Vol.13(3), pp. 202-216 July-September 2021
DOI: 10.5897/JAERD2021.1260
Articles Number: 0382A0F67734
ISSN: 2141-2170
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Journal of Agricultural Extension and Rural Development

Full Length Research Paper

Responses of smallholder farmers on sorghum production preferences and constraints in the Upper East Region of Ghana

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Received 7 July, 2021; Accepted 9 September, 2021

In spite of several strategies implemented to improve sorghum production in Ghana, average grain yield in farmers' fields remains low and far below the estimated potential. The development of effective strategies requires continuous, in-depth understanding of production constraints as well as farmer preferences for crop traits. To this end, a participatory rural appraisal using focus group discussions, interviews with semi-structured questionnaires and preference ranking was carried out among 122 smallholder sorghum farmers in the Upper East Region of Ghana. Majority (91%) of respondents were engaged in farming with more than half of their farm sizes allocated to sorghum cultivation. Drought, high cost of farm inputs and declining soil fertility were the top three constraints. Almost 42% of farmers described their soils as low in fertility. The most preferred traits by farmers were drought tolerance, high grain yield, earliness, grain quality as well as low fertilizer requirement. A better understanding of the perceptions of farmers and factors that limit the adoption of improved technology is important to guide policy towards the design of effective crop improvement and extension programmes. The study highlights the importance of breeding sorghum varieties with traits preferred by smallholder farmers that will lead to increased adoption of improved technology.

Key words: *Sorghum bicolor*, smallholder farmers, perception, production constraints, farmer-preferred traits.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) an important dietary staple and food security crop cultivated in arid and

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semi-arid environments (Duodu et al., 2003; Reddy et al., 2004). In Ghana, the crop is cultivated for subsistence by smallholder farmers mainly in the five northern regions (Kudadjie, 2006). More recently, sorghum is emerging as an industrial crop; its grains have been used as a substitute for barley in industrial breweries, allowing local farmers to earn additional income and the breweries to save foreign exchange (Angelucci and Bazzucchi, 2013). Additionally, its stover is useful as raw material for weaving baskets and mats, an important cottage industry that generates income for rural women (Kudadjie-Freeman and Dankyi-Boateng, 2012).

In spite of its importance, yields in farmers' fields are extremely low (less than 2.0 t/ha) compared to the 4.5 to 5.0 t/ha achieved in developed countries (Kombiok et al., 2012; FAOSTAT, 2013).

For instance, in the Upper East Region of Ghana, annual yields are estimated at 700 kg/ha (Al-Hassan and Jatoe, 2002). According to the FAO, sorghum production in northern Ghana dropped from 287,000 tonnes in 2011 to 230,000 tonnes in 2017 (FAOSTAT, 2018). Such low yields threaten food security and livelihoods of many smallholder farmers in northern Ghana (Quaye, 2008). Given that almost half of the country's poor is concentrated in northern Ghana (poverty incidence in the Upper East, Upper West and Northern Regions are 44.4, 70.7 and 50.4% respectively), addressing production constraints of an essential crop such as sorghum is critical (GSS, 2014).

To improve productivity of sorghum in Northern Ghana, several strategies have been proposed and are being implemented. These include the development of improved varieties, dissemination of quality seed and increased fertilizer use among others (Nkegbe and Shankar, 2014). However, in spite of these strategies, average yield of the crop in farmers' fields remains far below achievable levels. Consequently, its full potential as a cash crop remains largely untapped.

One key constraint to sorghum production in northern Ghana is widespread soil infertility over the range of agro-ecologies included in the area referred to. In view of this, several strategies have been proposed to increase the crop's productivity on marginal soils. Key among these is the promotion of fertilizer use among smallholder farmers (SARI, 1995; Kombiok et al., 2012). However, in spite of persistent efforts, reports indicate weak demand and low fertilizer use among sorghum farmers in Ghana and Africa as a whole (Zida, 2006; Bumb et al., 2011). This has largely been attributed to high cost of fertilizers and its unavailability on rural markets (Laube et al., 2012). Even when fertilizers and subsidies are available, there have been difficulties in convincing smallholder farmers to apply fertilizer to the crop (Jalloh et al., 2013; Rware et al., 2014). This suggests that other factors, besides unaffordability and unavailability of the agro-input might influence farmers' attitudes towards its use.

Another constraint that accounts for low yields of sorghum especially in subsistence farming systems or low-input cropping systems (Vom Brocke et al., 2010) is low adoption of improved sorghum varieties by farmers in sub-Saharan Africa (Aissata, 2018; Kaliba et al., 2018). For instance, in most parts of West Africa, land area cultivated to improved sorghum varieties is less than 2% of total cultivated land (Cline, 2007; Burke et al., 2009). Interestingly, farmers' perceptions have influenced their adoption of agricultural practices and technologies (Marenya et al., 2008; Fosu-Mensah et al., 2012; Ndamani and Watanabe, 2015).

In order to effectively address sorghum production constraints from the perspective of smallholder farmers who account for about 90% of sorghum production in Ghana (Rudema, 2006), there is need to understand their perceptions of production constraints, their preferences for sorghum traits as well as reasons for their low adoption of improved agricultural technologies. This information is relevant for developing effective strategies towards improving sorghum productivity of smallholder farmers in Ghana as well as sub-Saharan Africa.

In the present study, we employed a participatory rural appraisal (PRA) approach using focus group discussions followed interviews and preference ranking to identify production constraints and farmer perceptions that limit sorghum productivity in the Upper East Region of Ghana. Information from this study should provide direction for setting relevant breeding goals, which will enhance willingness of farmers to adopt improved technologies.

MATERIALS AND METHODS

Description of study areas

The study was conducted in 2017 in four villages; Gbane and Yameriga in the Talensi-Nabdam district (10°42'59.99" N 0°47'59.99" E) and Gumyoko and Tempelim in the Binduri district (10°58'19.70" N 0°18'30.13" E). Both districts are located in the Upper East Region of Ghana (10°45'0.00" N 0°45'0.00" E). Rainfall pattern is unimodal and characterised by a short rainy season from May to October (annual mean of 950 mm) followed by a long dry season of six to seven months. Temperatures are generally high (between 26 and 45°C). Natural vegetation is Guinea-Savannah woodland. Mean annual rainfall in Binduri and Talensi-Nabdam districts is 800 and 950 mm, respectively (Agriculture, 2019). Natural vegetation in Binduri is mainly Sahel-Savannah (GSS, 2013) compared to Guinea Savannah woodland in Talensi-Nabdam (Agriculture, 2019). These districts were selected based on the importance of sorghum to food security as well as socio-economic status. In both districts, sorghum is a major crop, grown mainly by small-scale, resource-poor farmers.

Sampling procedure and data collection

Focused group discussions were organised with stakeholders (farmers, agricultural extension officers and researcher) at each village to obtain information on general constraints. The districts were selected based on the long history of sorghum cultivation and relatively wide areas allocated to sorghum production. One group was organised per village, each comprising a maximum of seven farmers including male and female representation. Subsequently, heads of households or available family members involved in farming activities were interviewed individually using semi-structured questionnaires which comprised five sections with questions related to demographics, constraints to sorghum productivity, perceptions and assessment of soil fertility, fertiliser use and other soil management strategies. Farmers were asked to rank their preferences for sorghum production constraints and traits. Interviews were followed by visits to some sorghum fields during which direct observations were made. Agricultural extension officers assisted during sampling and data collection. The extension officers provided information on which smallholder farmers cultivated sorghum.

Data collection

Primary data were collected using focus group discussion (FGD) and semi-structured questionnaires. At each village, an FGD was organised with key stakeholders including smallholder farmers, village elders, youth and agricultural extension officers. Meetings for FGD involved a maximum of 7 participants including both male and female representation. Participants at FGD were mobilized by local agriculture extension officers. Information on general constraints to sorghum production were discussed during the FGD. Individual interviews were also conducted to explore issues that were more specific. Subsequently, questionnaires were prepared to collect primary data. The questionnaire comprised three sections with questions related to demographics, perceived constraints to sorghum production and farmers' preferences for traits in sorghum varieties cultivated. The smallholder farmers were then interviewed individually using the semi-structured questionnaires. A total of 122 farmers were sampled in the two districts.

Data analysis

Data collected from FGDs and questionnaires were first summarized into means and frequencies using Microsoft Excel version 2016. Summarized data were subjected to statistical analyses using IBM Statistical Package for Social Sciences (SPSS) software, version 23 (SPSS, 2015). Descriptive statistics, t-tests and Chi-square tests were carried out on the data where appropriate.

RESULTS

Demographic characteristics of households

Out of a total of 122 farmers interviewed in the two selected districts (Talensi-Nabdam and Binduri) (Figure 1) in the Upper East Region of Ghana, 73 were male (60%) and 49 female (40%) (Table1). A male majority was the trend in all four communities. The highest percentage of female farmers (47%) was observed in Yameriga, followed by Gumyoko (44%), Tempelim (37%) and Gbane (32%) (Table1). A significantly higher number ($p < 0.05$) of farmers were married in all four communities and more than half the number of farmers interviewed had between 1 and 5 children. Farmers' age ranged from 25 to 75 years although male farmers were averagely younger 43 years compared to female farmers (47 years). Sorghum is mainly cultivated as a subsistence crop, thus requires manual labour for land preparation, weeding and other cultural practices. These activities require physical strength and most farmers depend on family members to accomplish the tasks. Respondents belonged to three main religions; Christianity (41%), Islam (37%) and Traditional (22%). Overall, majority of respondents (57%) had no formal education, while the proportion of farmers with primary, secondary and tertiary education was 32, 8 and 3%, respectively (Table 1). Majority of female farmers (80%) had no education with only 16% having some basic education (Figure 2A). In contrast, only 41% of male farmers had no education while 42% had basic education. Although the number of farmers with secondary education was low in the communities sampled, the disparity in education levels between male (12%) and female (2%) farmers was maintained (Figure 2A). The highest literacy levels were recorded in Gbane where 57.1% of respondents had at least basic education. This was followed by Yameriga (50%), Gumyoko (34.4%) and Tempelim (33.3%) (Table 1).

Socio-economic characteristics of households

Farming is the main occupation in the sampled communities with 30% of the farmers engaged in farming for more than 15 years (Supplementary Table 1). Only 14% of the farmers had less than 5 years' experience in farming. More than half of the farmers (51%) had at least 11 years of farming experience. Fifty-five percent of farmers cultivate sorghum solely for household use (food and feed) whereas for 44% of farmers, the crop was cultivated as a source of income in addition to food or feed. For male farmers, sorghum cultivation was mainly for food and income (60%) compared to female farmers whereby sorghum was cultivated mainly for use as food (78%) (Figure 2B). Farmers made an average income of $50 (GHS 224) per person from cultivating sorghum in the previous season.

Farm size and area allocated to sorghum production

A large majority (93%) of farmers owned their farmlands. Overall, average farm sizes ranged from 2.4 acres in Gbane to 4.5 acres in Tempelim (Table 2). In all four communities, the average size of land allocated to sorghum cultivation was less than 2 acres in Gbane (1.3), Yameriga (1.5) and Gumyoko (1.6). Only in Tempelim, did farmers allocate averagely 2 acres for cultivation of sorghum (Table 2). For many smallholder farmers in the Upper East Region, farming is highly dependent on rain; thus, cultivation of other crops in addition to sorghum provides food security and reduces the risk of total crop failure.

Diversity of sorghum varieties cultivated

In the four communities sampled, farmers cultivated

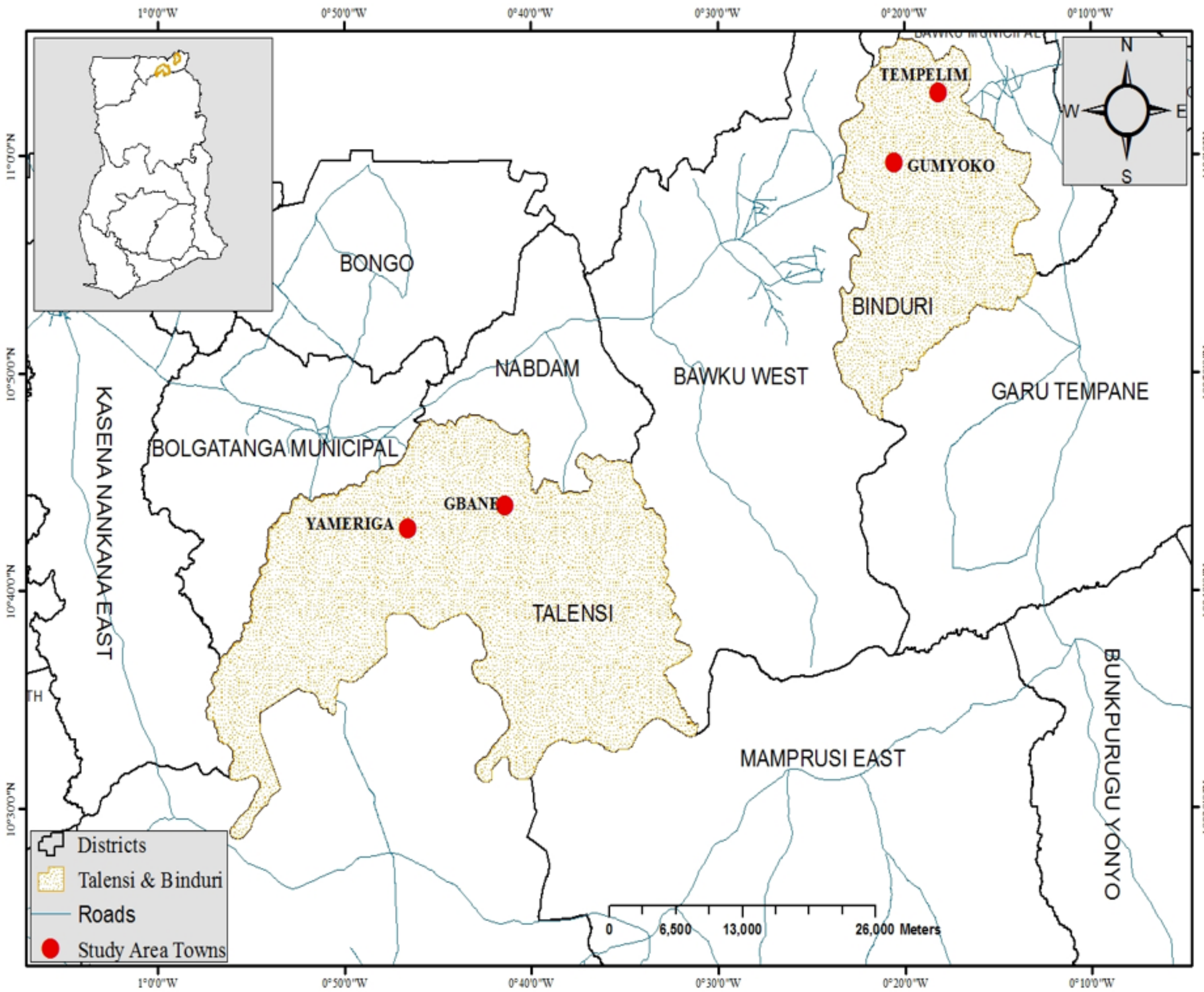

Figure 1. A map of Talensi-Nabdam and Binduri districts (dotted region) in the Upper East Region of Ghana showing the sampled communities (red circles).

several sorghum varieties, which include Naga Red, Belko-peleg, Belko-zia, Naga white, Kapaala, Dorado and Kowerig (Figure 3A). Overall, the most-cultivated variety was Kapaala (66%) followed closely by Naga-white (65%) and Belko-white (53%). Kadaga, Naga-red, Framida and Nacia were cultivated by 31, 15, 5, and 2% of farmers, respectively. However, when farmers were asked about their preferred sorghum variety, Kadaga was the most preferred (24%), followed by Naga-white (22%) and Kapaala (16%) in that order. Sorghum farmers interviewed in the Upper East Region grew up to four varieties albeit majority of farmers grew two varieties (Figure 3B). Farmers tend to grow at least two varieties to insure against bad weather, insects or diseases (Dogget, 1988). The selection of varieties for cultivation by farmers is based on traits preferred such as suitability for use as food or drink or capacity to withstand moisture stress (Gebretsadik et al., 2014). Besides sorghum, farmers cultivated other crops such as millet, rice, maize, groundnuts, soybean, cowpea, tomatoes and garden eggs to supplement household income and ensure food security.

Sources of seed and information

A large majority of farmers (70%) saved seeds from previous cropping seasons compared to farmers (15%) who purchased seed from farmer associations or from the Ministry of Food and Agriculture (MOFA) office (9%) (Figure 3C). Only 4% of the farmers obtained their seeds from the local market while 2% obtained seeds from non-governmental organizations (NGOs). The practice of farmers saving seeds for planting or exchange among themselves is characteristic of 'farmer seed systems in most countries (Sperling and Cooper, 2003). In subsistence farming systems, shortage of locally-adapted seed is common, thus, seeds saved by farmers is critical

Table 1. Demographic characteristics of households sampled in the four communities in the Upper East Region of Ghana/.

Variable	Characteristics	Communities				Total	Percentage
		Gbane	Gumyoko	Tempelim	Yameriga		
Gender	Male	19	18	19	17	73	59.8
	Female	9	14	11	15	49	40.2
	Total	28	32	30	32	122	100.0
Age (years)	<30	1	5	2	10	18	14.8
	31-45	15	13	14	12	54	44.3
	46-60	10	11	11	5	37	30.3
	>60	2	3	3	5	13	10.7
	Total	28	32	30	32	122	100.0
Religion	Christians	13	14	11	12	50	41.0
	Muslims	9	10	16	10	45	36.9
	Traditionalists	6	8	3	10	27	22.1
	Total	28	32	30	32	122	100.0
Marital status	Married	25	31	26	20	102	83.6
	Single	2	1	4	12	19	15.6
	Divorced	1	0	0	0	1	0.80
	Total	28	32	30	32	122	100.0
Number of children	No child	2	1	3	3	9	7.4
	1 to 5	14	23	8	19	64	52.5
	6 to 10	7	6	14	6	33	27.0
	11 to 15	5	1	4	4	14	11.5
	>15	0	1	1	0	2	1.6
	Total	28	32	30	32	122	100.0
Literacy level	None	12	21	20	16	69	56.6
	Basic education	12	9	7	11	39	32.0
	Secondary	2	1	2	5	10	8.2
	Tertiary	2	1	1	0	4	3.3
	Total	28	32	30	32	122	100.0

Percentages for gender ($P = 0.643$), age ($P = 0.094$), religion ($P = 0.346$), number of children ($P = 0.098$) and literacy level ($P = 0.373$) were not significantly different whereas percentages for marital status ($P < 0.05$) was significantly different at 5% level. N= 122.
Source: Field Data (2017).

to make up this shortfall (McGuire, 2008).

In general, farmers received information on improved sorghum cultivars, agronomic practices or technology mainly (71%) from agricultural extension officers (Figure 3D). More than half the number of farmers (52%) obtained information on sorghum production from their famer colleagues or through organised group discussions. Interestingly, a higher number of farmers obtained information from NGOs (25%) than they did from research institutions (18%). Although there are over 10 operational radio stations in the Upper East Region (NCA, 2016), only 4% of farmers received information on improved cultivars, agronomic practices or technology from radio.

General constraints to sorghum production

Farmers in the Talensi-Nabdam and Binduri districts cited eight major constraints to sorghum production. These include drought, high cost of inputs for farming (agro-chemicals, hired labour, tractors or oxen and seeds), declining soil fertility, *Striga*, diseases, post-harvest losses, land unavailability and pests (bird damage) (Table 3). Overall, drought was the most important constraint to sorghum production in all the communities except

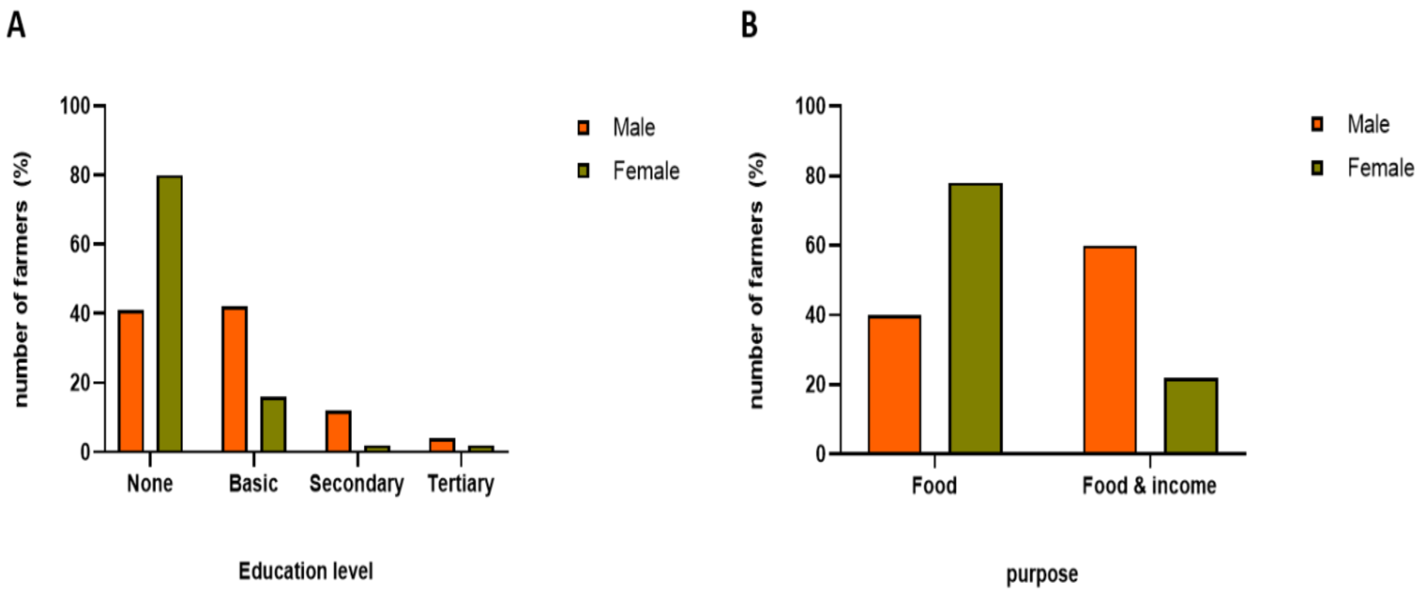

Figure 2. (A) Education levels and **(B)** purpose of sorghum cultivation among smallholder farmers in the four sampled communities in the Upper East Region of Ghana.

Table 2. Farm sizes and area allocated to sorghum cultivation in four communities in the Upper East Region of Ghana.

Community	Number of respondents	Average farm size (acre)	Average land allocated to sorghum (acre)	Proportion of land allocated to sorghum (%)
Gbane	28	2.42	1.31	54
Yameriga	32	3.16	1.48	47
Gumyoko	32	3.11	1.56	50
Tempelim	30	4.52	2.03	45

Farm sizes are categorized into < 1 acre; 2- 4 acres; 5 -7 acres; 8 -10 acres or >10 acres. N= 122.
Source: Field Data (2017).

Yameriga where high cost of farm inputs was the most important constraint. Similarly, in Ethiopia, severe drought particularly during the post flowering stage was ranked as a major constraint (Derese et al., 2018) while in Burkina Faso, drought was one of the most important constraint to sorghum production (Nofou et al., 2017). Sorghum is sensitive to drought especially during the stages of flag leaf appearance to the start of grain filling (Premachandra et al., 1994; Baigorria et al., 2007). Farmers in the two districts ranked land unavailability and pests (bird damage) lowest among the constraints to sorghum production. Declining soil fertility was ranked second in Gumyoko, fourth in Tempelim and Yameriga and fifth in Gbane (Table 3).

Farmers' perceptions of soil fertility status and its effect on sorghum production

Farmers were interviewed in the selected communities to enable understand how farmers perceive the fertility status of their soils and its effect on sorghum yields. More than half of the farmers (58.2%) in the communities sampled described their soils as moderately or highly fertile (Table 4). In contrast, almost 42% of farmers described their soils as low in fertility. In all four communities, only 6.6% of farmers described their soils as highly fertile. In general, farmers described darker, more compact and moist soils as fertile whereas soils with stony, reddish or 'lighter' color and texture were described as infertile. The main indicators of soil fertility were color (88.5%), crop performance (85%), soil texture (66%) and high moisture retention ability (46%) (Table 4). Only 13% of farmers considered the presence of weeds and other plants as indicators of soil fertility.

A large majority of farmers (95%) perceived symptoms of nutrient-stress in sorghum as easily-recognizable (Supplementary Table 2). In this regard, the most-mentioned symptoms were poor yields (43%) and stunted growth (75%). A much lesser proportion mentioned delayed maturity (22%), poor seedling establishment

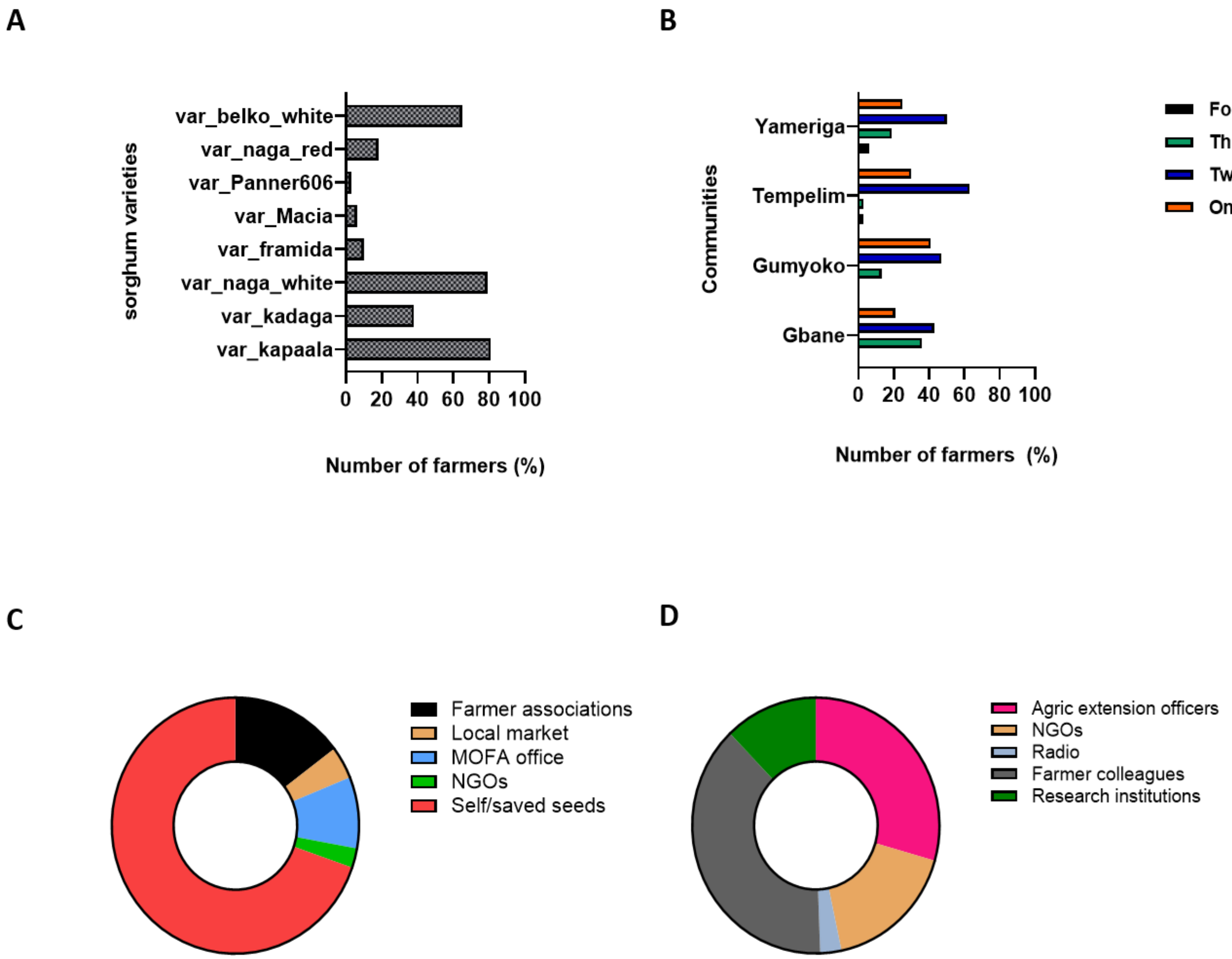

Figure 3. Diversity of sorghum varieties cultivated and sources of seed and information on improved technologies in the four communities: (A) sorghum varieties, (B) number of varieties grown by farmers, (C) source of seed, and (D) information on improved technologies.

Table 3. Ranking of sorghum production constraints by smallholder farmers across the four communities in the Upper East Region of Ghana.

Major constraint	Mean rank				Overall Mean	Std. Dev	Overall Rank
	Gbane	Gumyoko	Tempelim	Yameriga			
Drought	1.6 (1)	2.2 (1)	1.8 (1)	2.6 (2)	1.59	0.44	1
Cost of farm input	3.2 (2)	2.8 (3)	2.6 (2)	2.4 (1)	2.58	0.35	2
Declining soil fertility	4.7 (5)	2.3 (2)	3.9 (4)	4.4 (4)	3.76	1.09	3
Striga infestation	4.3 (4)	4.7 (4)	5.6 (5)	3.7 (3)	4.45	0.80	4
Diseases	4.0 (3)	5.2 (5)	5.8 (6)	4.7 (5)	4.82	0.78	5
Post-harvest losses	4.8 (6)	6.8 (8)	3.2 (3)	5.4 (6)	5.31	1.48	6
Land unavailability	7.1 (8)	5.5 (6)	6.3 (7)	6.6 (8)	6.65	0.66	7
Pests (bird damage)	6.3 (7)	6.4 (7)	6.7 (8)	6.2 (7)	6.79	0.21	8

The highest score = 1 and the lowest = 8. Figures in parenthesis represent rank for constraints in each community. Mean rank for drought (P = 0.003), cost of farm input (P = 0.001), declining soil fertility (P = 0.006), *Striga* infestation (P = 0.001), diseases (P = 0.001), postharvest losses (P = 0.006), land availability (P = 0.000) and pest (bird damage) were significantly different at 5% level among each community. Std Dev = Standard Deviation. N= 122.
Source: Field Data (2017).

Table 4. Farmers' description of soils for cultivation of sorghum in four communities in the Upper East Region of Ghana.

Variable	Characteristics	Gbane	Gumyoko	Tempelim	Yameriga	Total	Percentage
Description of soil	Highly fertile	4	0	1	3	8	6.6
	Moderately fertile	17	10	17	19	63	51.6
	Poor	7	22	12	10	51	41.8
	Total	28	32	30	32	122	100.0
Crop performance	Yes	25	25	27	27	104	85.2
	No	3	7	3	5	18	14.8
	Total	28	32	30	32	122	100.0
Soil texture	Yes	20	26	16	19	81	66.4
	No	8	6	14	13	41	33.6
	Total	28	32	30	32	122	100.0
Soil moisture	Yes	15	16	14	11	56	45.9
	No	13	16	16	21	66	54.1
	Total	28	32	30	32	122	100.0
Soil colour	Yes	26	27	26	29	108	88.5
	No	2	5	4	3	14	11.5
	Total	28	32	30	32	122	100.0
Soil cover	Yes	8	4	1	3	16	13.1
	No	20	28	29	29	106	86.9
	Total	28	32	30	32	122	100.0

Source: Field data (2017) N= 122
Percentages for crop performance (P = 0.53), soil texture (P = 0.09), soil moisture (P = 0.458) and soil colour (P = 0.729), were not significantly different whereas percentages for description of soil fertility and soil cover (P < 0.05) was significantly different at 5% level.

(9.8%) and leaf discolorations (0.8%) as symptoms of nutrient-stress on sorghum. Sixty seven percent of farmers adjudged that grain yield in sorghum could be improved through fertilizer application (Supplementary Table 2). However, only 38% of the farmers in all four communities applied fertilizer to the crop (Supplementary Table 3). Fertilizer application was highest in Gumyoko (63%) and lowest in Tempelim (20%). More farmers (43.5%) fertilized the crop with manure and/or household waste than with inorganic, mineral fertilizers (23.9%). Almost 33% fertilized the crop with a combination of inorganic and organic fertilizers (Supplementary Table 3). The most frequently cited constraint (82% of farmers) to fertilizer use was farmers' inability to afford the commodity. A lesser proportion (48%) mentioned unavailability of fertilizer as a constraint (Supplementary Table 3).

Traits preferred by sorghum farmers

Overall, drought tolerance was the most-preferred trait, followed by high grain yield and earliness (Table 5). Grain quality, which included characteristics directly or indirectly, linked to the grain such as taste, storage quality, suitability for food and beverage and threshability was the fourth most-preferred trait. Disease tolerance was ranked higher than resistance to bird damage. At the community level, high grain yield was the most-preferred trait in Gbane and Gumyoko, whereas drought tolerance and earliness were the most-preferred traits in Tempelim and Yameriga respectively (Table 5). Varieties with low fertilizer requirement ranked third in Gumyoko but fifth in all other communities. The arid and semi-arid environments in which sorghum is cultivated is characterised by low or erratic rainfall (mean annual of 950 mm) as observed in the Upper East Region. Thus, farmers in this region have a high preference for drought-tolerant sorghum varieties.

The highest score is 1 and the lowest is 8.

DISCUSSION

Sorghum is a dietary staple across Africa and it is crucial to the food security of over 500 million people

Table 5. Ranking of farmers' preference for sorghum traits in the four communities in the Upper East Region of Ghana.

Preference criteria	Mean rank				Overall Mean	Std. Dev.	Overall Rank
	Gbane	Gumyoko	Tempelim	Yameriga			
Drought tolerance	2.3 (2)	2.1 (2)	1.8 (1)	3.1 (4)	2.3	0.6	1
High grain yield	2.0 (1)	1.8 (1)	3.3 (4)	3.0 (3)	2.5	0.7	2
Early-maturing	3.1 (3)	3.9 (5)	2.8 (2)	2.0 (1)	3.0	0.8	3
Good grain quality	3.3 (4)	3.8 (4)	3.2 (3)	2.4 (2)	3.2	0.6	4
Low fertilizer requirement	5.7 (5)	3.7 (3)	4.2 (5)	5.4 (5)	4.8	1.0	5
Resistance to *Striga*	6.3 (6)	6.5 (6)	6.8 (7)	6.4 (6)	6.5	0.2	6
Disease tolerance	6.5 (7)	7.1 (8)	6.6 (6)	6.9 (8)	6.8	0.3	7
Tolerance to pests	6.9 (8)	6.7 (7)	7.1 (8)	6.7 (7)	6.9	0.2	8

N= 122.
Source: Field Data (2017).

(Dahlberg et al., 2011). Due to its ability to perform favourably under harsh and unpredictable climatic conditions, it provides a risk-reducing alternative to sole maize cropping and is a reliable source of income for many smallholder farmers in the Sahelian and Savannah zones (Buerkert et al., 2001; Sultan et al., 2013; Nofou et al., 2017). In this study, it was observed that farmers in the Upper East Region mainly cultivated sorghum for subsistence: to provide food for the household. Farmers indicated that income generation from sorghum was limited due to poor yields and their inability to exceed household food demand. As a result, farmers rely on off-farm economic activities such as sale of firewood and cooked food, gathering of fruits, and shea butter preparation for additional income. For smallholders, off-farm activities are important strategies for minimizing food insecurity and improving livelihood (Osarfo et al., 2016). Literacy levels were low among the farmers with more than 50% having no formal education. According to (Enu and Attah-Obeng, 2013), lack of formal education is a hindrance to agricultural productivity in northern Ghana. The general lack of formal education among sorghum farmers in the communities surveyed poses a barrier to effective assessment of soil fertility. Farmers with higher education often possess greater capabilities for assessing their environments and implementing improved technologies (Akinbile, 2003; Uematsu and Mishra, 2010). On the contrary, the high experience levels among the farmers seemed to compensate for low literacy levels. For instance, most farmers described their soils with easily observable indicators such as soil color, texture and crop performance. In a similar study in Ethiopia, farmers also cited crop performance as one of the main criteria for assessing soil fertility (Yeshaneh, 2015). Although leaf discolorations and poor stand establishment were also cited as symptoms of nutrient-stress in sorghum, farmers associated these symptoms more with drought than with poor soils. This observation might be due to the fact that, both abiotic factors present similar symptoms (Chen et al., 2015).

Although farm sizes were generally small, between 2 and 4.5 acres, more than half of cropped land was allocated to sorghum cultivation, indicating the crop's importance in the Upper East Region. In many parts of Ghana, farming is extremely labor-intensive with limited mechanization (Diao et al., 2014). Thus, larger farms require the hiring of expensive casual labor, tractors or oxen, an investment many smallholder farmers may be unable to make (Whitehead and Tsikata, 2003). In addition, the scarcity of arable land and/or high cost of renting additional land might account for the small farm sizes (Ohene-Yankyera, 2004).

Majority of farmers cultivated two sorghum varieties based on traits such as: early or late-maturing varieties, capacity to withstand biotic or abiotic stress or grain quality. Due to differences in ethnicity and language, identical sorghum varieties were referred to by different vernacular names. For example, red-grained varieties were interchangeably referred to as *Kezie, Keto* or *Kimolga*, an observation that has also been previously reported in Ghana by Kudadjie et al. (2004) and in Benin by Missihoun et al. (2012) . The most preferred varieties were Kapaala and Naga-white, both early-maturing varieties. Farmers preferred Kapaala because it provided a less risky option for farmers in case of insufficient rain (Kudadjie-Freeman and Dankyi-Boateng, 2012). The planting of early-maturing varieties is important in order to adapt to changing climatic conditions. In contrast, the popularity of the late-maturing, low-yielding Belko-white variety within the communities is likely due to its suitability for preparing *tuo zaafi* and other local foods (Kudadjie et al., 2004).

Access to information on agricultural innovations has been shown to increase farm output in many rural parts of Africa (Kimaru-Muchai et al., 2013). The most important sources of information for the farmers were from agricultural extension officers or family and friends.

However, informal channels of information such as from family and friends may expose farmers to the risks of inaccurate information, which is likely to hinder productivity (Benard et al., 2014). Electronic media such as radio and television were not important sources of information due to limited or no access to electricity.

Majority of the farmers save seeds for subsequent planting seasons, a frequent practice in northern Ghana and other parts of West Africa (Kudadjie-Freeman and Dankyi-Boateng, 2012; Dossou-Aminon et al., 2015). Although such seed systems have been practiced for decades, reports suggest that poor post-harvest handling of seeds as well as damage by pests may lead to poor plant establishment, a factor that may contribute to low yields among these farmers (Ochieng et al., 2011).

The major constraint to sorghum productivity was drought. Drought has been reported to be one of the main constraints to general crop productivity in northern Ghana (Kudadjie et al., 2004; Ndamani and Watanabe, 2015; Nofou et al., 2017). Given that sorghum is cultivated mainly under rain-fed conditions, the low and erratic rainfall patterns characteristic of this agro-ecological zone (mean annual rainfall of 800 - 950 mm) often exposes the crop to moisture stress leading to poor yields (Zougmoré et al., 2003). The second most important constraint was high cost of farm inputs (agro-chemicals, hired labor, tractors or oxen and seeds). Farmers described this mainly as cost of hiring tractors, oxen or labor for land preparation and maintenance. Farmers reiterated that limited access to ploughing services results in delays in sowing and limits farm sizes. Although the use of tractors and bullocks for land preparation has increased in northern Ghana, the patronage of such services is limited by high cost (Millar et al., 2007; Nin-Pratt and McBride, 2014). The third major constraint was declining soil fertility. Soil nutrient levels in smallholder farms in West Africa are often extremely low because of deforestation; overgrazing and burning of vegetation cover (Henao and Baanante, 2006; Omotayo and Chukwuka, 2009). In general, fertilizer application under sorghum cultivation was low due to farmers' inability to afford fertilizer. This observation has been widely reported in Ghana and has been attributed to extreme poverty rates among farmers in the region (Quaye, 2008; Laube et al., 2012; Abane, 2018). Thus, application of manure and/or household waste to the crop was an alternative for some farmers. Unfortunately, its use is constrained by insufficient quantities, laborious gathering from free-range animals as well as its transportation to farmlands (Tossah, 2000). Thus, a combination of both organic and inorganic fertilizers was a more popular choice among the farmers. Although high cost of fertilizers and limited availability were the most cited constraints in this survey, other studies suggest that farmers' perception of the crops' low response to applied fertilizer is a key impediment to its fertilisation (Kpongor et al., 2015; Kihara et al., 2016).

Based on the constraints outlined by farmers to sorghum production, tolerance to drought was identified as the most-preferred trait. Although farmers recognize the effect of drought on crop production, they often lack the capacity to implement adaptation practices (Ndamani and Watanabe, 2015). This may account for farmers' preference for drought-tolerant types. Preference for earliness in sorghum may be linked to lower risks of crop failure in case of insufficient rain and timely provision of food after the long dry season (Kombiok et al., 2012). As sorghum is widely consumed in northern Ghana (MacCarthy and Vlek, 2012), qualities of the grain such as taste, storage quality, suitability for food and beverage, threshability and market value were all important to farmers in the four communities in the Upper East Region.

Conclusions

In the four communities surveyed in the Upper East Region of Ghana, sorghum is cultivated mainly for food and/or feed. Drought, cost of farm inputs (agro-chemicals, hired labour, tractors or oxen and seeds) and declining soil fertility were ranked as the major constraints to sorghum productivity. Although farmers were cognizant of the effects of declining soil fertility on sorghum yield, majority (more than 60%) did not apply any form of fertilizer (mineral or organic) to improve sorghum yield on their farms. Furthermore, low literacy levels among farmers in the surveyed communities' limits the adoption of improved cultivars, agronomic practices or other technologies that can improve sorghum productivity on their fields.

Low and erratic rainfall in the surveyed communities most likely influenced the traits preferred by sorghum farmers: drought tolerance, high grain yield, earliness, low fertilizer requirement and suitability of grain for food and drink. In order to increase adoption of improved sorghum varieties or technologies by smallholder farmers, breeding programs must focus on developing farmer-preferred traits into locally-adapted varieties.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are grateful to the farmers of the study districts and agricultural extension officers in Talensi-Nabdam and Binduri districts in the Upper East Region for their help in organizing farmers' meetings, data collection as well as village leaders and farmers who participated in the survey. They are grateful to the

Government of Ghana, which through the Ghana Atomic Energy Commission, granted study leave to the first author. This study was funded with grants by the Alliance for a Green Revolution in Africa (AGRA) and the Bill and Melinda Gates Foundation (BMGF) to the West Africa Centre for Crop Improvement (WACCI), University of Ghana, Legon.

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SUPPLEMENTARY MATERIAL

Table 1. Socio-economic and farm characteristics of households in four communities in the Upper East Region of Ghana.

Variable	Characteristics	Communities				Total	Percentage
		Gbane	Gumyoko	Tempelim	Yameriga		
Farming as main occupation	Yes	28	32	20	32	112	91.8
	No	0	0	10	0	10	8.2
	Total	28	32	30	32	122	100.0
Farming experience (years)	≤5	0	8	3	6	17	13.9
	6 to 10	11	8	10	13	42	34.4
	11 to 15	8	6	8	4	26	21.3
	>15	9	10	9	9	37	30.3
	Total	28	32	30	32	122	100.0
Purpose for sorghum cultivation	Household use only	8	23	11	25	67	54.9
	Income only	0	1	0	0	1	0.8
	Both	20	8	19	7	54	44.3
	Total	28	32	30	32	122	100.0
Number of varieties grown	One	6	13	9	8	36	29.5
	Two	12	15	19	16	62	50.8
	Three	10	4	1	6	21	17.2
	Four	0	0	1	2	3	2.5
	Total	28	32	30	32	122	100.0
Total farm size	<1 ha	17	14	5	9	45	36.9
	1 to 2 ha	9	17	22	23	71	58.2
	3 to 4 ha	2	1	3	0	6	4.9
	Total	28	32	30	32	122	100.0
Area allocated to sorghum	< 1 ha	26	29	18	30	103	84.4
	1 to 2 ha	2	3	12	2	19	15.6
	Total	28	32	30	32	122	100.0

Percentages for farming experience ($P = 0.248$) and number of varieties grown ($P = 0.059$) were not significantly different whereas percentages for farming as main occupation, purpose for sorghum cultivation and area allocated to sorghum ($P < 0.05$) was significantly different at 5% level. N= 122

Source: Field Data (2017).

Table 2. Farmers' perceptions of soil fertility and its effect on sorghum production in four communities in the Upper East region of Ghana.

Variable	Characteristics	Communities				Total	Percentage
		Gbane	Gumyoko	Tempelim	Yameriga		
Is sorghum yield improved by fertiliser	Yes	23	21	18	20	82	67.2
	No	5	11	12	12	40	32.8
	Total	28	32	30	32	122	100
Is nutrient-stress recognisable on sorghum	Yes	26	31	27	32	116	95.1
	No	2	1	3	0	6	4.9
	Total	28	32	30	32	122	100
Stunted growth	Yes	22	29	15	25	91	74.6
	No	6	3	15	7	31	25.4
	Total	28	32	30	32	122	100
Reduced yield	Yes	14	8	14	17	53	43.4
	No	14	24	16	15	69	56.6
	Total	28	32	30	32	122	100
Delayed maturity	Yes	10	6	6	5	27	22.1
	No	18	26	24	27	95	77.9
	Total	28	32	30	32	122	100
Poor seedling establishment	Yes	3	3	2	4	12	9.8
	No	25	29	28	28	110	90.2
	Total	28	32	30	32	122	100
Leaf discolourations	Yes	1	0	0	0	1	0.8
	No	27	32	30	32	121	99.2
	Total	28	32	30	32	122	100

Percentages for sorghum yield improved by fertiliser ($P = 0.27$), nutrient-stress recognisable on sorghum ($P = 0.28$), reduced yield ($P = 0.09$), delayed maturity ($P = 0.25$), poor seedling establishment ($P = 0.89$) and leaf discolourations ($P = 0.34$), were not significantly different whereas stunted growth ($P < 0.05$) was significantly different at 5% level. N= 122.
Source: Field data (2017).

Table 3. Farmers' cropping systems and soil management practices in four communities in the Upper East region of Ghana.

Variable	Characteristics	Communities				Total	Percentage
		Gbane	Gumyoko	Tempelim	Yameriga		
Cropping system	Mono-cropping	3	2	0	0	5	4.1
	Mixed cropping	15	21	24	29	89	73.0
	Intercropping	10	9	6	3	28	23.0
	Total	28	32	30	32	122	100.0
Retention of crop residues	Yes	14	15	12	15	56	45.9
	No	14	17	18	17	66	54.1
	Total	28	32	30	32	122	100.0
Shifting cultivation	Yes	10	15	4	2	31	25.4
	No	18	17	26	30	91	74.6
	Total	28	32	30	32	122	100.0
Erosion control	Yes	24	18	12	19	73	59.8
	No	4	14	18	13	49	40.2
	Total	28	32	30	32	122	100.0
Application of fertilizers	Yes	13	20	6	7	46	37.7
	No	15	12	24	25	76	62.3
	Total	28	32	30	32	122	100.0
Type of fertiliser	Organic	6	6	5	3	20	43.5
	Inorganic	4	5	0	2	11	23.9
	Both	3	9	1	2	15	32.6
	Total	13	20	6	7	46	100.0
Cost of fertiliser as a constraint	Yes	22	28	26	24	100	82.0
	No	6	4	4	8	22	18.0
	Total	28	32	30	32	122	100.0
Unavailability of fertiliser as a constraint	Yes	16	18	13	11	58	47.5
	No	12	14	17	21	64	52.5
	Total	28	32	30	32	122	100.0

Percentages for retention of crop residues (P = 0.88), cost of fertilizer (P = 0.49) and unavailability of fertilizer (P = 0.21), were not significantly different whereas percentages for cropping system, shifting cultivation, erosion control, application of fertilizers and type of fertiliser (P < 0.05) was significantly different at 5% level. N= 122.
Source: Field data (2017).