Participatory approach of preferred traits, production constraints and mitigation strategies: implications for soybean breeding in Guinea Savannah zone of Ghana

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ABSTRACT
Soybean production is concentrated in the Guinea Savannah agro-ecological zone of Ghana. However, its cultivation is plagued with a number of constraints leading to low yields. A participatory approach was, therefore, used to identify farmers’ and processors’ preferred soybean traits and production constraints, climate change effects and strategies employed for mitigating these effects in three districts within the soybean growing areas in Northern Ghana. The study revealed that 72.0 % and 68.8 % of farmers in the Tolon and Savelugu districts, respectively, used improved soybean seeds for planting their fields. Over 13.0 % of farmers indicated late maturity as the most important constraint, followed by manual threshing difficulty and terminal drought which results in low grain yield and poor quality. About 70.0 % of farmers opined that climate change effects are causing obvious shifts in the rainfall pattern. Majority of the farmers (94.6 %) indicated that the onset of peak rainfall has changed in the past decade. Almost 44.0 % of farmers also indicated that severe drought has affected pods filling in the past. A third (33.3 %) of farmers indicated that drought usually sets in at pod initiation. The farmers enumerated some of the effects of early cessation of the rainfall in soybean production as drying up of immature and green seed (28.3 %), low grain yield (27.1 %) and poor seed quality (22.1 %). Some of the mitigation strategies employed by the farmers include early planting (40.0 %) and mulching (25.0 %) to retain soil moisture for enhanced growth of crops. The order of farmers’ preferences new soybean varieties were shattering resistance (16.0 %), high grain yield (14.0 %), large seeds size (13.1 %), and early maturity (11.8 %), whereas processors preferred varieties with large seed size (30.6 %), high protein content (28.7 %), pest resistance (15.9 %) and short cooking duration (12.7 %). Both the farmers and processors indicated their willingness to pay more for seeds with the desired traits. These findings will aid soybean breeders in developing new varieties that possess desired traits preferred by both farmers and processors for increased soybean cultivation and utilization.

1. Introduction
Soybean plays a significant role in enhancing household nutrition of low-income earning families due to its high protein content. The crop can also improve soil fertility when intercropped or grown in rotation with cereals, with the advantage of reducing the need for nitrogen fertilisers for subsequent maize crops (Kermah et al., 2018). The soybean industry in Ghana offers various opportunities for value chain actors from seed and grain production to processing and marketing (Denwar et al., 2019). The crop has the potential to improve livelihoods and reduce poverty through the growth and modernization of the soybean sector. Soybean cultivation is mainly done by local farmers in Ghana, with most production concentrated in the northern part of the country. However, consumption of the crop occurs in the southern and middle...
belts where most poultry farmers who use soybean fortified feed and soybean processing factories are located. The introduction of the soybean into Ghana occurred about a century ago, and the crop has the potential for generating income and improving the nutrition of the populace. However, the adoption and effective integration of soybean into the traditional farming system on a large scale and for industrial-scale processing have lagged behind (Plahar, 2006; Ali and Singh, 2010). Likewise, increases in household consumption have been prolonged (Plahar, 2006; Ali and Singh, 2010). This is due to poor knowledge of soybean utilization by households the weak industrial base for soybean production, processing and packaging (Plahar, 2006). Besides, no reliable market channel exists to enable optimal economic benefits to be derived from the production, processing and marketing of the crop (Plahar, 2006).

Currently, the average soybean yield among smallholder farmers in Ghana ranges from 549 to 887 kg/ha (Amanor-Boadu et al., 2015) despite the availability of improved soybean varieties. This yield level is considerably far lower than the global average of 2810 kg/ha (Purdy and Langmeier, 2018), a major drawback to the successful large-scale production that would enhance sustainable industrial processing and utilization of the crop. Indeed, domestic production has not even kept up with local demand, resulting in significant growth in imports (Eshun et al., 2018; Gage et al., 2012).

To better understand and address this problem, participatory rural appraisal (PRA) tools were employed in the study to identify farmers and processors’ preferred traits as well as production constraints and mitigation strategies in the major production areas in Ghana. In any plant breeding programme with the objective of improvement in the traits of preferred varieties, Nkongolo et al. (2009) explained that it is essential for PRA to be carried out to identify the level of farmers’ local knowledge, their interests and ability to experiment and innovate, and their active exchange of information and technologies. Bellon (2001) and Azu (2017) further emphasized that participatory appraisal and participatory varietal and trait selection are essential to assessing farmer and consumer perceptions, preferences, and selection criteria for the crop of interest. Farmer and consumer-participatory appraisal is a widely established method employed in plant breeding to enhance the willingness of farmers and consumers or other stakeholders to accept and effectively use a resulting improved material (Ceccarelli et al., 2013; Steinke and Etten 2017). Invariably, farmer-participatory appraisal enables the integration of farmers’ indigenous technical knowledge, preferences, and the prioritization of the varieties or traits preferred by the stakeholders along the crop value chain in order to carry out demand-driven varietal improvement research goals. Research success in this regard facilitates the achievement of greater impact in the use of newly released crop varieties (Adesina and Zinnah 1993; Witcombe et al., 2005).

In this study, PRA tools were used to capture and better understand varietal and trait preferences of soybean by farmers and other stakeholders such as processors and identify soybean production constraints in Guinea Savannah Agro-ecological zone of Ghana.

2. Materials and methods

2.1. Description of the study area

The PRA survey was carried out in the Guinea Savannah agro-ecological zone of Ghana (Figure 1). The major growing areas were identified based on information collected from extension agents of the Ministry of Food and Agriculture (MoFA). All the major soybean growing areas covered in this study are located in the Guinea Savannah agro-ecological zone of the Northern region (Figure 2). The region is bordered on the North by North East region, east by the eastern Ghana-Togo international border, south by the Oti region, and Savannah region on the West. The agro-ecological zone is characterised by dry weather with a single rainy season, usually from May to December, and an average annual rainfall of 750–1050 mm. The wet season is followed by a prolonged dry season between January and April. The Northern region experienced the lowest temperature of 14 °C, often recorded between December and January, and the highest daytime temperature of 40 °C during the end of the dry season. The vegetation is primarily grassland, mixed with fire-resistant trees and shrubs with thick bars often referred to as woodland savannah. This woodland is typically composed of short trees that do not usually form closed canopies and are often very widely spaced.

2.2. Selected districts and communities

Three major soybean producing and processing districts or municipalities were identified based on soybean production records and levels with the assistance of extension agents of MoFA. The districts were Tolon, Savelugu, and Yendi. Briefly, the Tolon district lies between latitudes 9° 15’ and 10° 02’ North and Longitudes 0° 53’ and 1° 25’ West. The district shares boundary to the North with Kumbungu, to the West with North Gonja, the south with Central Gonja, and Sagnarigu District to the

Figure 1. Map of Ghana showing the agro-ecological zone where the experiment was conducted.

Figure 2. Vegetation map of Ghana. Sources: Osei-Tutu, P., Nketiah, S., Kyereh, B., Owusu-Ansah, M. and Faniyan, J. (2010). Hidden Forestry Revealed: Characteristics, Constraints and Opportunities for Small and Medium Forest Enterprises in Ghana, IIEG Small and Medium Forest Enterprises Series No. 27.
Open-ended questions were used in the focus group discussions in order to identify the combination of most important traits they desire in variety preferred by the Interdisciplinary Research in Earth Science (IDS) program, NASA Award #: G00009708. Accessed on 2/01/2022. https://geog.sdsu.edu/Research/P rojects/IPC/research/ids.html.

East (Ghana Statistical Service, GSS, 2014 Population and Housing Census).

The next district, Savelugu, shares a boundary with Nanton district to the North, Karaga district to the East, Kumbungu district to the West, and Sagnerigu district to the South. Last but not the least is Yendi district which is located in the eastern corridor of the Northern Region and lies at Latitude 9 °35 ’ North and 0 °30 ’ West and 0°15 ’ East (GSS, 2014). The district shares the boundary with the Saboba district to the east, to the south with Cher-eponi and Zabzugu districts, to the north with the Nanumba North district, and the west with Gushegu and Mion districts.

The vegetation of these three districts which is described as woodland (tree) savannah, is under continual degradation due to settlements and farming activities (Figure 3). The districts have a unimodal rainfall pattern and receive a mean annual rainfall of 1,125 mm, often recorded from April to November. Temperature ranges 21°C to 36°C. The soil material is sedimentary, predominantly of the Voltarian sandstones, shales, and mudstones (Metropolitan Medium Term Development Plan (MMDTP), 2014). The soils derived from the above parent materials range from laterite, ochrosols, sandy soils, alluvial soils, and clay. The organic content is low and is increasingly worsened by extensive bush burning and bad agricultural practices (MMDTP, 2014). These poor soils are responsible for the characteristic low crop yields per acre and consequent food shortages during the dry or lean season in the districts (MMDTP, 2014).

The three selected districts, Tolon, Savelugu, and Yendi, are among Ghana’s five top soybean producing districts (SRID, 2017). With the assistance of extension agents of MoFA, four communities in each district or municipality, were selected based on accessibility, cost considerations, and production levels (Table 1). The survey was carried out from January to March 2020 in all three districts. A total of 300 respondents, comprising 240 farmers and 60 processors, responded to the questionnaires distributed and were involved in the PRA using focus group discussion and direct observation.

2.3. PRA methodology

PRA tools used comprised focus group discussions and direct observations. The focus group discussions were done once per district, where participants in the same district were transported to one community in the district. This was done to save time and cost, as some farmers were still threshing and/or sorting their soybean grains during the period. Open-ended questions were used in the focus group discussions in order to obtain views that otherwise would not have been mentioned. The discussions were usually conducted with all the mixed respondents, except when gender-sensitive issues were discussed that men and women were separated. The language used was the local dialect with the help of a translator and assistants.

During the discussions, farmers and processors were asked to list their preferred soybean varieties, the traits preferred to be incorporated into the current breeding programme, and the characteristics of soybean they prefer for enhanced market value. These discussions provided an insight into soybean production constraints, cultivation practices, utilization, and the characteristics of soybean traits preferred by farmers and processors.

These initial focus group discussions with farmers and processors were not intended to rank farmers’ and processors’ preference criteria but to identify the combination of most important traits they desire in variety development currently. Information collected was used to design questionnaires for farmers and processors for a further comprehensive study. The questionnaires were interpreted in the local dialect to farmers/pro-cessors who could not read and write and their responses recorded.

2.4. Sampling and questionnaire administration

To have an in-depth assessment of soybean production constraints and preferred traits of farmers and processors, semi-structured questionnaires were designed, which consisted of both close- and open-end questions as a follow-up on the PRA study. The objectives of the survey was explained to the farmers who were willing to participate in the study. Data were collected on anonymity and used solely for research purpose. The questionnaire used comprised four sections for farmers and three sections for processors with questions related to demographics, variety information, agronomic practices, production constraints, climate change and its effects on production, storage methods, as well as preferred traits of both farmers and processors. In all, three hundred participants, comprising 240 farmers and 60 processors were purposively selected from twelve communities in the three survey districts, thus four communities per district. The number of sampled respondents in each community are presented in Table 2. Informed consent was obtained from all the individual participants included in the study. Again, participants were made to understand that the results of the research may be published, but that their names or identities will not be revealed.

2.5. Data analyses

Statistical Package for Social Sciences (SPSS) version 17.0 and Microsoft Excel were used to analyse the data collected. Descriptive statistics in the form of frequencies and percentages were used to present data. Cross tabulations were also done. Comparisons were made between districts, communities, and males and females. Friedmans’ test was used to rank soybean production constraints by farmers. Chi-squared tests at 5
% significant level were used to test for significant differences among categorical variables. Graphical results were displayed using pie charts, line charts, and histograms.

### Table 2. Number of farmers and processors across the study sites.

| Districts | Community | Farmers | Processors |
|-----------|-----------|---------|------------|
|           |           | 20      | 5          |
| Tolon     | Tanayili  | 20      | 5          |
|           | Nyankpala | 20      | 5          |
|           | Kpalogo   | 20      | 5          |
|           | Zergu     | 20      | 5          |
| Savelugu  | Bunlung   | 20      | 5          |
|           | Tamahi    | 20      | 5          |
|           | Kambon Tooni | 20   | 5          |
|           | Yano      | 20      | 5          |
| Yendi     | Sunson    | 20      | 5          |
|           | Nalomba   | 20      | 5          |
|           | Kulkpana  | 20      | 5          |
|           | Malizeri  | 20      | 5          |
| Total     |           | 240     | 60         |

3. Results

3.1. Demographic characteristics of soybean farmers and processors

Almost (32.1 %) of the soybean farmers in the Guinea Savannah zone of Ghana who were interviewed were between the ages of 30–39, followed by the age group 40–49 (30.5 %). A similar trend was observed among the soybean processors where 35.0 % were between the age group of 30–39, the same as for the ages 40–49. Out of the 240 farmers interviewed across the three districts, 180 respondents, with an average age of 60, were males, representing 75.0 % of farmers interviewed. However, the scenario among soybean processors was comparatively different, with a majority (55.0 %) of them being females.

Islam is the most dominant religion among soybean farmers and processors. At least 8 out of every 10 of them were Moslems (88.4 and 80.0 %, respectively) in the three districts, followed by Christianity at 10.9 and 15.0 % among farmers and processors, respectively.

Literacy level was very low among the respondents interviewed, with about two-thirds of farmers and three out of every five processors having no formal education. Again, 17.9 % of the farmers and a quarter (25.0 %) of the processors had basic education, 12.5 % of the farmers, and 15.0 % of the processors had secondary education. The remaining respondents had either secondary education (12.5 % for farmers and 15.0 % for processors) or tertiary education (3.4 % for farmers and 2.7 % for processors).

### Table 3. Demographic characteristics of processors and farmers used for the study.

| Variable          | Characteristics | Processors |          |          |
|-------------------|----------------|------------|----------|----------|
|                   | Tolon | Savelugu | Yendi | Average | Percentage (%) |
| Age               | 20-29 | 5 | 4 | 4 | 4 | 20 | 12 | 6 | 13 | 10.3 | 12.9 |
|                   | 30-39 | 10 | 7 | 4 | 7 | 35 | 30 | 25 | 22 | 25.7 | 32.1 |
|                   | 40-49 | 3 | 8 | 10 | 7 | 35 | 24 | 28 | 21 | 24.4 | 30.5 |
|                   | 50-59 | 0 | 0 | 2 | 1 | 5 | 6 | 12 | 19 | 12.3 | 15.4 |
|                   | 60-69 | 1 | 0 | 0 | 0 | 0 | 6 | 6 | 4 | 5.3 | 6.6 |
|                   | 70-79 | 1 | 1 | 0 | 1 | 5 | 2 | 3 | 1 | 2.0 | 2.5 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Sex               | Male  | 5 | 20 | 1 | 9 | 45 | 60 | 52 | 68 | 60 | 75 |
|                   | Female| 15 | 0 | 19 | 11 | 55 | 20 | 28 | 12 | 20 | 25 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Religion          | Christian | 2 | 4 | 4 | 3 | 15 | 18 | 4 | 4 | 8.7 | 10.9 |
|                   | Muslim | 17 | 15 | 15 | 16 | 80 | 60 | 76 | 76 | 70.7 | 88.4 |
|                   | Traditional | 2 | 1 | 1 | 1 | 5 | 2 | 0 | 0 | 0.6 | 0.8 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Literacy level    | None  | 7 | 16 | 12 | 12 | 60 | 49 | 63 | 47 | 53 | 66.3 |
|                   | Basic education | 8 | 2 | 6 | 5 | 25 | 8 | 13 | 22 | 14.3 | 17.9 |
|                   | Secondary | 5 | 2 | 2 | 3 | 15 | 16 | 4 | 10 | 10 | 12.5 |
|                   | Tertiary | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 2.7 | 3.4 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Marital status    | Married | 17 | 19 | 17 | 18 | 90 | 73 | 73 | 70 | 72 | 90.0 |
|                   | Single  | 2 | 1 | 1 | 1 | 5 | 4 | 4 | 5 | 4.3 | 5.4 |
|                   | Divorced | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 3 | 2.0 | 2.5 |
|                   | Widowed | 0 | 1 | 1 | 1 | 5 | 1 | 2 | 2 | 1.7 | 2.1 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Number of children| 0-5   | 13 | 13 | 13 | 13 | 65 | 21 | 17 | 23 | 20.3 | 25.4 |
|                   | 6-10  | 7 | 7 | 7 | 7 | 35 | 44 | 47 | 40 | 43.7 | 54.6 |
|                   | 11-15 | 0 | 0 | 0 | 0 | 0 | 6 | 8 | 12 | 8.7 | 10.9 |
|                   | >15   | 0 | 0 | 0 | 0 | 0 | 9 | 8 | 5 | 7.3 | 9.1 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
| Main occupation   | Animal farmer | 3 | 0 | 3 | 2 | 10 | 1 | 1 | 1 | 1 | 1.3 |
|                   | Tofu producer/processors | 8 | 1 | 9 | 6 | 30 | 0 | 0 | 0 | 0 | 0.0 |
|                   | Commercial/industrial processors | 6 | 7 | 9 | 7 | 35 | 0 | 0 | 0 | 0 | 0.0 |
|                   | Crop production | 3 | 9 | 0 | 4 | 20 | 67 | 79 | 79 | 75.0 | 93.8 |
|                   | Shea extraction | 0 | 3 | 0 | 1 | 5 | 4 | 0 | 0 | 1.3 | 1.6 |
|                   | Formal/govt worker | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 2.7 | 3.4 |
| Total             |       | 20 | 20 | 20 | 20 | 100 | 80 | 80 | 80 | 80 | 100 |
education. In comparison, 3.4 % of the farmers had tertiary education, but none of the processors had a tertiary level of education. Savelugu district had the highest illiteracy level compared to Tolon and Yendi districts.

Whereas most of the soybean farmers (90.0 %) and processors (90.0 %) were married, some 5.4 % and 5.0 % of the farmers and processors (respectively) were never married. None of the processors was found in the divorced category. However, 2.5 % of the farmers were divorced. It was also found out that 2.1 % of the farmers and 5.0 % of the processors had lost their spouses.

In this study, it was observed that 9.1 % of farmers had more than 15 children. The processors had a lesser number of children of not more than 10. Majority (54.6 %) of farmers have between six and ten children. The majority (65.0 %) have up to five children among the processors.

As high as 93.8 % of farmers interviewed engaged in crop production as their main occupation, while 3.4 % were government/formal workers. On the other hand, a little above a third (35.0 %) of the processors indicated that their main occupation was commercial/industrial processing, followed by tofu processing (30.0 %), while 20.0 % cultivated crops (Table 3).

### 3.2. Agronomic practices employed by soybean farmers

Only ploughing was mostly employed in land preparation for soybean cultivation in the three districts covered by this study (Table 4). Some farmers (14.2 %) however combine ploughing, harrowing and ridging. Very few farmers did harrowing only (0.4%). A majority (76.7 %) of farmers plant soybean in July, whereas 16.6 and 6.7 % establish their

| Variable                      | Characteristics                          | Savelugu | Tolon | Yendi | Frequency | Percentage (%) |
|-------------------------------|------------------------------------------|----------|-------|-------|-----------|----------------|
| Method of land preparation    | Plough, harrow and ridge                 | 5        | 27    | 2     | 34        | 14.2           |
|                               | Plough only                              | 75       | 53    | 77    | 205       | 85.4           |
|                               | Harrow only                              | 0        | 0     | 1     | 1         | 0.4            |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| Month of planting             | May                                      | 0        | 0     | 0     | 0         | 0.0            |
|                               | June                                     | 5        | 6     | 5     | 16        | 6.7            |
|                               | July                                     | 60       | 70    | 54    | 184       | 76.7           |
|                               | August                                   | 15       | 4     | 21    | 40        | 16.6           |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| Planting in rows              | No                                       | 13       | 3     | 34    | 50        | 20.8           |
|                               | Yes                                      | 67       | 77    | 46    | 190       | 79.2           |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| Weeds management              | Manual weeding                           | 29       | 13    | 12    | 54        | 22.5           |
|                               | Herbicide                                | 6        | 12    | 0     | 18        | 7.5            |
|                               | Herbicide and manual weeding             | 45       | 55    | 68    | 168       | 70.0           |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| Fertilizer application        | No                                       | 64       | 29    | 77    | 170       | 70.8           |
|                               | Yes                                      | 16       | 51    | 3     | 70        | 28.2           |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| If yes, fertilizer type       | Organic                                  | 1        | 1     | 0     | 2         | 2.9            |
|                               | Inorganic                                | 15       | 50    | 3     | 68        | 97.1           |
| Total                         |                                         | 16       | 51    | 3     | 70        | 100.0          |
| Kinds of organic and inorganic fertilizers | Animal faeces                           | 1        | 1     | 0     | 2         | 2.9            |
|                               | NPK                                      | 12       | 31    | 2     | 45        | 64.3           |
|                               | Sulphate of Ammonia                      | 0        | 0     | 1     | 1         | 1.4            |
|                               | TSP                                      | 1        | 14    | 0     | 15        | 21.4           |
|                               | Yara legumes                             | 1        | 5     | 1     | 7         | 10.1           |
| Total                         |                                         | 15       | 51    | 4     | 70        | 100.0          |
| Knowledge about soybean inoculant | No                                   | 77       | 18    | 42    | 137       | 57.1           |
|                               | Yes                                      | 3        | 62    | 38    | 103       | 42.9           |
| Total                         |                                         | 80       | 80    | 80    | 240       | 100.0          |
| If yes, have you used inoculant before | No                                    | 1        | 50    | 33    | 84        | 81.6           |
|                               | Yes                                      | 2        | 12    | 5     | 19        | 18.4           |
| Total                         |                                         | 3        | 62    | 38    | 103       | 100.0          |
| Farming experience (years)    | 1–10                                     | 80       | 77    | 60    | 217       | 90.4           |
|                               | 11–20                                    | 3        | 17    | 20    | 8.4       |
|                               | 21–30                                    | 0        | 0     | 3     | 1         | 1.2            |
| Total                         |                                         | 80       | 80    | 80    | 80        | 100.0          |
| Cropping system               | Sole cropping                            | 55       | 58    | 42    | 52.0      | 65.0           |
|                               | Intercropping                            | 25       | 22    | 38    | 28.0      | 35.0           |
| Total                         |                                         | 80       | 80    | 80    | 80.0      | 100.0          |
| Crop intercrop with soybean   | Maize                                    | 14       | 11    | 30    | 55        | 64.7           |
|                               | Sorghum                                  | 1        | 1     | 1     | 3         | 3.5            |
|                               | Millet                                   | 10       | 10    | 7     | 27        | 31.8           |
| Total                         |                                         | 25       | 22    | 38    | 28.0      | 100.0          |
fields in August and June, respectively. About four out of every five farmers (79.2 %) plant in rows, while 20.8 % of the farmers broadcast their soybean seeds. Most of the farmers control weeds on their soybean farms using a combination of herbicides and manual weeding. Only 22.5 % of the farmers practice manual weeding, and 7.5 % applied only herbicides for weeds control.

Generally, fertilizer is not commonly used for soybean production among farmers in Guinea Savannah ecology. However, almost all the farmers (97.1 %) who apply fertilizer use mostly inorganic fertilizer as against only 2.9 % of farmers using organic fertilizer. NPK fertilizer topped in the type of inorganic fertilizers that most farmers applied (64.3 %). Across the three districts, 57.1 % of farmers do not know about nitrogen-fixing bacteria that can be used to boost soybean plant health, growth, and yield. Meanwhile, only 18.4 % of farmers who know soybean inoculants have ever used some on their farms (Table 4).

Farmers with the longest farming experience of 21–30 years made up 1.2 % of soybean growers, while those with farming experience between 1 – 10 years constituted the majority (90.4 %). Those with 11–20 years (8.4 %) were next in ranking. Generally, the more experienced farmers were found in the Yendi district compared to Savelugu and Tolon districts. Sixty-five percent of the farmers grow only soybean on their farms, whereas 35.0 % intercrop soybean with cereals. Maize comprised of 64.3 % of the cereal crops intercropped with soybean, followed by soybean intercropped with millet (32.1 %) and sorghum (3.6 %).

3.3. Sources of seed, grain, and varietal information acquire by farmers and processors

Less than a third of farmers (30.0 %) purchased their seeds from the local market just above a quarter of them (26.0 %) used seeds saved from their previous cropping season, with 16.0 % of farmers getting their seeds from MoFA, while 12.0 % purchased their seeds from agro-input shops. Seeds purchased from the local seed store constituted just 2.0 % of the total. Non-governmental organization (NGOs) and farmer friends constitute 7.0 % of the sources where farmers obtained seeds for cultivation (Figure 4A). Meanwhile, most processors buy their grains from the

![Figure 4. Sources of (A) Seed, (B) Grain, (C) Information and (D) Time taken by farmers to replace seed for planting (years).](image-url)
Information on research activities, technology development and innovation, seeds, fertilizers, and other agricultural information is mainly passed onto farmers through MoFA (40.0 %), radio/TV (31.0 %), research institutes (18.0 %), NGOs (9.0 %) and family/friends (2.0 %) (Figure 4C). Forty percent of farmers replaced their soybean seeds used for planting every two years, while others (27.0 %) replaced every three years or every four years (18.0 %). Ten percent replaced their seeds every five years, and only five percent of them replaced their seeds every year.

A total of eight soybean varieties are known and cultivated by farmers in the Guinea Savannah ecological zone of Northern Ghana (Table 5). The most popular variety cultivated by at least three out of every five (62.5 %) farmers is Jenguma, a non-shattering variety developed by CSIR-SARI in 2003. The next common variety is Afayak which is cultivated by more than a quarter (27.5 %) of farmers, followed by Salintuya I (2.9 %) and Soung Pungun (2.9 %). The least known varieties are Quaschrie and Salintuya II (Table 5). However, farmers were growing just four among the eight known soybean varieties. The most preferred varieties are Jenguma (67.1 % of farmers), Afayak (27.5 %), Favour (3.3 %), and Soung Pungun (2.1 %) (Table 5).

Soybean variety selection is based on the trait of interest the farmers desire in the particular variety. Over 70 % of the farmers preferred non-shattering varieties. Another section of farmers based their varietal selection on higher yields (Table 6). Five percent of the farmers considered high market value and how fast the variety sells at the market to select a particular variety for cultivation. Some other farmers also preferred early maturing varieties and used earliness as a selection criterion. Large seed size and medium maturing had the least influence on variety selection and preference by farmers (Table 6).

### 3.4. Utilization of improved soybean seeds by farmers

Assessment of improved soybean seed usage in the three districts studied revealed that farmers in the Yendi district used less improved seeds for planting (23.8%) than the other two districts (Figure 5A). Seventy-two percent of farmers in the Tolon district used improved soybean seeds, while 68.8% of farmers in the Savelugu district grew improved soybean seeds on their farms. Generally, more than 55.0 % of farmers planted their soybean farms using improved seeds (Figure 5A). However, 69.0 % of farmers in the three districts identified cash constraints as the main reason preventing them from using improved soybean seeds. Unavailability of improved seeds (14.0 %), lack of information about improved seeds (10.0 %), lack of awareness about improved seeds (5.0 %), and ineffective seed distribution systems in remote areas (2.0 %) (Figure 5C) were other reasons cited by farmers. On the other hand, 72 out of 80 farmers interviewed in the Yendi district stated that improved soybean seeds were not affordable, while 45 farmers and 26 farmers from Savelugu and Tolon districts, respectively, affirmed that improved soybean seeds were not affordable. In general, 97 farmers out of 240 farmers interviewed in the three districts indicated that improved soybean seeds were affordable (Figure 5B).

### 3.5. Constraints faced by soybean farmers

Soybean production constraints identified in the Guinea Savannah Ecological Zone of Northern Ghana are presented in Table 7. In general, fifteen constraints were cited by the farmers. More than 13.0 % of the farmers stated late maturity as their major constraint, followed by difficulty in harvesting, drought, and low grain yield, among others, were also identified as important constraints to soybean production (Table 7). In addition, when the farmers in the three districts ranked the constraints, it was observed that the late maturity period ranked as the overall topmost constraint (Table 6), indicating that this is the most pressing issue in soybean production which warrants further breeding effort. Low pod filling, low grain yield, poor seed quality, and drought were ranked as the second, third, fourth, and fifth constraints, respectively. The least three constraints are diseases, insect pests, and shattering (Table 8).
3.6. Farmers’ perception about climate change and the limitation on soybean productivity

More than 7 out of every 10 farmers (70.0 %) strongly agreed that there is an obvious climate change effect being observed through a shift in rainfall pattern. The farmers considered climate change effects as the foremost threat and challenge in soybean production (Table 9). However, only 0.8 % disagreed that climate change has not affected soybean production. Generally, 70 out of the 80 farmers interviewed at Yendi district strongly agreed that a shift in rainfall pattern was a major challenge in soybean production.

A greater proportion of the farmers (94.6 %) in this study attest that the onset of peak rainfall has changed in the past decade, while a minority of 5.4 % do not hold this view. All the farmers interrogated in the Savelugu district agreed that there were changes in the onset of peak rainfall (Table 9). The majority of the farmers (77.9 %) indicated March as the month for the onset of the rainy season in the Guinea Savannah agro-ecological zone in the past decade. One out of every five farmers considered April for the onset of the rainy season, while 2.1 % indicated that the onset of the rainy season has shifted to May in the past decade.

### Table 7. Soybean production constraints identified by farmers in the three districts.

| Constraints                        | Frequency | Percentage (%) |
|------------------------------------|-----------|----------------|
| Late maturity varieties            | 33        | 13.8           |
| Difficulty using manual threshing  | 31        | 12.9           |
| Lack of early maturity varieties   | 26        | 10.8           |
| Difficulty in harvesting           | 23        | 9.6            |
| Drought                            | 21        | 8.8            |
| Low grain yield                    | 16        | 6.7            |
| Unavailability of improved seed    | 16        | 6.7            |
| Insufficient tractor services      | 13        | 5.4            |
| Difficulty in planting             | 12        | 5.0            |
| Lack of funds for production       | 11        | 4.5            |
| Poor seed filling and quality      | 10        | 4.2            |
| Poor grain price at the market     | 10        | 4.2            |
| Difficulty in controlling weeds    | 7         | 2.9            |
| Disease and pest infestation       | 6         | 2.4            |
| Lack of storage facilities         | 5         | 2.1            |
| Total                              | 240       | 100            |

### Table 8. Ranking of soybean production constraints by farmers across the three distracts.

| Constraints                        | Savelugu Mean | Savelugu Rank | Tolon Mean | Tolon Rank | Yendi Mean | Yendi Rank | Overall Mean | Std deviation | Overall rank | P-values |
|------------------------------------|---------------|---------------|------------|------------|------------|------------|--------------|---------------|--------------|----------|
| Late maturity                      | 1.65          | 1             | 1.08       | 1          | 1.50       | 1          | 1.69         | 0.71          | 1            | 0.000    |
| Insect pests                       | 8.68          | 8             | 11.01      | 12         | 10.25      | 10         | 10.17        | 1.76          | 11           | 0.000    |
| Diseases                           | 9.64          | 10            | 9.39       | 10         | 10.26      | 11         | 9.95         | 1.43          | 10           | 0.000    |
| Lack improved variety             | 9.35          | 9             | 8.63       | 9          | 8.50       | 9          | 9.02         | 0.90          | 9            | 0.000    |
| Poor seed quality                  | 4.96          | 5             | 3.98       | 3          | 5.00       | 6          | 4.85         | 2.07          | 4            | 0.000    |
| Poor seed germination              | 10.66         | 11            | 6.99       | 8          | 8.00       | 8          | 8.75         | 3.00          | 8            | 0.000    |
| Low pod filling                    | 4.02          | 4             | 3.69       | 2          | 3.63       | 2          | 4.01         | 1.90          | 2            | 0.000    |
| Drought                            | 3.74          | 3             | 4.93       | 4          | 4.50       | 4          | 4.58         | 1.93          | 5            | 0.000    |
| Difficulty in harvesting           | 4.98          | 6             | 6.87       | 7          | 7.13       | 7          | 6.43         | 2.99          | 7            | 0.000    |
| Low yield                          | 3.34          | 2             | 5.34       | 6          | 4.00       | 3          | 4.43         | 1.84          | 3            | 0.000    |
| Low pod clearance                  | 5.98          | 7             | 5.33       | 5          | 4.63       | 5          | 5.55         | 1.87          | 6            | 0.000    |
| Shattering                         | 11.02         | 12            | 10.78      | 11         | 10.63      | 12         | 10.9         | 1.22          | 12           | 0.000    |
Most of the farmers (79.2%) believed that the shift in rainfall pattern has resulted in a delay in the onset of the peak rainfall, and hence the peak of the rains is now observed mostly in May in the three districts. Twenty percent of the farmers consider the onset of the peak of the rainy season to be in June. Almost all (99.0%) of the respondents indicated that the shift in rainfall timing and pattern had affected soybean production. Similarly, 97.8% of the farmers agreed that they experience severe drought yearly on their soybean farms (Table 9). All the respondents from Savelugu and Tolon districts agreed to this challenge. Almost forty-four percent of the sampled farmers experienced severe drought at the stage when their soybean pods are filling, a third (33.3%) at the pod initiation stage, and 17.9% at the flowering stage. The majority of the farmers (80.8%) suggested that rainfall terminates in mid-October, 18.8% indicated the rain terminates in the first week of November. Finally, 0.4% chose the end of September as the period rainfall terminates.

Table 9. Perception of the shift in rainfall pattern on soybean production by farmers.

| Variable | Characteristics          | Savelugu | Tolon | Yendi | Total | (%) |
|----------|--------------------------|----------|-------|-------|-------|-----|
| Shift in rainfall pattern as a major challenge in soybean production | Strongly agree | 45 | 54 | 70 | 169 | 70.4 |
| | Agree | 30 | 20 | 8 | 58 | 24.2 |
| | Indifferent | 5 | 2 | 2 | 9 | 3.8 |
| | Disagree | 0 | 2 | 0 | 2 | 0.8 |
| | Strongly disagree | 0 | 2 | 0 | 2 | 0.8 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Has the onset of peak rainfall changed in the past decade | No | 0 | 5 | 8 | 13 | 5.4 |
| | Yes | 80 | 75 | 72 | 227 | 94.6 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Month for the onset of rainy season in the past decade | March | 60 | 67 | 60 | 187 | 77.9 |
| | April | 20 | 13 | 15 | 48 | 20 |
| | May | 0 | 0 | 5 | 5 | 2.1 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Month for the onset of peak rainfall season in the last five years | April | 0 | 1 | 1 | 2 | 0.8 |
| | May | 65 | 66 | 59 | 190 | 79.2 |
| | June | 15 | 13 | 20 | 48 | 20 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Change in the timing or rainfall predictability affected soybean production | No | 0 | 0 | 3 | 3 | 1.3 |
| | Yes | 80 | 80 | 77 | 237 | 98.7 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Do you experience terminal drought every year | No | 0 | 0 | 6 | 6 | 2.5 |
| | Yes | 80 | 80 | 74 | 234 | 97.5 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| At which stage of your soybean growth phase does terminal drought occur | Vegetative | 5 | 0 | 7 | 12 | 5 |
| | Flowering stage | 10 | 20 | 13 | 43 | 17.9 |
| | Pod initiation stage | 30 | 20 | 30 | 80 | 33.3 |
| | Pod filling stage | 35 | 40 | 30 | 105 | 43.8 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Month rainfall termination | End of September | 0 | 0 | 1 | 1 | 0.4 |
| | Mid-October | 65 | 70 | 59 | 194 | 80.8 |
| | First week in November | 15 | 10 | 20 | 45 | 18.8 |
| | Total | 80 | 80 | 80 | 240 | 100 |
| Effect of early cessation of rainfall on soybean yield and seed quality | Forced maturation of green pods | 20 | 15 | 19 | 54 | 22.5 |
| | Immature and green seed drying-up | 20 | 25 | 23 | 68 | 28.3 |
| | Poor seed quality | 20 | 15 | 18 | 53 | 22.1 |
| | Low grain yield | 20 | 25 | 20 | 65 | 27.1 |
| | Total | 80 | 80 | 80 | 240 | 100 |

Most of the farmers (79.2%) believed that the shift in rainfall pattern has resulted in a delay in the onset of the peak rainfall, and hence the peak of the rains is now observed mostly in May in the three districts. Twenty percent of the farmers consider the onset of the peak of the rainy season to be in June. Almost all (99.0%) of the respondents indicated that the shift in rainfall timing and pattern had affected soybean production.

Similarly, 97.8% of the farmers agreed that they experience severe drought yearly on their soybean farms (Table 9). All the respondents from Savelugu and Tolon districts agreed to this challenge. Almost forty-four percent of the sampled farmers experienced severe drought at the stage when their soybean pods are filling, a third (33.3%) at the pod initiation stage, and 17.9% at the flowering stage. The majority of the farmers (80.8%) suggested that rainfall terminates in mid-October, 18.8% indicated the rain terminates in the first week of November. Finally, 0.4% chose the end of September as the period rainfall terminates.

Table 10. Mitigation strategies employed by farmers against the effect of short rainfall duration on soybean production.

| Mitigation measures | District | Total | Percentage |
|---------------------|----------|-------|------------|
| Planting on ridges  | 4 | 10 | 2 | 16 | 6.7 |
| Mulching            | 15 | 20 | 25 | 60 | 25.0 |
| Afforestation       | 15 | 10 | 5 | 30 | 12.5 |
| Early planting      | 30 | 25 | 40 | 95 | 39.5 |
| Earthening-up around plants during pod development stage | 16 | 13 | 8 | 37 | 15.5 |
| Total               | 80 | 80 | 80 | 240 | 100.0 |
Farmers in the three districts used for this study enumerated four main problems with early stoppage of rainfall to soybean production (Table 9). Those challenges included immature and green seed drying-up (28.3%), low grain yield (27.1%), forced maturation of green pods (22.5%), and finally, poor seed quality (22.1%).

3.7. Mitigation strategies against short rainfall duration challenges on soybean production

Farmers employ diverse approaches to retain soil moisture to enhance the growth of their soybean. Almost forty percent of farmers used the early planting strategy to overcome the effect of the early end of the rains on soybean production (Table 10). Also, a quarter of the farmers (25.0%) resort to the use of mulch to conserve soil moisture to minimize the effect of short rainfall duration on their soybean production. Earthening-up around plants during pod development is practiced by 15.5% of the farmers, followed by afforestation where farmers (12.5%) plant trees around their farms to reduce rainwater runoff, leading to less soil erosion, while the forest cover results in lower surface temperatures, thereby providing a cooling effect on soils. Some farmers (6.7%) plant on ridges and others (0.8%) use irrigation to combat the effect of early stoppage of rainfall on soybean production in the Guinea savannah ecological zone.

Farmers desire shattering resistant soybean (16.0% of farmers), high grain yield (14.0%), large-sized seed (15.1%), early maturing variety (11.8%), and soybean with high pod clearance (8.0%), while others looked for traits such as disease resistance (3.6%), pest resistance (3.3%), profuse nodulation ability (2.5%), resistance to lodging (2.3%) and small seed size (1.0%). On the other hand, processors require soybean with a large seed size (30.6%), high protein content (28.7%), resistance to pests (15.9%), and low cooking time (12.7%) (Table 11).

3.8. Farmers and processors desired soybean traits in new variety development

Farmers are prepared to pay five Ghana Cedis (GH¢ 5.00, € 0.66) to fifteen Ghana Cedis (GH¢ 15.00, $ 1.99) for a kilogram of certified seeds (Figure 6A) as against the current government subsidised price of three Ghana Cedis and fifty pesewas (GH¢ 3.50, € 0.47) for a kilogram of certified seed. It was observed that as high as 39.0% of the farmers are willing to pay ten Ghana Cedis (GH¢ 10.00, $ 1.33) for soybean certified seeds possessing their desired traits.

In the case of the processors, it was observed that currently, a bowl of soybean grain which equal 2.5 kg was sold between five Ghana Cedis (GH¢ 5.00, € 0.66) to seven Ghana cedis (GH¢ 7.0, € 0.93) depending on the time of the season. However, farmers are willing to pay more for the (2.5 kg) if the soybean grain were developed to have their traits of interest. The expected premium price ranged from five Ghana Cedis (GH¢ 5.00, € 0.66) to ten Ghana Cedis (GH¢10.00, $ 1.33). About forty percent of the processors are ready to pay nine Ghana cedis (GH¢ 9.00, $ 1.20) for a 2.5 kg soybean grain, while 6.0% were keen to pay ten Ghana Cedis (GH¢ 10.00, $ 1.33) for 2.5 kg of soybean grain (Figure 6B). Generally, it was observed that both farmers and processors were eager to pay additional money to have soybean with their traits of interest.

The flow chart below according the Participatory Rural Appraisal (PRA) survey that was carried out in the Guinea Savannah agro-ecological zone of Ghana (Figure 7) in three major soybean growing districts to identify soybean preferred traits, production constraints and mitigation strategies in the Guinea Savannah Agro-ecological zone of Ghana showing the following results (Figure 7). From the flow chart it appeared that the identification of soybean preferred traits will directly or indirectly relate to the demographic characteristics of the value chain actors (farmers and processors). The value chain actors (farmers and processors) will influence the sources of seed, grain and varietal information. The agronomic practices employed can directly affect the socio economic characteristics of farmers and indirectly influence the processors. Desired traits will have a positive relationship on premium price,

| Table 11. Soybean traits preferred by farmers and processors. |
|---------------------------------|-----------------|-----------------|
| Soybean traits                  | Farmers          | Processors       |
|                                 | Frequency        | Percentage (%)   | Frequency | Percentage (%) |
| Shattering resistance           | 211              | 16.0            | -         | -             |
| High grain yield                | 186              | 14.0            | -         | -             |
| Large seed size                 | 172              | 13.1            | 48        | 30.6          |
| Early maturity                  | 155              | 11.8            | -         | -             |
| High pod clearance              | 105              | 8.0             | -         | -             |
| High protein content            | 70               | 5.3             | 45        | 28.7          |
| High oil content                | 70               | 5.3             | 8         | 5.1           |
| High biomass                    | 66               | 5.0             | -         | -             |
| Drought resistance              | 58               | 4.4             | -         | -             |
| Low cooking time                | 58               | 4.4             | 20        | 12.7          |
| Disease resistance              | 47               | 3.6             | -         | -             |
| Pest resistance                 | 43               | 3.3             | 25        | 15.9          |
| Profuse nodulating ability      | 33               | 2.5             | -         | -             |
| Resistance to lodging           | 30               | 2.3             | -         | -             |
| Small seed size                 | 13               | 1.0             | 7         | 4.5           |
| Less beany taste (other)        | -                | -               | 4         | 2.5           |

Figure 6. Premium price farmers and processors wish to pay for soybean with preferred traits (A) Certified seed (1kg) and (B) Grain (1bowl = 2.5 kg).
value chain actors will want to pay. Soybean production constraints and effects of climate change and limitation will directly or indirectly related to influence yield. The mitigation strategies such as planting early maturing soybean varieties, planting on ridges to conserve moisture will serve as escape means to increase yield. On the other hand, the development of soybean with desired traits such as early maturing soybean varieties will impact the utilization of improved varieties and will reduce climate change effect on soybean productivity in the Guinea Savannah agro-ecological zone of Ghana.

4. Discussion

Majority of farmers and processors in soybean production, processing, and marketing in the Guinea Savannah Agro-ecological zone of Ghana are in their youthful age (30–49 years) (Table 3). This means that most farmers in the area are in the economically active age group. It is noteworthy that the average age of farmers in Ghana is estimated to be 55 years (MoFA, 2015). A relatively youthful group among the farmers in the study area is good for agricultural development and its sustainability. Another implication is the likelihood of higher soybean productivity since most production activities are carried out using manual labour. Mechanization in soybean production is yet to become a routine practice. Another reason for the younger persons venturing into soybean farming is that farming is the main occupation of the people. Hence, farming is usually introduced at a very early stage of development. Again, this could indicate that soybean production in Northern Ghana has a brighter future if the right innovations, policies, and technologies are devoted towards the development of soybean. A similar observation revelation was made by Adjebeng-Danquah et al. (2020) in cassava production in the Northern region. The economic implication of the youthful age bracket in the study area means a significant impact on agricultural output as knowledge and expertise in agriculture, such as production, operation and management, will be transferred to the youth by the elderly farmers (Guancheng et al., 2015). This accumulated knowledge and skills transferred to the youth will help them maximize the efficient use of agricultural input which will lead to increase productivity and economic livelihood of the farming community.

Soybean farming activities constitute a male-dominated venture, whereas females controlled soybean processing undertakings. This observation may be because males are the main land-owners in that part of the country and so have greater access to land compared to female farmers (Adjebeng-Danquah et al., 2020).

On the other hand, because females are mostly involved in the preparation of food for their families, the processing of soybean for making different products like soybean tofu (khebab), soybean dawa-dawa, soymilk, drinks and tom-brown are commonly seen as “female work”, and hence most males are unwilling to do those kinds of jobs. However, less number of female farmers involved in soybean production in Guinea Savannah Agro-ecological zone translates into lower household income, greater food insecurity, and lowered wellbeing of the women’s families and wider communities. As broad-based agricultural development in low-income countries such as Ghana will need higher population of women to make decisions and take advantage of opportunities in farming to secure their families financially. Agricultural gender equalities has been shown to be fundamental for increasing socioeconomic situation of farmers’ families and reduction in food insecurity (Kassie et al., 2015).

Comparatively, more of the processors had formal education than farmers (Table 3). Farmers had a higher number of members in a household than processors. This may be due to the labor demand and intensity of farming activities; hence, the higher the members of the household, the more hands available to support the farming work.

In Ghana, agriculture is predominantly on a smallholder scale, and as such, mechanized farming is limited. A survey by the Statistics, Research and Information Directorate of MoFA (2017) indicated that the main farming system is traditional, which involves limited use of mechanization. However, this study identified an improvement in the use of machinery as the respondents used either ploughing only, harrowing only, or a combination of ploughing, harrowing, and ridging as a method for preparing their lands for sowing soybean (Table 4). Most farmers used ploughing only to prepare their lands, indicating that this type of farm equipment is easily accessible to the farmers compared to the other equipment like harrows and ridgers.

Farmers indicated that the rainfall is mostly stabilized, and moisture becomes adequate during the month of July to support germination and growth of soybean. Most farmers from the three districts do not apply fertilizer to the soybean plants. However, a minority of farmers from the Tolon district apply fertilizer. This practice in Tolon may be due to the more knowledge they might have acquired on the importance of fertilizer use in soybean production. The awareness of many farmers was raised...
through the demonstration activities of a research institute situated in the Tolon district. This institution has worked closely, over the years, with farmers in the release of all the soybean varieties being grown in Northern Ghana. Besides, the activities of some NGOs such as MEDA-GROW in that district have been more significant compared to the other districts. The majority of these farmers used N.P.K on soybean instead of TSP fertilizer. The predominant use of NPK instead of TSP fertilizer is attributed to the poor income status of farmers, which restricts them from accessing TSP fertilizer. This disparity is important because TSP as a P nutrient fertilizer is more effective for soybean growth compared to NPK. Soybean, like other legumes, can fix nitrogen, hence does not need much inorganic nitrogen compared to phosphorus. Such poor fertilizer use practice may be responsible for the low yields reported by farmers in Northern Ghana. This study confirms the reports by Gelfand and Philip Robertson (2015), Nziguheba et al. (2016), Salvagiotti et al. (2008), and Dodd and Mallarino (2005) who emphasized that sufficient soil P availability is critical to support soybean growth and yield. Nonetheless, socio-economic constraints to smallholders prevent access to P inputs. November is the main month for harvesting soybean because almost all the varieties cultivated by the farmers mature in 120–125 days (SARI, 2018).

Generally, farmers in the Yendi district were more experienced in soybean production than those in Tolon and Savelugu districts (Table 4). Some farmers had as long as twenty-one to thirty years of experience in soybean production. Such experienced farmers mostly serve as nodal points for technology and good agricultural practices training. The vast expertise achieved by such farmers could impact soybean technology transfer, dissemination, and adoption of new varieties since this group of farmers would have tested several technologies in the past and can project the influence of any new technologies on crop yields. This finding corroborates reports by Mahama et al. (2020), who studied the determinants of adoption intensity of sustainable soybean production technologies.

Again, it was observed that soybean is mostly intercropped with cereal crops such as maize, sorghum, and millet on smaller areas, while a greater proportion of farmers cultivated soybean in sole cropping (Table 4). This practice emphasizes soybean production as an income-generating crop to farmers. Also, intercropping soybean with cereals means farmers do not have to buy inorganic fertilizers like NPK for their cereal crops since soybean can naturally fix nitrogen in the soil. Farmers reported that soybean cultivation in pure stands controls the weeds better and improves soil fertility from the decomposition of shed leaves during maturity.

Seed is very vital in any crop production system. The source from which a farmer obtained seed for cultivation can determine the quality of the seed or grain produced. In this study, most farmers obtained seeds using informal systems, such as saving seeds from the previous year, purchasing seeds from local markets, or from friends and families (Figure 4A). However, about a third of the respondents obtained seeds from the formal system like MoFA, NGOs, agro-input dealers, and local seed stores (Figure 4A). More than thirty percent of farmers’ land size is planted with seeds from the formal system. This is an indication that the formal seed sector is receiving some response from farmers through the promotion of seed through government policies like the Planting for Food and Jobs Programme, where inputs including seeds are subsidised for farmers. These findings are contrary to the report by Ghana EGS (2018), where it was reported that only six percent of soybean cropping lands are planted to seeds from the formal system. On the other hand, the majority of processors obtained soybean grains from the local market (Figure 4B). The farmers leading significant sources of information were MoFA/Extension officers, radio/TV, and research institutions (Figure 4C). Some information was also received through NGOs and also family and friends. Access to information on agricultural innovations has increased farm output in many rural parts of Africa (Kimaru-Muchai et al., 2012). The access of farmers in the surveyed districts to information from formal sources is a good sign for the development of agriculture in the study area. This indicates that extension officers, mass media (radio/TV), researchers like agronomists, breeders, and other agencies had invested much time and resources to get to this level of success in agricultural communication and associated impact.

Contrary to the findings of Awuni et al. (2018), mass media through radio/TV was among the vital sources of information on new technologies and innovation sharing by farmers in the study area. This means that the transfer of technologies via mass media can reach and impact more farmers adopting soybean production technologies. Farmers who replaced seeds every two years dominated (Figure 4D). This finding is consistent with Ghana EGS (2018) report, which revealed that farmers have shifted from replacing seed every four years to two years.

Eight soybean varieties are known and cultivated by farmers in the study area (Table 5). The majority of farmers identified the older soybean varieties released by CSIR-SARI from 1985 to 2003 than the current ones released from 2012 to 2019 (Ghana Variety release, 2019). However, the most popular (Jenguma), the least shattering variety (Favour), and Soung Pungun, which CSIR-SARI released in 2019 and 2012, respectively, could not be easily recognized by many of the farmers. Four varieties, Jenguma, Afayak, Favour, and Soung Pungun were the most cultivated of the eight varieties known to farmers in the study area. Jenguma was the most widespread soybean variety. Although the variety was released 18 years ago, it is still the most popular in farmers fields. This confirms the observation of Walker et al. (2015) that improvements in agricultural productivity in Africa have trailed, as revealed by the fact that varieties can stay popular with farmers for as long as 14 years or more.

Among farmers in the three study districts, low pod shattering is the key criterion in selecting a particular soybean variety for cultivation. This is because farmers leave their matured soybean crops in the field to harvest other crops such as groundnut, Bambara groundnut and sweet potato, whose underground products become more difficult with time since the ground gets harder due to moisture loss. Other selection indicators were high yield potential, high market value, and earliness.

Certified seeds were less popular among farmers in the Yendi district than Tolon and Savelugu. Seventy percent of farmers in Tolon districts and more than sixty-eight percent of farmers in Savelugu district used certified seeds. This may be due to the positive influence of the activities of a research institute in the Tolon district. The favourable impact of the proximity of the institute reflects more in Savelugu, a closer district compared to the Yendi district. The location of the research institute has had a positive influence on farmers, as they usually participated in improved variety demonstrations organised by researchers from the research institute.

The main constraints encountered in using improved soybean seeds by farmers were financial constraints, unavailability of improved seeds, lack of information about improved seeds, lack of awareness about improved seeds, and ineffective distribution systems in remote areas (Figure 5C). The Ghana Early Generation Seed (EGS) identified similar bottlenecks in a 2018 survey conducted on the supply of early generation seeds of soybean in Ghana.

Fifteen challenges were enumerated as soybean production constraints by farmers in the three districts. The most important challenge that impedes soybean farming in the area was the late maturity period of available varieties (Table 7). The second constraint was low pod filling due to low soil moisture at the pod development stage. Low grain yield was the third major worry. Poor seed quality resulting from poor seed filling and immature seed development was the fourth major constraint. The fifth constraint was drought due to low and erratic rainfall patterns characteristic of this agro-ecological zone. Poor rainfall distribution patterns expose the crop to moisture stress leading to poor yields (Zougmore, 2003). The last three production problems of soybean farming are diseases, insect pests, and pod shattering (Table 8).

There were divergent views from the farmers regarding the alteration in rainfall patterns as a consequence of climate change. Generally, farmers in the Yendi district believe rainfall patterns have drastically changed, and there is some delay in the onset of the rains in present
times. The opinions of farmers in the other two districts appeared contradictory. In general, the farmers believed that changes in the onset of the rains, rainfall levels, and distribution patterns have negatively impacted soybean production over the years in the agro-ecological zone. Terminal drought was identified as a major problem in soybean production, especially at flowering, pod initiation, or the pod filling stages (Table 9). Farmers reported a strong variability in annual rainfall levels with a shortened duration of fewer than four months. The short duration of the rainy season, coupled with the erratic nature of the rains in the savannah agro-ecological zone, has affected crop production. Especially crops that require a long duration to attain maturity, limiting crop production to only those with short life cycles of not more than three months (Adamu, 2000). Furthermore, Armah et al. (2010) also identified erratic rainfall, inadequate irrigation facilities, and annual wildfires as the major challenges to agricultural development in the Savannah Agro-ecological zone of Northern Ghana. The mitigation approaches used by farmers include mulching, early planting, earthening-up during pod development, planting on ridges, and planting trees around farmlands (Table 10).

Resistance to pod shattering, high grain yield, large seed size, earliness, and high pod clearance were the most important traits determining which farmers selected variety (Table 11). In contrast, processors soybean grain preference are based on large seed size, high protein content, resistance to pests, low cooking time, and high oil content (Table 11). Work by Buah et al. (2020) identified the most preferred traits by farmers as high grain yield, low pod shattering, earliness, and the high number of pods per plant when the participatory approach to variety selection on soybean production was used in Ghana. Preferences for improved varieties were, in the order of importance: earliness (65–90 days), large seed size, high grain yield (>2000 kg/ha), drought resistance, and high protein content.

These are the demand-led, breeding traits farmers are willing to pay a premium price to have incorporated in soybean breeding lines presently. The willingness of the respondents to have the aforementioned preferred traits incorporated in soybean-certified seeds and grains demonstrated that stakeholders are ready to pay an extra premium price when these traits are developed for their use and advantage. Farmers were willing to pay even as high as 15 cedis for a kilogram of certified seed with traits of interest, whereas processors were prepared to pay 10 cedis for 2.5kg of grains.

5. Conclusion

From the study, Jenguma, Afayak Favour, and Soung Pungun were identified as the most cultivated soybean varieties in the Guinea Savannah Agro-ecological zone of Northern Ghana. More than sixty percent of the farmers interviewed in Tolon and Savelugu districts use certified soybean seeds to cultivate soybean. Production of the crop in the sampled communities is challenged with several constraints, including late maturity period of available varieties, terminal drought, difficulty in harvesting, and difficulty in using manual means for threshing, culminating in low grain yield and poor seed quality.

Farmers were conscious of the adverse effects of a shift in rainfall patterns on soybean production. Terminal drought was identified as a major problem due to changes in the climatic pattern on soybean production in the surveyed communities, especially at flowering, pod initiation, and pod filling stages of development. The mitigation strategies used by farmers to avert the several effects of these problems were mulching, early planting, earthening-up during pod development, planting on ridges, and planting trees around farmlands.

Farmers’ most preferred traits were earliness, large seed size, high grain yield, pod shattering resistance and drought resistance. In contrast, processors preferences included large seed size, high protein content, resistance to pests, low cooking time, and high oil content. Due to the willingness of both farmers and processors to pay an extra price to have their preferred traits incorporated into new soybean varieties through breeding, it will be better for researchers to use a demand-led breeding approach to develop an ideal variety that possesses all the desired end-user preferred traits. This will give researchers broader knowledge on must-have traits, winning traits, niched traits, and low potential traits available in their localities to capitalize on those traits for setting soybean breeding goals.

Suggestions and Potential Opportunities Based on the results of the study, the following suggestions were formulated to improve soybean production in Guinea Savannah Agro-ecological zone of Ghana.

- From the studies, it was observed that farmers want early maturing soybean that can fit into the current short duration of the rainy season of three months, coupled with the erratic nature of the rains during the cropping season. Therefore, Soybean Breeders should integrate the development of earliness (80–85 maturing days) into their breeding programmes as the available commercial soybean varieties have maturity periods ranging from 105-135 days.
- Availability of improved or certified seeds, information on new technologies, and other essential inputs is vital if the promptness of adopting the new innovation is to be improved. Hence information on technologies developed by researchers should be made available to farmers through Extension Agents of MoFA as they are the major source where information is communicated to farmers.
- Consumer preferences for improved soybean variety in cooking time, taste, and palatability need to be examined to be included in the development of soybean product profiling that covers the whole value-chain actors. This will help Soybean Breeders in the formulation of research goals to develop new varieties with stakeholders desired traits for the Guinea Savannah Agro-ecological zone.
- Finally, this research recommends that studies should be done to understand how soybean as a legume could influence the profitability of intercrop cereals crops such as maize, millet, and sorghum in a mixing cropping farming practice.

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The authors declare no conflict of interest.

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