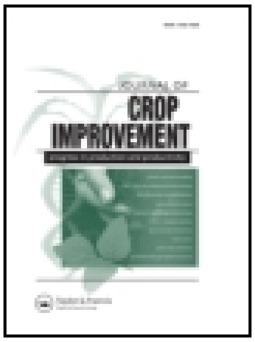

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Farmers' perceived constraints to groundnut production, their variety choice and preferred traits in eastern Ethiopia: implications for drought-tolerance breeding

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important food and cash crop globally. The eastern region of Ethiopia is known for its groundnut production despite the low productivity attributable to diverse biotic and abiotic stresses and socioeconomic constraints. The objective of this study was to assess farmers' perceived production constraints, variety choice, and preferred traits of groundnut in eastern Ethiopia to guide future groundnut variety development and release. Participatory rural appraisal studies were conducted in two major groundnut-producing districts (Babile and Fedis) in eastern Ethiopia. Data were collected through a semi-structured questionnaire, transect walks, and focus group discussions. All respondent farmers widely cultivated local or obsolete, introduced varieties because of a lack of seed of modern groundnut cultivars. Ninety percent of respondents reported drought stress, mainly occurring during the flowering stage, as the leading constraint to groundnut production. Other groundnut production constraints included poor soil fertility (reported by 88% of respondents), lack of access to improved seed (67%), pre-harvest diseases (59.5%), use of low yielding varieties (52.5%), inadequate access to extension services (41.5%), limited access to credit (21.5%), and limited availability of improved varieties (18.5). Farmer-preferred traits included high shelled yield (reported by 27.67% of respondents), early maturity (16.84%), tolerance to drought stress (13.67%), market value (11.17%), good seed quality (10%), adaptability to local growing conditions (5.8%), and resistance to diseases (5.17%). Therefore, the aforementioned production constraints and farmer-preferred traits are key drivers that need to be integrated into groundnut breeding and variety release programs in eastern Ethiopia.

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Arachis hypogaea; participatory rural appraisal; seed system; soil fertility

Introduction

Groundnut or peanut (*Arachis hypogaea* L.; 2n = 4x = 40) is one of the major food and oilseed crops in the world. It is an annual legume crop that is predominantly self-pollinated. Groundnut is a rich source of oil (45–56%), protein (25–30%), carbohydrates (9.5–19.0%), minerals (P, Ca, Mg, and K),

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and vitamins (E, K, and B) (Gulluoglu et al. 2016). It is used in intercropping or crop rotation systems because of its ability to improve soil fertility through atmospheric nitrogen fixation (Ajeigbe et al. 2014). Globally, groundnut is cultivated on 27.66 million ha, with an annual total production of 43.98 million tons (FAOSTAT 2018). The leading groundnut producing countries in the world are India (20.97%), China (16.35%), Nigeria (9.68%), and Sudan (8.37%) (FAOSTAT 2018).

In Ethiopia, groundnut is commonly produced for food, cash income, and animal feed. It is solely grown by smallholder farmers under dryland conditions in the lowland and drought-prone areas of the country. The national mean yield is 1.796 tons/ha, and the total area under groundnut production is 80,841.57 ha (CSA 2018). In the country, groundnut is largely produced in the Oromia Region, constituting 59.2% of the total national production, followed by Benishangul-Gumuz (24.83%), Amhara (7.43%), Harari (3.29%), and Southern Nation and Nationalities People (1.29%) regions (Central Statistical Agency (CSA) 2018). The eastern parts of Ethiopia, encompassing Babile, Fedis, and Gursum, are the leading groundnut-producing zones (Chala et al. 2013; Guchi et al. 2014). Babile and Fedis districts are characterized by low and erratic, poorly distributed rainfall. Further, fungal diseases, such as early leaf spot (*Cercospora arachidicola)*, late leaf spot (*Phaeoisariopsis personata*), and rust (*Puccinia arachidis*) are the major factors limiting groundnut production in these agro-systems. A limited number of introduced groundnut varieties were released for cultivation in the country (MoANRs, 2016). For instance, Babile-1 and Babile-2, with a relatively high pod yield and moderate resistance to leaf spot disease, were released in 2016. However, these varieties are late maturing and low yielding and were not bred for drought tolerance. Therefore, there is a need to develop groundnut varieties with tolerance to abiotic and biotic stresses that are adapted for cultivation under rainfed and drought-affected agro-ecologies.

Understanding farmer- and market-preferred traits and identification and prioritization of their production constraints are crucial to enhance the adoption rate of improved varieties among farmers and their value chains (Nigam et al. 2005; Daudi et al. 2018). Participatory rural appraisal (PRA) is a multidisciplinary tool that is reportedly effective in capturing farmers' perceptions regarding their production constraints, variety choice, and trait preferences (Banla et al. 2018; Amelework et al. 2016). It enables farmers to conduct their own analysis, plan, and take action. PRA studies have been successfully used in Togo and Tanzania to guide crop breeding programs through pinpointing production challenges and market- and farmer-preferred quantitative and qualitative traits of groundnut (Banla et al. 2018; Daudi et al. 2018). Banla et al. (2018) identified, through participatory assessment, leaf spot diseases, rosette, and groundnut bud necrosis as key production constraints to groundnut in Togo. Daudi et al. (2018) reported the major groundnut production constraints to be diseases, insect pests, drought, and non-availability of improved varieties in Tanzania. In Ethiopia, sorghum researchers used PRA tools and indicated the important sorghum production constraints to be moisture stress, insect pests, *Striga*, shortage of agricultural land, poor soil fertility, diseases, and lack of improved varieties possessing farmer-preferred traits (Amelework et al. 2016; Derese et al. 2017; Mengistu et al. 2018). However, in the major groundnut-production belts of eastern Ethiopia, there is no recent study documenting farmers' perceived production constraints, and market- and farmer-preferred traits. Up-to-date and well-described production constraints and prioritized traits of groundnut are key drivers for developing new cultivars. This should enable release of high-performing cultivars possessing suitable product profiles relevant to farmers and their value chains. Therefore, the objective of the current study was to assess farmers' perceived production constraints, variety choice and preferred traits of groundnut to guide breeding of drought-tolerant and high-yielding varieties adapted to the eastern Ethiopia agro-ecologies.

Material and methods

Description of the study areas

The study was carried out in 2018 in two selected districts of eastern Ethiopia, viz., Babile (9° 13′ 09″ N latitude and 42° 19′ 25″ E longitude; 1642 m above sea level) and Fedis (9°07′N Latitude and 42°4′E Longitude; 1702 meters above sea level) (Figure 1). Babile is situated some 35 km away from Harar and about 555 km east of Addis Ababa. The district has a total area of 3,169.06 km^2 (Musa et al. 2016) and a population of 115,229 (CSA 2013). It has a predominantly well-drained sandy loam soil that is ideal for groundnut production. The rainfall distribution of the area is bimodal, with the main rain (locally referred to as *Meher* rain) received during July to October and short rain (locally known as *Belg* rain) during March to May (Anteneh 2017). The mean annual maximum and minimum temperatures are 28.1°C and 15.5°C, respectively, with the total annual rainfall ranging from 507 to 984 mm. Rainfall distribution at Fedis is also bimodal. Fedis has a total area of 1,105.02 km^2 (Musa et al. 2016) and a population of 135,532 (CSA, 2013). The mean annual maximum and minimum temperatures in Fedis are 27.8°C and 8.8°C, respectively, with a total annual rainfall of 659.2 mm (Anteneh 2017).

Sampling procedures

A multi-stage sampling technique was implemented to ensure good representativeness of groundnut grower households in the study areas. In the first stage, the districts of Babile and Fedis were selected from the Oromia region (eastern Hararghe zone) on the basis of their current high levels of groundnut production. In the second stage, four peasant associations (PAs), viz., Ifa, Tula, Bishan Babile and Likale, were selected from Babile and two PAs, viz., Balina Arba and Tuta Balina were selected from Fedis district. Twenty-five farmers were selected in each

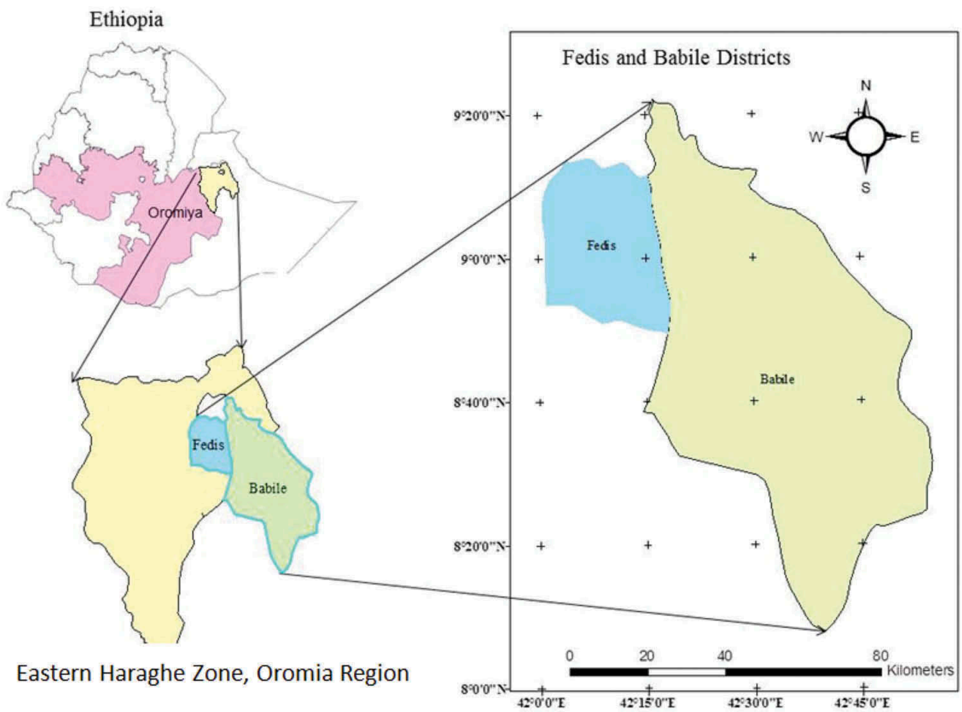

Figure 1. Map of Ethiopia showing the study sites.

peasant association on the basis of their experience in groundnut production. This provided a total of 150 farmers for face-to-face interviews. Furthermore, four focus group discussions (FGDs) were held, two in Babile district and two in Fedis district. Each FGD comprised 12 to 15 participants, representing farmers, district extension experts and developmental agents (DAs). During the FGDs, four DAs and one district extension expert were involved in each district. A checklist was prepared for the FGDs, which focused mainly on groundnut production constraints, uses, groundnut variety preference, and marketing aspects.

Data collection

Data were collected using a semi-structured questionnaire, transect walks, and FGDs. DAs and district extension experts facilitated the FGDs and data collection. Data were collected on demographic descriptors (e.g. gender, education status, and farm size), groundnut farming system, and farmers' knowledge about improved groundnut varieties, constraints to groundnut production, market access, and varietal trait preference.

Data analysis

Both qualitative and quantitative data were coded and analyzed using the Statistical Package for the Social Sciences software version 22 (SPSS 2013). Data were subjected to analysis using the cross-tabulation procedure and descriptive statistics, such as frequencies and percentages, were determined. Further, Chi-square and t-test were conducted to determine statistical significance among the test parameters across districts.

Results and discussion

Socio-economic descriptions of households

The present study highlighted the socio-economic characteristics of groundnut farmers in eastern Ethiopia using the variables gender, age, family size, education level and farm size (Table 1). Out of the 150 farmers interviewed, 16.5% were women and 83.5% men. There was a highly significant difference ($p < 0.01$; $\chi^2 = 12.91$) in gender representation between the two districts. Participation of women in groundnut production was relatively higher in Babile district (29%) compared with Fedis (4%). Among the respondent farmers, 56.5% were between 31 and 50 years of age, indicating that groundnut production was dominated by middle-aged adults. About 35.5% of the respondents were categorized as young adults (Table 1).

There was a significant difference ($p < 0.05$; $\chi^2 = 8.559$) in family size between the two districts (Table 1). In Babile, 57% of the respondents had a family size of 6 to 9 individuals, whereas in Fedis, 52% of respondents had a family size of ≤5 individuals. About 54% of the respondents had 1 to 5 grade education, 4.5% had 6 to 8 grade education, and the rest of the farmers (41.5%) had no formal education (Table 1). Due to the low level of education in the study areas, agricultural service providers need to communicate with the farmers using vernacular language in transmitting the latest technical knowledge or new technologies for their rapid adoption. This concurs with the finds of Daudi et al. (2018) in Tanzania.

Table 1. Demographic and socio-economic information about the farmers in the study areas.

		District							
		Babile†		Fedis‡					
Variable	Category	Frequency	Percent	Frequency	Percent	%mean	*df*	χ^2	*P value*
Gender	Male	71	71	48	96	83.5	1	12.91	0.000
	Female	29	29	2	4	16.5			
Age (year)	18–30	29	29	21	42	35.5	2	4.121	0.127
	31–50	59	59	27	54	56.5			
	>50	12	12	2	4	8			
Family size	≤5	33	33	26	52	42.5	2	8.559	0.014
	6–9	57	57	24	48	52.5			
	≥10	10	10	0	0	5			
Education status	Non-formal	39	39	22	44	41.5	2	5.962	0.051
	1–5	60	60	24	48	54			
	6–8	1	1	4	8	4.5			
Farm land size (ha)	<2	67	67	41	82	74.5	2	4.154	0.125
	2–3.5	31	31	9	18	24.5			
	>3.5	2	2	0	0	1			

†No. of respondents = 100
‡No. of respondents = 50

About 74.5% of respondents owned a farm of <2 ha, whereas 24.5% owned a farm of 2 to 3.5 ha and 1% owned a farm of >3.5 ha. In both districts, groundnut was the third most important food and cash crop in the area after sorghum and maize, the key food security crops in the study areas (Figure 2). During the FGDs, farmers explained that they used a low amount of inorganic fertilizers for cereal crops grown after groundnut, due to its ability to fix valuable nitrogen into the soil.

Roles of farmers in groundnut farming and marketing

The roles of farmers in various groundnut farming and marketing activities are summarized in Table 2. Selection of suitable seed is one of the most important agronomic practices in groundnut production. In the study areas, limited numbers of local or improved varieties were available. Consequently, the respondent farmers did not have options in selecting a suitable variety for production. Farmers practiced mass selection among the available landrace varieties. Results revealed that seed selection was mainly done by men (reported by 68.7% of respondents); participation by women was substantially less (31.3%). During the study period, groundnut production fields were mainly prepared by men (78%); by women (9.3%), by children (1.3%), by men and women (4.7%), by men and children (2%), by women and children (2%), and by men, women and children (2.7%). Hand weeding in groundnut is commonly done twice in a cropping season; 28% of men and 10.7% of women participated in this practice during the study period.

In the present study, women were also involved in key groundnut post-harvest activities, such as shelling (42% of respondents), fumigation of storage facility (82%), and storing (43.3%). Groundnut shelling is the most challenging postharvest operation. This activity was left to women and children in the study areas.

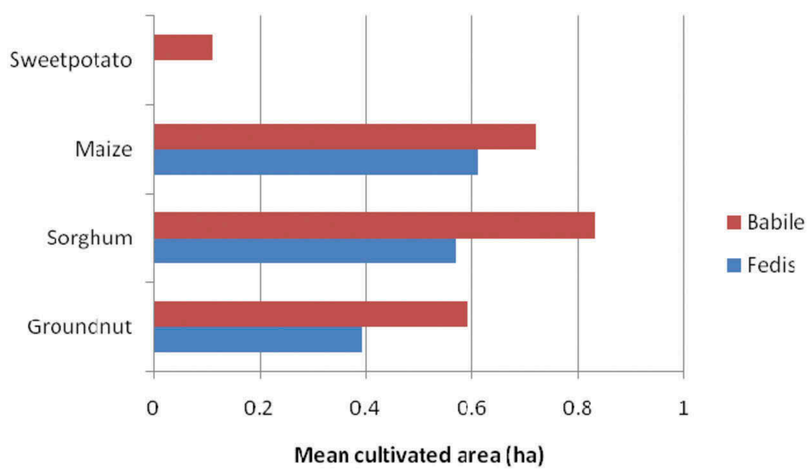

Figure 2. Mean cultivated land (ha) allocated for major food and cash crops grown during the 2017/18 cropping season in the study areas.

Table 2. Roles of farmers in various groundnut farming and marketing activities (%) in both the study areas.

Role	Men	Women	Children	Men and women	Men and children	Women and children	Men, women and children
Seed selection	68.7	31.3	0	0	0	0	0
Land preparation	78.0	9.3	1.3	4.7	2	2	2.7
Planting	52	9.3	0	25.3	0	13.3	0
Fertilizer application	35.3	24.6	2.7	22.7	0	14.7	0
Weeding	28	10.7	0	35.3	2	0	24
Harvesting	22.6	0	0	0.7	0	2	74.7
Shelling	8.0	42	8.7	0	0	18.0	23.3
Fumigation of storage facility	9.3	82.0	0	2	0	6.7	0
Storing	46.0	43.3	0	10.7	0	0	0
Selling	63.3	32.6	2	0.7	0.7	0	0.7

Hand shelling keeps the rate of kernel breakage low compared with mechanical shelling. However, hand shelling is labor-intensive, time-consuming and leads to sore thumb syndrome or painful wounds on fingers when large quantities are handled (Gitau et al. 2013). In this regard, farmers in the study areas desired efficient and affordable shellers.

During groundnut harvesting, men, women, and children were involved in both the study areas. Groundnut pod shelling was done largely by women and children, who accounted for 68.7% of this activity. In the study areas, groundnut is mostly sold unshelled, while a limited amount is sold shelled. Farmers in the study area used shelled groundnut for home consumption, planting, and selling in the local market. Results indicated that groundnut was sold mostly by men (reported by 63.3% of respondents) and women (32.6%). In addition, children (2%), men and women (0.7%), men and children (0.7%), men, women, and children (0.7%) were engaged in groundnut marketing. The main marketplace for groundnuts was Harar city for the Fedis district, which is located about 24 km away from Fedis. Similarly, groundnut farmers in Babile district sold their produce in Babile town and Harar city. During the study period, 100 kg of unshelled groundnut were sold [500 Birr (about 18 USD)]. The low groundnut price in the study areas was attributable to poor market access and a lack of storage and processing facilities or value addition. Often, farmers accessed market information from neighbors and nearby farmers.

Groundnut cropping system and production status

Table 3 contains a summary of perceptions of farmers about their soil type, fertility status, and type of fertilizer used in groundnut production during the 2017/2018 cropping season. It was noted that the predominant soil types in the study areas were sandy, sandy loam, silty clay loam, and clay soils, reported by 35.5, 55%, 8.5%, and 1% of respondents, respectively. There was a highly significant difference ($p < 0.01$; $\chi^2 = 92.487$) in soil type between the two districts. In Babile, 67% of agricultural land was sandy, whereas in Fedis,

Table 3. Farmers' perception about soil type, soil fertility status, fertilizer use, and type in groundnut production in the study areas.

		District							
		Babile		Fedis					
Variable	Category	Frequency	Percent	Frequency	Percent	%mean	*df*	χ^2	*P value*
Soil type	Sandy	67	67	2	4	35.5	3	92.487	0.000
	Silty clay loam	17	17	0	0	8.5			
	Sandy loam	14	14	48	96	55			
	Clay	2	2	0	0	1			
Soil fertility status	Poor	14	14	15	30	22	2	6.023	0.049
	Medium	50	50	23	46	48			
	Good	36	36	12	24	30			
Fertilizer application	Yes	78	78	27	54	66	1	9.143	0.002
	No	22	22	23	46	34			
Fertilizer type	Urea	71	91.03	26	96.3	93.7	1	0.792	0.374
	DAP†	7	8.97	1	3.7	6.3			

†DAP: Diammonium phosphate

majority of the soil type (96%) was sandy loam. The fertility status of groundnut production area could be regarded as good (30%), medium (48%), and poor (22%) based on farmer-perception and field observations through transect walks. Most of the respondents (66%) used inorganic fertilizers for groundnut production. Among the farmers that used inorganic fertilizers, 93.7% used urea and 6.3% used diammonium phosphate (DAP). Farmers who used fertilizers indicated obtaining better pod yield (Figure 3). Depending on soil tests, side application of calcium (Ca) in the form of gypsum @ 250–500 kg/ha during peak flowering stage could enhance unshelled groundnut yield (Prasad, Kakani, and Upadhyaya 2010). Calcium is an important nutrient for groundnut because of its ability to improve pod filling. Therefore, further research is needed to determine the optimum rate of Ca for improving groundnut yield and quality and fertilizer-use efficiency.

Farmers in Babile district used a seed rate of 90 kg/ha, whereas a seed rate of 94 kg/ha was used in Fedis because of frequent dry spells and poor seed germination. The seed rates used by farmers are in agreement with the national recommendation, which is between 60 and 110 kg/ha (Amare et al. 2017). A t-test showed a highly significant difference ($p < 0.01$) in unshelled yields between the two districts. Higher mean unshelled yield was recorded in Babile (1375 kg/ha) compared with Fedis district (1301 kg/ha) (Table 4). However, the yields reported by farmers in both districts were lower than the mean national yield of 1796 kg/ha in the same year (Central Statistical Agency (CSA) 2018). According to the respondent farmers, 94% of groundnut was cultivated as a sole crop and 6% was intercropped with sorghum. Almost all groundnut growers (97%) practiced crop rotation with sorghum; a small proportion used maize (3%) instead of sorghum.

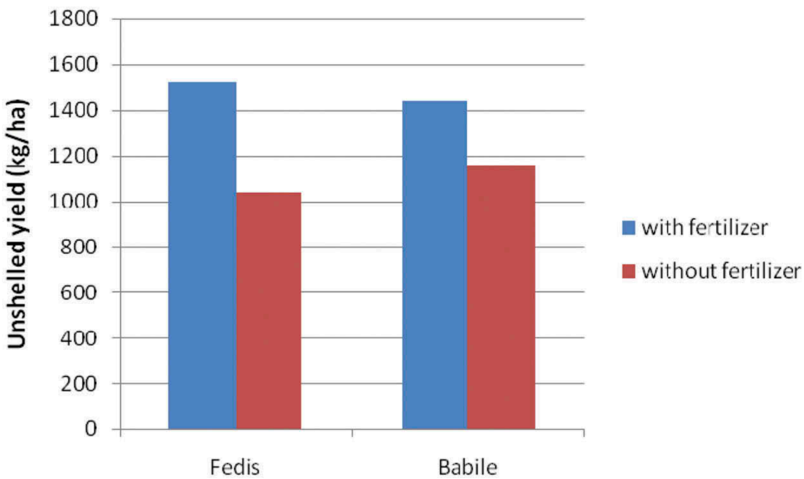

Figure 3. Comparison of unshelled groundnut yields (kg/ha) with and without fertilizer use in 2018 cropping season in Fedis and Babile areas.

Table 4. Comparison of groundnut production management practices and yield potential in the study areas.

	Babile					Fedis				
Management practices and yield	Mean	SD†	Std. Error	*df*	*t*-value	Mean	SD†	Std. Error	*df*	*t*-value
Seed rate (kg/ha)	90.97	14.83	1.48	99	61.355**	94.24	26.28	3.72	49	25.357**
Urea fertilizer (kg/ha)	44.44	24.69	2.93	70	15.168**	61.73	33.73	6.62	25	9.331**
DAP‡ fertilizer (kg/ha)	42.86	12.20	4.61	6	9.295**	50.00	.00[a]	.00	-	-
Yield (kg/ha)	1375.63	344.94	34.49	99	39.881**	1301.20	479.46	67.81	49	19.190**

** Significant at 0.01 probability level
†SD = standard deviation
‡DAP = Diammonium phosphate

Understanding production status of a particular crop in a given area is useful for generating information on how and why the crop is replaced by other crops (i.e. reduced production status) or replacing other crops (increased status). In addition, this issue may also be related to other factors, such as market demand and access, utilization, and production constraints, which may affect the production status of the crop. In the present study, 54% respondents perceived that groundnut production areas had remained constant, 16% indicated that area increased, while the remainder 30% indicated that production area had decreased (Table 5). The perceptions were further explored through FGDs. Fifty-four percent of the respondent reported that groundnut production remained constant because of the increased number of family members and a lack of agricultural land. Under this circumstance, farmers would need to maximize their groundnut productivity through the utilization of inputs like improved varieties and other recommended agronomic practices. Fan et al. (2012) reported an increased total groundnut production in China that was mainly attributable to increased yield per unit area rather than expansion in the

Table 5. Farmers' groundnut cropping system and perceptions on production trends.

		District				
		Babile†		Fedis‡		
Variable	Category	Frequency	Percent	Frequency	Percent	%mean
Cropping system	Sole cropping	94	94	47	94	94
	Intercropping	6	6	2	6	6
Groundnut rotation with	Sorghum	98	98	48	96	97
	Maize	2	2	2	4	3
Groundnut production status	Constant	48	48	30	60	54
	Increasing	26	26	3	6	16
	Decreasing	26	26	17	34	30

†No. of respondents at Babile = 100
‡No. of respondents at Fedis = 50

cultivated area. Idoko and Sabo (2014) suggested that small-scale groundnut producers could have increased their production capacity if technology packages and capital were made available to them. Availability of seeds of resource-use efficient cultivars and adoption of integrated crop management technologies, together with enabling policy environment, can contribute to acceleration and stabilization of groundnut production (Upadhyaya and Dwivedi 2015). Further, farmers reported the main reasons for reduced production area were several biotic and abiotic stress factors, and socioeconomic constraints, such as poor market linkages.

Farmers' awareness of groundnut varieties

Farmers were not aware of improved groundnut varieties in their areas. About 75.5% of the farmers reported a lack of information about improved varieties. Farmers in the study areas continuously cultivated three groundnut varieties, i.e. Oldhale, Sartu, and Roba. About 13% of the respondents used a variety Roba. Roba (ICG 7794) is a large-seeded and late-maturing groundnut variety. It is an introduced variety, released in 1989, for cultivation in high rainfall areas in Ethiopia (MoANRs 2016). During the FGD, a few female farmers in Babile mentioned using Roba to process groundnut butter. About 44.5% of the respondents grew the landrace variety Oldhale, whereas 42.5% of the farmers grew Sartu. Oldhale has an upright growth habit, whereas Sartu has a runner or prostrate growth habit. During FGD, participants explained that Oldhale was used for its good oil quality and grain yield potential. Based on seed size, farmers made selections and found three sub-groups of the variety Oldhale: large, medium, and small. Farmers used large seeds of this variety for production, with the expectation that large seeds provided better shelled yield. Farmers used small and medium size seeds of the same variety for household oil processing.

In the study areas, groundnut is mainly consumed in a roasted form, and large-seeded groundnuts are highly preferred for this purpose. Farmers in the study areas classified Sartu as early maturing and Oldhale as medium maturing varieties; these were highly preferred for their relatively better drought tolerance.

Based on FGD and transect walks, it was noted that groundnut varieties in the study areas were susceptible to root rot and leaf spot diseases.

Chi-square analysis revealed the presence of a significant difference between the two districts for groundnut seed sources ($p < 0.05$; $\chi^2 = 19.95$) (Table 6). Because of low access to seeds of improved varieties, 42% of the farmers used groundnut seed obtained from other farmers, whereas 37.5% used own farm-saved seed. About 7% of farmers used seed received from research centers (National Groundnut Research Program of Haramaya University and Fedis Agricultural Research Centers), 10.5% sourced seed through government extension program and 3% received seed from non-government organizations (NGOs), such as Self Help, the Hararghe Catholic Secretariats (HCS) and Catholic Relief Service (CRS). In the present study areas, there were no private sector or government groundnut seed enterprises. Consequently, farmers could not get access to seeds of improved groundnut varieties. In the study areas, the adoption rate of improved varieties was low (13%). This implies that unless the groundnut seed system in these areas is improved, farmers will continue to use

Table 6. Farmers' awareness about improved groundnut varieties, seed sources, and participation in technology transfer activities (%).

		District							
		Babile		Fedis					
Variable	Category	Frequency	Percent	Frequency	Percent	%mean	*df*	χ^2	*P value*
Seed source	Farmers saved	45	45	15	30	37.5	4	19.95	0.001
	Government Extension	3	3	9	18	10.5			
	NGOs†	2	2	2	4	3			
	Research Centers	14	14	0	0	7			
	Other farmers	36	36	24	48	42			
Information about improved varieties	Yes	19	19	15	30	24.5	1	2.301	0.129
	No	81	81	35	70	75.5			
Variety grown	Roba	22	22	2	4	13	2	39.51	0.000
	Sartu	17	17	34	68	42.5			
	Oldhale	61	61	14	28	44.5			
Participation in technology transfer	Yes	53	53	21	42	47.5	1	1.614	0.204
	No	47	47	29	58	52.5			
Method of technology transfer	On-farm trial activities	16	30.19	4	19.05	24.62	3	7.054	0.07
	Invited to farmers field day	8	15.09	9	42.86	28.98			
	FTC‡	27	50.94	8	38.10	44.52			
	Learning from other farmers	2	3.77	0	0.00	1.89			

†NGOs = non-government organizations
‡FTC = Farmers Training Center

local unimproved varieties. Govindaraj, Kumar, and Basu (2009) reported a 65% yield increase in groundnut because of the adoption of improved varieties. Therefore, sustainable groundnut production and productivity can be ensured through the development of improved varieties and supply of quality seeds to the farmers. Access to quality seed needs to be enhanced by involving all stakeholders, including government institutions, NGOs, farmer cooperatives, and unions.

During the FGD, farmers mentioned that, because of various production constraints, groundnut yields had declined during the past years. For instance, more than 85% of farmers reported a lack of access to improved groundnut varieties. About 47.5% of the respondents participated in training on groundnut technology transfer. Three fourths (74) of farmers were involved in technology transfer, of which 28.98% and 24.62% participated in farmers' field days and on-farm trial activities, respectively (Table 6). In this study, farmer training centers were found to be the best source of information and technology transfer option, followed by attendance at farmers' field days and on-farm trials. Therefore, the linkage between technology provider institutes and extension service providers was encouraging, which needs to be strengthened further. Furthermore, demonstration of improved varieties at farmer training centers has to be sustainably implemented.

Rainfall pattern

In the study areas, groundnut is cultivated only under rainfed conditions, and the crop stand is often prone to drought stress, notably at the flowering stage. Table 7 contains a summary of the frequency of drought stress, susceptible growth stage of groundnut, and farmers' drought-coping mechanism. There was a non-significant difference ($p > 0.05$; $\chi^2 = 5.479$) in frequency of drought stress between the two districts. About 42.5%, 45.5%, and 12% of the respondents mentioned drought occurred in groundnut production once every year, once every 2 years and once every 3 years, respectively. Results showed that 83% of drought stress occurred during the main cropping season (July to October) and 17% during the offseason production (March to May). A large majority of the respondents (80.5%) reported that drought stress occurred during the flowering stage, whereas 12% and 7.5% of the respondents reported drought stress being critical during seedling and pod-filling stages, respectively. Meisner and Karnok (1992) reported 49% and 37% unshelled yield reduction in groundnut because of drought stress during peak flowering and early pod-filling stages, respectively. Girdthai et al. (2010) reported that terminal drought stress or end-of-season drought reduced unshelled yield by 35%. In the study areas, the main rainfall is expected between mid-March and early-April, during which farmers plant groundnut. Delayed rainfall and poor distribution, such as extending up to May, is often associated with drought stress and subsequent crop failures. As a drought-stress-coping mechanism, 48.5% of

Table 7. Farmers' experience regarding drought stress in groundnut production and their coping mechanism.

Variable	Category	District				%mean	*df*	χ^2	*P value*
		Babile†		Fedis‡					
		Frequency	Percent	Frequency	Percent				
Frequency of drought stress	Every 1 year	47	47	19	38	42.5	2	5.479	0.065
	Every 2 years	47	47	22	44	45.5			
	Every 3 years	6	6	9	18	12			
Drought season	*Belg* (march to May)	70	70	48	96	83	1	13.427	0.000
	Meher (July to October)	30	30	2	4	17			
Growth stage affected by drought	Seedling	12	12	6	12	12	2	8.462	0.015
	Flowering	73	73	44	88	80.5			
	Grain feeling	15	15	0	0	7.5			
Copping mechanism of drought	Early maturity variety	47	47	9	18	32.5	2	12.123	0.002
	Drought tolerant variety	16	16	11	22	19			
	Replace with other crop	37	37	30	60	48.5			

†No. of respondents at Babile = 100
‡No. of respondents at Fedis = 50

the farmers replaced groundnut with other food security crops, such as sorghum and maize; 32.5% of the farmers resorted to planting an early-maturing groundnut variety (e.g. variety Sartu), 19% of the respondents grew a relatively drought-tolerant groundnut variety, Oldhale.

Constraints to groundnut production

In the study areas, groundnut production was constrained by various biotic and abiotic stresses (Table 8). There was a nonsignificant difference ($P > 0.05$; $\chi^2 = 16.315$) in production constraints between the two districts. Farmers identified the major groundnut production constraints as follows: drought stress (90% of respondents), poor soil fertility (88%), poor supply of improved seed (67%), pre-harvest diseases (e.g. root rots and leaf spots) (59.5%), low-yielding varieties (52.5%), poor access to extension services (41.5%), poor access to credit (21.5%), and limited availability of improved varieties (18.5%).

Farmers in the study area reported poor soil fertility as the next yield-limiting factor in groundnut production. Anteneh (2017) reported low soil fertility status as one major abiotic constraint to sustainable groundnut production in the same study areas, which is in agreement with the present study. Groundnut diseases, such as root rot and leaf spot, are among the most important biotic factors that

Table 8. Farmer-perceived constraints to groundnut production in eastern Ethiopia (%).

Production constraints	District		mean	df	χ^2	P value
	Babile	Fedis				
Drought stress	88	92	90	15	16.315	0.361
Poor soil fertility	78	98	88			
Poor supply of improved seed	64	70	67			
Pre-harvest diseases	67	52	59.5			
Low yielding varieties	51	54	52.5			
Low access to extension services	37	46	41.5			
Low access to credit	15	28	21.5			
Limited availability of improved varieties	23	14	18.5			
Undesired improved varieties	21	16	18.5			
Post-harvest diseases	10	24	17			
Limited agricultural lands	13	20	16.5			
Lack of appropriate storage facility	10	20	15			
Limited availability of inorganic fertilizers	14	12	13			
High cost of seed	11	14	12.5			
Insect pests	15	8	11.5			
High cost of commercial fertilizers	8	12	10			

limit groundnut production. As a good disease-management practice, farmers grew groundnut in rotation with cereal crops like sorghum (Table 5). But more effective disease control options, such as the use of resistant varieties, ensured sustainable groundnut production. Farmers in the study areas recycled groundnut seed of the same variety year after year. This practice is conducive to disease build up and reduces seed germination percentage, viability, and vigor, which significantly affect the performance of the crop. Extremely low seed replacement rate is one of the hindrances to introducing high-yielding varieties (Singh and Singh 2016). Thus, effective strategies need to be developed to enhance the seed replacement rate of the crop.

Conversely, farmers in Fedis district reported *Orobanche* spp. being noxious weeds. *Orobanche* weeds may cause 5–100% yield loss in oilseed crops, especially in the arid and warmer areas (Habimana, Nduwumuremyi, and Chinama 2014). The same authors reported *Orobanche* germination increased under less fertile soils (e.g. low nitrogen conditions). Thus, improving the soil fertility status can be considered one of the options to control these weeds. Because *Orobanche* control through hand weeding could be laborious, application of chemicals can be effective to reduce the cost of production.

Farmer-preferred traits of groundnut variety

There was a nonsignificant difference ($p > 0.05$; $\chi^2 = 10.891$) in farmer-preferred traits of groundnut variety between the two districts. Farmer-preferred traits were high shelled yield, early maturity, drought tolerance, market value, good seed quality, and best adaptability to local growing conditions, in that order (Table 9). During the FGD, farmers indicated that large seed, uniform seed size, and tan to red kernel color were market-preferred traits, with a price premium. Further,

Table 9. Farmer-preferred traits of a groundnut variety in the study areas.

	District								
	Babile		Fedis						
Trait	Frequency	Percentage	Frequency	Percentage	% mean	Rank	df	χ^2	*P* value
High Yield	74	24.67	46	30.67	27.67	1	9	10.89	0.283
Good Seed quality	38	12.67	11	7.33	10	5			
Early maturity	57	19	22	14.67	16.84	2			
Drought tolerance	38	12.67	22	14.67	13.67	3			
Resistance to field insect pests	8	2.67	3	2	2.34	10			
Resistance to diseases	11	3.66	10	6.67	5.17	7			
Resistance to storage pests	9	3	9	6	4.5	8			
Marketability	39	13	14	9.33	11.17	4			
Best adaptability	17	5.67	9	6	5.84	6			
Good biomass	9	3	4	2.67	2.84	9			

farmers preferred to grow groundnut varieties with upright growth habit rather than runner types because of their being unsuitable for intercropping.

Conclusion

In the present study, farmers identified drought stress, poor soil fertility, poor seed supply systems, pre-harvest diseases (root rot and leaf spot), low yielding varieties, low access to extension services, low access to credit and limited availability of improved varieties as the major groundnut production constraints. Among the identified production constraints, recurrent drought was reported by the majority of the respondents to significantly reduce unshelled groundnut yield across study areas. Farmers cultivated unimproved landraces and few obsolete and late-maturing introduced varieties. The present study found that farmers sought high-yielding and well-adapted modern groundnut varieties for production under drought stress, poor soil fertility, and diseases. Results also indicated a lack of sustainable groundnut seed system in the region. There is a need to strengthen formal, semi-formal, and private seed systems to sustain the supply of new varieties in the region. The study identified the following farmer-preferred traits: high shelled yield, early maturity, drought tolerance, market value, good seed quality, and adaptability to local growing conditions and resistance to diseases. Therefore, groundnut breeding programs should consider and integrate the production constraints and farmer-preferred traits during the development of improved varieties. This would enhance the production and productivity of groundnut in eastern Ethiopia.

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