case Study of Barani Area Development Project in Agriculture , *Live Stock and Forestry Development in Kohat*). **2(8)**

Ayenan, M. A. T., Ofori, K., Ahoton, L. E., & Danquah, A. (2017). Pigeonpea [(*Cajanus cajan* (L.) Millsp.)] production system, farmers' preferred traits and implications for variety development and introduction in Benin. *Agriculture and Food Security*, **6(1)**, 1–11. https://doi.org/10.1186/s40066-017-

0129-1

Bambangi, S., & Abubakari, A. (2014). Ownership and Access to Land in Urban Mamprugu , Northern. **3**, 13–23.

Bottrell, D. G., & Schoenly, K. G. (2018). Integrated pest management for resource-limited farmers: Challenges for achieving ecological, social and economic sustainability. *Journal of Agricultural Science*, **156(3)**, 408–426. https://doi.org/10.1017/S0021859618000473

Buah, S. S. J., Denwar, N. N., Kanton, R. A. L., & Kombiok, J. M. (2018). Participatory Approach to Variety Selection Using Soybean Production in Ghana as a Model. **28(2)**, 14–30.

Daudi, H., Shimelis, H., Laing, M., Okori, P., and Mponda, O. (2018). Groundnut production constraints, farming systems, and farmer-preferred traits in Tanzania. *Journal of Crop Improvement*, **32(6)**, 812–828. https://doi.org/10.1080/15427528.2018.1531801

Dawson, J. C., Murphy, K. M., and Jones, S. S. (2008). Decentralized selection and participatory approaches in plant breeding for low-input systems. *Euphytica*, **160(2)**, 143–154. https://doi.org/10.1007/s10681-007-9533-0

Dogbe, W., Etwire, P. M., Martey, E., Etwire, J. C., Baba, I. I. Y., & Siise, A. (2013). Economics of Soybean Production : Evidence from Saboba and Chereponi Districts of Northern Region of Ghana. **5(12)**, 38–46. https://doi.org/10.5539/jas.v5n12p38

Dugje, I. Y., Omoigui, L. O., Ekeleme, F., Bandyopadhyay, R., Lava Kumar, P., & Kamara, A. Y. (n.d.). Farmers' Guide to Soybean Production in Northern Nigeria. www.iita.org

Kaga, A., Shimizu, T., Watanabe, S., Tsubokura, Y., & Katayose, Y. (2012). Evaluation of soybean germplasm conserved in NIAS genebank and development of mini core collections. **592**, 566–592. https://doi.org/10.1270/jsbbs.61.566

Kimathi, S. M., Ayuya, O. I., & Mutai, B. (2021). Adoption of climate-resilient potato varieties under partial population exposure and its determinants: Case of smallholder farmers in Meru County, Kenya. *Cogent Food and Agriculture*, **7(1)**. https://doi.org/10.1080/23311932.2020.1860185

Klauck, J. (2020). Farmer-researchers – how to promote knowledge acquisition in Participatory Plant Breeding . : HAL Id : hal-01210082

Kopa, M., & Tichy, T. (2012). Concordance Measures and Second Order Stochastic Dominance - Portfolio Efficiency Analysis. *E+M Ekonomie a Management*, **4**, 110–120.

Kumi, N., Asante, V. A., Abiodun, B. J., & Lamptey, B. L. (2023). Impact of rainfall onset date on crops yield in Ghana. May, 1–10. https://doi.org/10.3389/fsufs.2023.1176385

Lammerts van Bueren, E. T., Struik, P. C., & Jacobsen, E. (2002). Ecological concepts in organic farming and their consequences for an organic crop ideotype. NJAS - *Wageningen Journal of Life Sciences*, **50(1),** 1–26. https://doi.org/10.1016/S1573-5214(02)80001-X

Manyong, V. M., Ojiako, I. A., Ikpi, A. E., & Rastilantie, M.-. (2005). Determinants of rural farmers' improved soybean adoption decisions in northern Nigeria Determinants of rural farmers' improved soybean adoption decisions in northern Nigeria WFL Publisher Science and Technology. In *Journal of Food, Agriculture & Environment* **(Vol. 5, Issue 2)**. www.world-food.net

Marenya, P., Wanyama, R., Alemu, S., Westengen, O., & Jaleta, M. (2022). Maize variety preferences among smallholder farmers in Ethiopia: Implications for demand-led breeding and seed sector development. *PLoS ONE*, **17**(9 September), 1–19. https://doi.org/10.1371/journal.pone.0274262

Marozzi, M. (2014). Testing for concordance between several criteria. *Journal of Statistical Computation and Simulation*, **84(9)**, 1843–1850. https://doi.org/10.1080/00949655.2013.766189

Mbanya, W. (n.d.). Assessment of the Constraints in Soybean Production: A Case of Northern Region, Ghana.

Mishra, R., Tripathi, M. K., Sikarwar, R. S.,

Singh, Y., & Tripathi, N. (2024). Soybean (Glycine max L. Merrill): A Multipurpose Legume Shaping Our World. *Plant Cell Biotechnology and Molecular Biology*, **25(3–4)**, 17–37. https://doi.org/10.56557/pcbmb/2024/v25i3-48643

Mishra, V. K., Paris, T., Ismail, A. M., Nayak, A. K., Sharma, D. K., Gautam, R. K., & Singh, R. K. (2014). Agroecology and Sustainable Food Systems Farmers 'Participatory Varietal Selection : A Sustainable Crop Improvement Approach for the 21st Century. 3565. https://doi.org/10.1080/21683565.2013.870101

MoFA. (2019). Medium Term Expenditure Framework (MTEF) for 2019-2022. Ministry of Food and Agriculture-Ghana Programme Based Budget Estimates for 2019, **92** pp. https://www.mofep.gov.gh/sites/default/files/pbb-estimates/2019/2019-PBB-MoFA.pdf

Moses, A. (2012). Evaluation of new soybean varieties for market traits and adaptation in Uganda. December 2012, 66.

Ndeko, A. B. (2022). Farmers ' preferred traits , production constraints , and adoption factors of improved maize varieties under South-Kivu rainfed agro-ecologies , eastern D . R . Congo : Implication for maize breeding. *Researchsquare*, **1**–41.

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., and Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, **3(10)**, 809–820. https://doi.org/10.1038/s41893-020-00617-y

Plahar, W. A. (2006). OVERVIEW OF THE OVERVIEW OF THE SOYBEAN INDUSTRY IN SOYBEAN INDUSTRY IN GHANA GHANA. www.csir.org.gh/fri.html

Ministry of Food and Agriculture (MoFA) (2018). REPUBLIC OF GHANA MEDIUM TERM EXPENDITURE FRAMEWORK (MTEF) FOR 2018-2021 PROGRAMME BASED BUDGET ESTIMATES. www.mofep.gov.

Ribeiro, P. F., Badu-apraku, B., Gracen, V. E., Danquah, E. Y., and Ewool, M. B. (2017). This document is discoverable and free to researchers across the globe due to the work of AgEcon Search . Help ensure our sustainability . Farmers Perception of Low Soil Fertility and Hybrid Maize and the Implications in Plant Breeding. https://doi.org/10.5539/sar.v6n2p1

Richards, P. (2014). Participatory rural appraisal: A quick and dirty critique Commodities of Empire Project View project Project on the thought of Mary Douglas View project. https://www.researchgate.net/publication/238772781

Salifu, M., Aidoo, F., Hayford, M. S., Adomako, D., & Asare, E. (2017). Evaluating the suitability of groundwater for irrigational purposes in some selected districts of the Upper West region of Ghana. *Applied Water Science*, **7(2)**, 653–662. https://doi.org/10.1007/s13201-015-0277-z

Sall, S., Norman, D., & Featherstone, A. M. (2000). Quantitative assessment of improved rice variety adoption: The farmer's perspective. *Agricultural Systems*, **66(2)**, 129–144. https://doi.org/10.1016/S0308-521X(00)00040-8

Singh Mahra, G., Kumar, P., Solanki, C., Tomar, D. S., Kaushik, S. K., Tewari, R., & Rao, V. K. J. (2015). Identifying Grass Root Problems and Generating Sustainable Solutions through Participatory Rural Appraisal. In *Indian Res. J. Ext. Edu* (**Vol. 15**, Issue 4).

Singh, P., Nedumaran, S., Ntare, B. R., Boote, K. J., Singh, N. P., Srinivas, K., & Bantilan, M. C. S. (2014). Potential benefits of drought and heat tolerance in groundnut for adaptation to climate change in India and West Africa. *Mitigation and Adaptation Strategies for Global Change*, **19(5)**, 509–529. https://doi.org/10.1007/s11027-012-9446-7

Sylvester, S., & Chinkonda, J. (2012). an Assessment of the Role of Traditional Leadership in Facilitating Community Development in Rural Malawi.

Thiele, G., Dufour, D., Vernier, P., Mwanga, R. O. M., Parker, M. L., Schulte Geldermann, E., Teeken, B., Wossen, T., Gotor, E., Kikulwe, E., Tufan, H., Sinelle, S., Kouakou, A. M., Friedmann, M., Polar, V., & Hershey, C. (2021). A review of varietal change in roots, tubers and bananas: consumer preferences and other drivers of adoption and implications for breeding. *International Journal of Food Science and Technology*, **56(3)**, 1076–1092. https://doi.org/10.1111/ijfs.14684

Walker, T. S. (2008). BACKGROUND PAPER FOR THE WORLD DEVELOPMENT REPORT 2008 Participatory Varietal Selection , Participatory Plant Breeding , and Varietal Change Participatory Varietal Selection.

Yvonne Price, (2011). Analyzing Ethnographic Research on Idigenous Knowledge in Development studies: An Anti-Colonial Inquiry Master of Arts Thesis. Department of Sociology and Equity Studies. University of Toronto.