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Sugarcane production under smallholder farming systems: Farmers preferred traits, constraints and genetic resources

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Abstract: Smallholder sugarcane production sector is under researched and under-developed with limited industrial link and support. The objectives of this study were to assess the current state of sugarcane production, farmers' perceived production constraints and preferred traits, and to collect germplasm grown by smallholder farmers in southern Ethiopia for strategic breeding and conservation. The study was conducted across 16 administrative zones, 28 districts and 56 peasant associations involving 560 smallholder sugarcane growers in southern Ethiopia using a participatory rural appraisal approach. Sugarcane genetic resources were collected through structured sampling. Findings from this study indicated that monocropping was identified as the predominant sugarcane farming system. Respondent farmers prioritized drought tolerance (21%), increased cane yield (20%), early maturity (18%), marketability (17%), and high biomass (14%) as the top preferred traits of sugarcane. Ninety diverse sugarcane landraces were collected from homesteads of smallholder farmers. Findings from this study would serve as baseline information towards sugarcane research and development emphasizing the constraints and preferences of smallholder sugarcane growers in Ethiopia or similar agro-ecologies.

ABOUT THE AUTHORS

Our research team is involved in crop production and plant breeding of food security crops in Africa. The group's mandate is to enhance and empower both small scale and growers with highly productive and locally adapted crop genetic resources. Areas of interest include abiotic and biotic stresses to crop production, productivity, and quality. Major crops of interest include wheat, maize, sorghum, maize, sugarcane, and sweet potatoes both is southern and eastern Africa.

PUBLIC INTEREST STATEMENT

The objectives of this study were to assess the current state of sugarcane production, farmers' perceived production constraints and preferred traits, and to collect germplasm grown by smallholder farmers in southern Ethiopia for strategic breeding and conservation. Findings from this study indicated that monocropping was identified as the predominant sugarcane farming system. Respondent farmers prioritized drought tolerance (21%), increased cane yield (20%), early maturity (18%), marketability (17%), and high biomass (14%) as the top preferred traits of sugarcane. Ninety diverse sugarcane landraces were collected from homesteads of smallholder farmers. Findings from this study would serve as baseline information towards sugarcane research and development emphasizing the constraints and preferences of smallholder sugarcane growers in Ethiopia or similar agro-ecologies. This is the first study to report farmers preferred traits and constraints, and genetic resources of sugarcane under smallholder farming systems in Ethiopia.

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Subjects: Bioscience; Environment & Agriculture; Food Science & Technology

Keywords: landraces; participatory rural appraisal; production systems; smallholder farmers; sugarcane

1. Introduction

Sugarcane is an important crop widely cultivated for multiple purposes by smallholder farmers in sub-Saharan Africa (SSA), including in Ethiopia. Sugarcane cultivation by smallholder subsistence farmers started centuries ago and preceded the commercial sector in Ethiopia (Esayas, 2014). A report by the Central Statistics Agency (CSA) (2013) of Ethiopia showed that 997,240 households grew sugarcane in about 22,388.48 hectares of land. The Southern Nations Nationalities and Peoples' Regional State (SNNPR) is the major sugarcane producing region occupying 52.4% of the total area allocated to sugarcane cultivation in the country (Ethiopian Sugar Corporation (ESC), 2013). However, sugarcane production and productivity under smallholder farming systems are constrained by biotic, abiotic, and socioeconomic factors. Lack of improved varieties with drought tolerance, limited access to credits to acquire inputs and farm and processing equipment and inadequate research and extension support are reported to be important constraints to sugarcane production (Livingston, Schonberger, & Delaney, 2011). Constrains such as erratic rainfall, soil acidity, limited access to credit and rises in production costs have been mentioned to be the major constrains faced by sugarcane growers in other African countries including South Africa and Nigeria (Girei & Giroh, 2012; Singels et al., 2013).

Participatory rural appraisal (PRA) is an interdisciplinary research approach useful to capture farmers' needs, perceptions, constraints, and preferences (De Groote & Bellon, 2000). Agricultural technologies developed through participatory research have a greater chance of adoption (Ashby & Lilja, 2004; Asiedu-Darko, 2014; Ghimire, Wen-chi, & Shrestha, 2015; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015). This approach has been used by government and nongovernmental organizations (NGOs) scientists to asses' local knowledge, sustainability of natural resources, agricultural development, health status, or other socioeconomic issues. It is a priority step in participatory plant breeding, which favors wide adoption of new varieties (Ceccarelli et al., 2001; Rebeka, Shimelis, Laing, Tongoona, & Mandefro, 2014).

Presently, the demand for sugar outstrips its production in Ethiopia. The Government of Ethiopia is currently enhancing the production capacity of old and new sugar estates to meet local demand and for export. The country aims to boost annual sugar production from the current level of 0.3 to 2.25 million tons together with generation of 181 million litres of ethanol. The sugar factories are also expected to contribute about 448 megawatt electric power through co-generation (Ethiopian Sugar Corporation (ESC), 2013). In the country sugar is produced by the state owned factories which own large sugarcane estates to supply cane for processing.

Globally, sugarcane breeders develop better adapted and high yielding varieties to meet the requirements of the sugar industry. Likewise, the sugarcane industry in Ethiopia is initiating a breeding program which is expected to deliver locally bred varieties adapted to the diverse sugarcane growing environments. An initiative by South Africa to establish the South African Sugarcane Research Institute points on the need to breed locally adapted varieties to avoid over-reliance on imported varieties (Zhou, 2013). Consequently, it is vital to broaden the germplasm base for breeding locally adapted varieties. The genetic variability within the local sugarcane germplasm widely grown under smallholder production systems has not been explored.

In SSA, the smallholder sugarcane production sector is under researched and underdeveloped, with limited industrial link and support. The challenges and opportunities of the smallholder

sugarcane growers are not well documented. This sector could contribute to the local sugar industries through co-production and supply of cane to complement the needs of the existing sugar mills. In South Africa there are about 24,000 registered smallholder sugarcane growers producing an estimated amount of 19 m tons of sugarcane per annum and supplying cane for processing South African Sugar Association (SASA) (2016), which could further be enhanced through cooperative throughout production and value chain (Nicolaas Bezuidenhout, Bodhanya, & Brenchley, 2012). In Ethiopia, there is no information on sugarcane production systems, farmers' perceptions on preferred traits and constraints under small-scale sugarcane farming systems. Further, there was limited effort on the collection and characterization of the widely grown local germplasm or landrace sugarcane varieties. These varieties have long agricultural values, adaptation and co-evolution with prevailing pests and diseases across different agro-ecological regions of the country. Hence, the landraces could serve as a rich source of novel genes desired for future sugarcane breeding. Therefore, the objectives of this study were to document the current state of sugarcane production, farmers' perceived production constraints and preferred traits, and to collect germplasm grown by smallholder farmers in southern Ethiopia for effective breeding and conservation. Results of this study may serve as baseline information for variety design and development and enhanced adoption of sugarcane production technology for sustainable production emphasizing the needs and constraints of smallholder growers.

2. Materials and methods

2.1. Description of the study areas

The study was carried out in the SNNPR, located between 4°43′and 8°58′ North and 34°88′-39°14′ East. The region covers the southern and south-western parts of Ethiopia (Southern Nations Nationalities & Peoples' Region (SNNPR), 2014). The region is known for its sugarcane production since time immemorial predominantly by smallholder sugarcane growers (Esayas, 2014). The SNNPR is divided into 13 administrative zones and eight special Weredas. The Weredas are relatively small autonomously functional districts which are not part of a zone. The region has diverse agro-ecological zones including hot arid and semi-arid climate that characterize the southern areas such as the flat plain of Debub Omo Zone. Also, the SNNPR has tropical humid conditions in the north and north western highlands. The arid and semi-arid regions constitute about 57.4% of the SNNPR (http://www.snnprs.gov.et/about.html).

2.2. Sampling procedures

The study was carried out during 2010/2011 across twelve administrative zones and four special Weredas of the SNNPR. Table 1 summarizes the sample structure and size. A multistage cluster sampling method was used conforming to the hierarchical administrative setup of the study sites and to include representative samples. The zones and special Weredas were selected based on long agricultural history and relatively wide areas allocated to sugarcane production. Two districts in each administrative zone were sub-sampled. In turn, from each district two sub-districts (locally referred as "Kebeles") or peasant associations (PAs) were selected, making a total of 48 PAs. Further, two PAs were selected from each special Wereda providing a total of 56 PAs (Table 1). Ten sugarcane farmers were sampled from each selected PA representing various socioeconomic backgrounds in a total of 560 farmers for the study. It was planned to have a gender balance aiming 50% of each gender. However, female farmers were not available for interviews due to various social commitments. The sample consisted of a greater proportion of males (82.14%) than females (17.86%). Zonal agricultural experts and district agricultural development officers assisted during sampling and data collection.

2.3. Sugarcane germplasm collection

Sugarcane germplasm was collected during the 2010/2011 growing season from homesteads, farmers' fields and local markets. Germplasm was collected using a stratified random sampling technique. Figure 1 depicts the collections sites. Two to four districts/Weredas were selected from each zone, from which 2 to 5 sub-districts/Kebeles were selected per district/Wereda. Purposive sampling

Table 1. Zones, districts, sub-districts and number of sugarcane growing smallholder farmers sampled across 16 zones in the SNNPR of Ethiopia

Zones	Districts	Sub-districts (PAs)	Female	Male	Total
Gurage	Absege	Nachakulit	7	3	10
		Jejeba	8	2	10
	Meskan	Meskan	1	9	10
		Enseno	0	10	10
Silttie	Silttie	Balokeriso	1	9	10
		Abzana	0	10	10
	Werabe	01 Kebele	2	8	10
		02 Kebele	2	8	10
Gamogofa	Bonke	GeresseZala	2	8	10
		Tsophi	1	9	10
	Chencha	Kogo	1	9	10
		Gule	0	10	10
Sidama	Boricha	Yloubancho	3	7	10
		AldadaDela	2	8	10
	Wondogenet	ShashaKakalo	1	9	10
		WeshaSoyama	3	7	10
South Omo	Debub Ari	Mester	0	10	10
		Bazet	1	9	10
	Selamago	Aomoronbemo	2	8	10
		Narmashiki	3	7	10
Konso Special Wereda	Konso Special Wereda	GasergeKebele	0	10	10
		BussoKebele	1	9	10
Amaro special Wereda	Amaro special Wereda	Jijolakebele	1	9	10
		Korebiko	2	8	10
Gedeo	Wenago	Deko	2	8	10
		BeleBukisa	1	9	10
	Bule	Geledacho	0	10	10
		Basura	2	8	10
Wolayta	Damotgale	Gacheno	4	6	10
		Buge	3	7	10
	DamotWoyide	Oloba	3	7	10
		Kinido Koyo	2	8	10
Dawro	Loma	Wushay	2	8	10
		GesaChere	1	9	10
	Mareka	Madokuyl	3	7	10
		Batokelbo	1	9	10
KembataTembaro	KachaBira	Mesena	4	6	10
		Wonko	2	8	10
	Timbaro	Gaecha	1	9	10
		Beda	2	8	10
Halabakulito Special Wereda	HalabaKulito Special Wereda	Alemtena	3	7	10
		Bedene	2	8	10

(*Continued*)

Table 1. (*Continued*)

Zones	Districts	Sub-districts (PAs)	Female	Male	Total
Sheka	Masha	Shibo	3	7	10
		Beto	1	9	10
	Yeki	Addisbirhan	3	7	10
		Fide	0	10	10
Kefa	Gimbo	Bonga 01	2	8	10
		Baka	0	10	10
	Cheta	Aja	0	10	10
		Kolla	1	9	10
Bench Majii	MizanTeferi	Hibret	2	8	10
		06 Kebele	1	9	10
	Maji	Haro	2	8	10
		Adikas	0	10	10
Konta Special Wereda	Konta Special Wereda	Cheka Bocha	2	8	10
		GenjiShasho	1	9	10
Total			100	460	560

was used when necessary based on information supplied by key informants on the unique and quality sugarcane types grown in these areas. In the selected sub-districts/Kebeles sugarcane clones were collected following the methods proposed by Hawkes (1980). Each distinct morphotype in a village was randomly sampled.

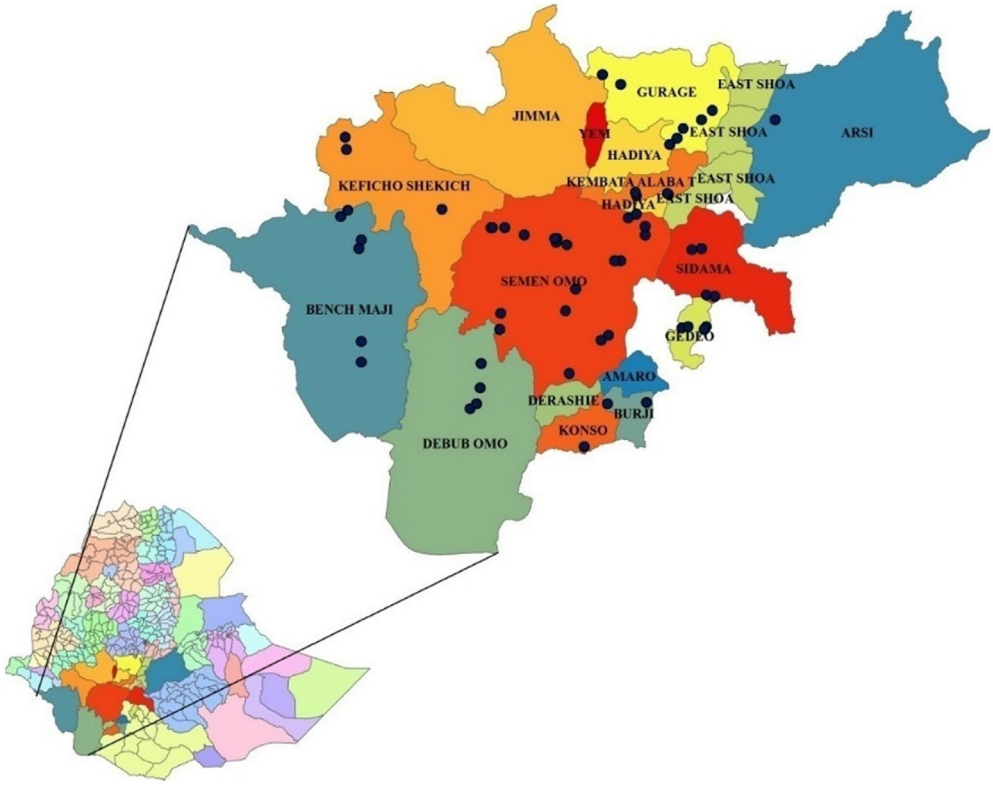

Figure 1. A map of Ethiopia showing sugarcane germplasm collection sites (black circles) in the SNNPR.

2.4. Determination of the physical and chemical properties of soils under sugarcane production

To determine the predominant physical and chemical properties and the fertility status of soils under sugarcane production, samples were collected and analysed across germplasm collection areas. Geo referencing (latitude and longitude) of the study sites were made with a Garmin GPS. In every germplasm sampling area, a composite soil sample was taken between 0–30 and 30–60 cm depths. Soil samples were analysed for organic carbon, total nitrogen (N), soil pH, soil electrical conductivity (EC), available phosphorus (P), and available potassium (K) contents using standard procedures (Yakima 1993). Soil pH was measured potentiometrically using a digital pH meter (Jenway Model-3320, GransmoreGeeen). Soil EC was measured using digital conductivity meter (Jenway Model-4310, GransmoreGeeen). Organic carbon was determined following the wet digestion method described by Walkley and Black (1934). Total N was determined using the Kjeldahal procedure (Yerima, 1993). Available phosphorous was determined using the Olsen method (Olsen & Sommers, 1982), and Bray II method (Bray & Kurtz, 1945) for acidic soils. Available K was measured by flame-photometry using the sodium acetate extractant method at pH 4.8 (Sahlemedhin & Taye, 2000). Soil texture was determined by hydrometer method (Sahlemedhin & Taye, 2000).

2.5. Data collection

2.5.1. Primary data

Primary data was collected using key informant interviews, pair-wise ranking, semi-structured interviews (SSI), focus group discussion (FGD) and direct observation. Key informants included smallholder sugarcane growers, clan leaders and elders, youth, agricultural development agents , Regional and Zonal Agricultural Bureaus, and government administrative officials. Local agriculture extension workers and sub-district managers at the respective localities facilitated the PRA process by mobilizing farmers to participate during FGDs. FGDs were accompanied by SSI. Meetings for the FGD and SSI were held outdoor involving 10 participants each.

During the FGDs, farmers discussed sugarcane farming problems that were common and general in nature. They were also interviewed individually to explore more specific issues, particularly, those that were traditionally sensitive to the farmers. Checklists were developed and questionnaires prepared to collect primary data. Discussions were held with farmer groups and individual key informants to allow the participants to independently raise relevant issues. The objectives and significance of the project were explained and communication procedures established. Farmers were encouraged to use familiar languages to them. A member of the research team most versed with the local language in a particular area, facilitated the group discussions.

The FGDs followed four themes which included cultural practices of sugarcane production, perceived constraints affecting sugarcane production, farmers' preferences for named local sugarcane cultivars, and traits of interest in the cultivars. Amongst other variables, participants were asked to: (1) identify main cropping season and the major crops grown, (2) describe cultural practices of sugarcane production and main production constraints, (3) list sugarcane varieties that they grow using local names, (4) describe the uses of sugarcane and (5) to list and rank their criteria for variety selection. These variables were considered since they could be having an impact on the low sugarcane production and productivity under small holder farming systems in Ethiopia. Information on the sampled sugarcane germplasm were recorded and passport data were collected following the method of Bioversity International (Hawkes, 1983).

2.5.2. Secondary data

Secondary data was collected from the zonal and district agricultural offices. The offices of agriculture in the respective districts and central statics agency (CSA) of Ethiopia were the main sources of the secondary data. Secondary data collected included production system, land use, local benefits and uses, and production challenges faced by smallholder sugarcane farmers in south Ethiopia.

2.5.3. Data analysis

Data from interview questionnaires and FGDs were coded, captured, and summary statistics such as the mean and ranks were computed using the SPSS computer package (SPSS, 2005). Other data describing the germplasm collected and quantitative data from soil parameters were summarized using the same software.

3. Results and discussion

3.1. Importance of sugarcane production and other major crops grown

In the study areas, farmers practiced both crop and livestock production. The farm size per household ranged from 0.04 to 3.42 ha, with a mean of 0.47 ha (SD = 0.31). The major crops grown in the zones and areas allocated to different crops during the study period are summarized in Supplemental Table 1. In the region a wide range of crops are cultivated. The most widely gown crop in the SNNPR is enset (*Ensete ventricosum* (Welw.) Cheesman; Musaceae), a drought tolerant staple food crop grown for multi-purposes. Cereals and pulses dominate the high- and low-altitude areas. Root crops such as sweet potatoes, potatoes, taro and cassava are widely grown especially in mid-altitude areas. According to Central Statistics Agency (CSA) (2011), Sidama Zone constitutes 51.5% of the land area covered by sugarcane followed by Wolayta Zone (9.6%). In Ethiopia, the SNNPR accounts to 52.4% of the total area allocated to sugarcane cultivation by smallholder farmers (Central Statistics Agency (CSA), 2011).

During FGDs, participants mentioned that sugarcane is mainly used for making confectioneries, household consumption (chewing), sell for immediate cash and feeding livestock. In Kembata-Tembaro Zone, sugarcane is used to prepare local beverage called "Karibo"; while in Amaro Zone, the leaves are used for thatching and as firewood in places like the Siltiie Zone. A large quantity of sugarcane is produced in the Wondogenet Wereda of the Sidama Zone where some farmers regularly trade their cane harvests in Addis Ababa, the capital city of Ethiopia.

Table 2. Mean soil physical and chemical properties of sugarcane fields across 16 zones in the SNNPR of Ethiopia

Zones	PH	EC (ds/m)	OC (%)	N (%)	P (ppm)	K (ppm)	Soil texture (%)		
							Sand	Silt	Clay
Gamogofa	8.17	0.327	2.01	0.21	164	1496	16	40	45
Konso Special Wereda	8.32	0.161	0.51	0.17	3.79	283	36	23	41
South Omo	6.41	0.151	2.08	0.217	84.77	642	40	23	38
Silttie	7.43	0.167	1.41	0.148	5.97	348	14	20	67
Gurage	7.35	0.058	1.99	0.154	10.86	426	24	26	50
HalabaKulito Special Wereda	7.67	0.069	1.36	0.102	2.54	511	36	29	36
Sidama	6.64	0.068	1.97	0.146	12.07	404	26	32	42
Gedeo	6.8	0.16	1.8	0.192	32.08	806	9	17	75
Amaro Special Wereda	7.36	0.053	1.09	0.094	19.87	139	42	21	37
Wolayta	7.48	0.074	0.84	0.081	3.86	407	32	42	26
Kembata Tembaro	6.94	0.043	2.26	0.154	5.89	343	21	31	48
Dawro	6.24	0.07	1.8	0.191	9.15	316	8	27	66
Konta Special Wereda	6	0.08	2.34	0.302	122	285	20	35	45
Sheka	6.72	0.223	3.83	0.294	33.01	897	31	23	47
Kefa	5.89	0.079	1.81	0.198	8.6	510	14	31	56
Bench Majii	5.35	0.09	2.52	0.241	18.61	91	20	38	43

During 1989, the Regional Agricultural Bureau attempted to improve and diversify the use of sugarcane juice owing to the extensive sugarcane production and supply. Subsequently, the Rural Technology Expansion Project ("*Memriya*"), in collaboration with FAO, installed a Jaggerry plant in Gacheno Wereda at Boditi for the Buge Kebele farmers and in the Wolayta Zone for women farmers. The extracted juice was used either to prepare local drinks such as "Besso" (barley flour mixed with water and sugar) or "Kinoto" (a non-alcoholic dark beer) or to prepare homemade cakes. The juice had improved shelf life which resulted in considerable reduction of sugarcane wastage. Further, the by-products of juice preparation were used as animal feed or as a firewood in place of wood. However, the project discontinued and the technology was not widely adopted by farmers. The prices of the Jaggerry products were far less than the cane itself. Also the installation and operation costs of the Jaggerry plant was unaffordable to small-scale farmers.

3.2. Physical and chemical properties o sugarcane production fields and farming systems

Table 2 summarizes the soil physical and chemical properties observed in the surveyed sugarcane production fields. The soil texture ranged from clay, clay loam to sandy clay loam (Table 2) and the pH was slightly acidic except some areas showing slight alkalinity. The organic carbon content of the soils was low (< 4%) possibly due to monocropping of sugarcane over the years (Esayas, 2014). Farmers use green leaves from sugarcane plants as livestock feed since they are rich in crude fiber and solid carbohydrates (Mahala, Mokhtar, Amasiab, & Attaelmnan, 2013). The total soil N content was low (0.1–0.2%) reflecting frequent mono-cropping since sugarcane is a heavy feeder of N (Glyn, 2004), requiring supplemental N for sustainable production. Overall, the study areas had high levels of soil P except some localities where the level of P was below 6 ppm where the soil phosphorus could have been subject to long periods of P adsorption by the soil and extraction by the crop whose residues were not recycled into the soil (Balemi & Negisho, 2012). Available K was sufficient for sugarcane production and the K content was relatively high, i.e., above the minimum (> 35 ppm) required for sugarcane production.

Sugarcane farming practices are similar in the region, except limited variations between few zones. Generally, hand hoes, a spade like hoes are used for soil preparation, while in few cases draft animal power is used. The land is normally ploughed 2–3 times followed by planting seed-canes along weed-free furrows. The spacing between furrows varies from place to place even within the same zone or Wereda. Seed-canes or setts harvested from the top parts of the cane stalk consisting of 2–4 buds are used for planting. One to four setts are planted parallel to each other, slanting at approximately 45° which is a common practice (Verheye, 2010). In some areas the top parts of the setts are planted above ground, while in others are buried below the ground. In the region sugarcane fields are cultivated at least three times depending on the occurrence and level of weed infestation.

In some zones sugarcane is planted in swampy areas and on stream beds, which are marginal for cultivation of other crops. Typically, sugarcane production in the region is practiced under rain-fed condition. However, supplementary irrigation from local streams and water wells is provided 1–5 times.

Interestingly, in Konso Special Wereda farmers have been channeling irrigation water using carved woods from terraced hills of the Konso areas for sugarcane cultivation. Terraces were prepared for conservation agriculture and excess water from these structures was discharged and collected. Water reservoirs situated in or near communal and protected forests were built and used for sugarcane farming as well as for other social and cultural purposes.

Respondent farmers used compost or manure to fertilize cane fields in most surveyed zones and Weredas, which have an advantage over inorganic fertilisers of improving soil physical and biological properties together with the soil nutrient status (Diacono & Montemurro, 2010). Compost was applied once or twice during the growing period. In some places, dried and senesced sugarcane leaves

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Table 3. Constraints to sugarcane production and their relative importance (%) across 16 zones of the SNNPR of Ethiopia

	Zones[a]																	
Constraints	**Gur**	**Silt**	**Gfo**	**Sdm**	**Som**	**Kon**	**Ama**	**Ged**	**Wol**	**Daw**	**Kta**	**Hkl**	**Shk**	**Kfa**	**Bmj**	**Kot**	**Mean**	**Rank**
Moisture stress	19.7	18.1	16.5	20.1	20.5	19.1	15.2	17.7	19.1	12.3	18.5	17.5	15.8	15.5	16.6	13.7	17.2	1
Poor soil fertility	17.2	16.7	17.2	16.5	15.2	15.2	14.5	12.6	16.2	12.5	15.5	15.6	12.5	15.8	17.7	16.5	15.5	2
High cost of inorganic fertilizers	12.7	14.2	12	14.5	13.3	12.5	14	11.1	15.3	11.5	13.3	14.5	10.6	14.5	14.2	14.6	13.3	5
Lack of improved variety	8.8	10	9.8	9.6	7.5	13.5	15.6	11.5	10	14.3	8.8	10.2	11.5	11.6	10.5	9.6	10.8	7
Weak extension services	9.8	7.1	11.1	9.2	8.7	14	12.7	13.6	13.2	10.1	12.5	11.1	14.5	12.2	11.3	12.4	11.5	6
Diseases and pests	6.3	5.3	4.3	4.2	4.8	3.2	0	3.2	1.5	5.6	3.7	4.3	5.6	6.3	2.1	3.5	4.0	8
Shortage of land	10.8	13.6	13.5	13.6	14.5	14.1	14.5	13.5	14.2	17.1	13.5	13.5	11.8	10.5	14.4	16.8	13.7	4
Low and instable price	14.7	15	15.6	12.3	15.5	8.4	13.5	16.8	10.5	16.6	14.2	13.3	17.7	13.6	13.2	12.9	14.0	3

[a]Gur = Gurage; Sil = Silte; Gfo = GamoGofa; Sdm = Sidama; Som = South Omo; Kon = Konso Special Wereda; Ama = Amaro Special Wereda; Ged = Gedeo; Wol = Wolayta; Daw = Dawro; Kta = Kembata Tembaro; Hkl = Halabakulito Special Wereda; Shk = Sheka; Kfa = Kefa; Bmj = Bench Maji; Kot = Konta Special Wereda.

were left on the ground to decompose which was later mixed with the soil during cultivation. Some interviewed farmers in Gurage, Sidama and Wolayta Zones used inorganic fertilizers, but the amount and time of application was irregular. Only few farmers in Wondogenet and Shebedino areas in Sidama Zone followed controlled application of inorganic fertilizers. In these areas farmers applied diammonium phosphate at the rate of 250 kg/ha during planting, while Urea (46.4% N) at 250 kg/ha was split applied, half during planting and the rest about four months after planting. Generally, sugarcane is planted during the rainy season (April–July), and harvested at cane maturity (Supplemental Table 2). The number of saleable stalks harvested from plant cane or ratoon showed variability across the study zones (Supplemental Table 2). Sugarcane is mainly cultivated as a sole crop but it is sometimes intercropped with some vegetable and root crops such as cabbage, sweet potato and ginger. Generally smallholder sugarcane farmers in the study areas are not following recommended sugarcane cultivation practices in contrast to some districts in India where more than 60% of the farmers are reported to be adopting recommended technologies (Surat, 2009).

3.3. Major constraints to sugarcane production

The major challenges to sugarcane production in the study zones are summarized in Table 3. The leading sugarcane production and marketing constraints identified by respondent farmers included drought stress, low soil fertility, fluctuating prices, shortage of land, high cost of inorganic fertilizers, poor extension services, lack of improved varieties and pests and diseases. Drought stress has become a continued phenomenon in many parts of the region, limiting sugarcane production and productivity. Reduced and poor distribution of rainfall associated with climate change is heavily impacting on dryland agricultural crop production and productivity in many parts of the world, including East Africa, calling for innovations with regard to germplasm development (Mwadzingeni, Shimelis, Dube, Laing, & Tsilo, 2016; Singels et al., 2013). In East Africa almost 96% of the crop production is rainfed, hence, crops are susceptible to frequent droughts (Hellmuth, Moorhead, Thomson, & Williams, 2007).

Low soil fertility attributed to monocropping was identified as the second most important constraint by 15.5% of the respondent farmers across the study zones (Table 3). Wortmann et al. (2006) reported low soil fertility as one of the important yield reducing factors in east Africa due to monocropping and limited use of fertilizers. Although organic fertilizers such as compost and manure could help improve the soil physical and chemical properties (Diacono & Montemurro, 2010), the bulk required per unit area and limited availability to farmers curtail its large-scale application. Replenishment efforts from compost to manure were insufficient to retain productivity of the soils. In Ethiopia, unavailability, high cost and poor distribution of inorganic fertilizers were common problems for sugarcane production because of the bias towards the main food crops.

Fourteen percent of interviewed farmers indicated that unpredictable sugarcane price was the major marketing problem (Table 3). In seasons of bumper harvests, farm prices are considerably low. In the present study, the major market outlet for sugarcane were local markets as indicated by 97% of the respondent farmers. Only a small proportion of farmers (< 3%) sold their products to other markets in the cities or through the middlemen. The market challenges are worsened by lack of alterative market outlets, inadequate value addition mechanisms and limited processing facilities to prepare juice or other products. Therefore, there is a need to establish small and medium sugarcane enterprises and processing plants. Further, high transport costs affect sugarcane marketing. The challenges faced by local growers seem to be similar to those faced in other countries in the African continent including Nigeria and South Africa (Girei & Giroh, 2012; Singels et al., 2013). Sugarcane out growers scheme of the Wonji sugar estate in Ethiopia is currently enabling small-scale farmers to supply good harvests of sugarcane to sugar mills. The industry also supports the farmers in the management of the crop through skill transfer. In Zambia, smallholder sugarcane farmers were organized under the out growers scheme of the sugar industry. These farmers achieved high returns on investment in sugarcane production (World Bank, 2009). The sugar industries should provide extension services, training, and organization support to smallholder sugarcane growers in pursuit of developing this sector in SSA. Smallholder and subsistent farmers in east Africa have

limited and inefficient marketing strategies and facilities as well as storage facilities. Large quantities of agricultural produce perish before they are marketed, since smallholder farmers lack the technology for timely value addition and preservation (Kamara, van Koppen, & Magingxa, 2002). Poor road system and networks is still a serious constraint to smallholder sugarcane farming, leaving some famers to depend on inefficient forms of transportation including use of animals drawn carts (AfDB, 2009).

Shortage of land is another major constraint to sugarcane production in the SNNPR. Land shortages in the highlands (> 1500 meters above sea level), forced farmers to intensively cultivate unsuitable lands and steep slopes. This has exacerbated deforestation and land degradation in the region. The uncertainties regarding land tenure and the inadequate access to land have been a critical challenge to smallholder farming in east Africa. Furthermore, the available land in the region is overly subdivided into small and uneconomic units, with farm sizes range from 0.5 to 2.5 ha. In Kenya, for example, mean farm sizes for the top and bottom land quartiles were 6.69 and 0.58 hectares, respectively, including rented land (Jayne, Mather, & Mghenyi, 2006). According to Kimaru and Jama (2005), another challenge threatening agricultural productivity in east Africa sustained is land degradation manifested through soil erosion and loss of fertility.

Respondent farmers described poor extension service and lack of credit facilities to buy inputs as important constraints to sugarcane production. In Ethiopia, research support and access to credit services are prioritized to main food crops. To mitigate the problem of marketing and enhance economic gains, the value chain of the sugarcane industry should incorporate small-scale growers. This will empower smallholder sugarcane farmers to derive high level of monetary and nonmonetary benefits. Gininda, Antwi, and Oladele (2014) reported that in South Africa, the main constraints faced by smallholder sugarcane farmers are drought stress, land scarcity, low prices, access to formal markets, diseases, limited irrigation water, low level of education, lack of inputs, and high input cost, among others.

Table 4. The most important farmers-preferred traits of sugarcane varieties ranked by sampled farmers of 16 zones in the SNNPR of Ethiopia

	Zones[a]																	
Preference trait	**Gur**	**Silt**	**Gfo**	**Sdm**	**Som**	**Kon**	**Ama**	**Ged**	**Wol**	**Daw**	**Kta**	**Hkl**	**Shk**	**Kfa**	**Bmj**	**Kot**	**Mean**	**Overall Rank**
Early maturity	3.75	3.00	3.50	4.25	3.75	4.00	3.50	4.25	3.75	3.00	3.75	4.25	4.00	4.50	3.75	4.00	3.81	3
High cane and juice yields	4.00	3.25	4.25	4.75	4.75	4.50	4.00	4.75	4.00	4.00	3.75	4.25	4.50	4.75	4.00	4.25	4.23	2
Marketability	4.00	3.00	4.00	3.75	3.50	3.75	3.00	3.50	3.50	3.50	3.00	3.50	3.25	3.75	3.25	3.75	3.50	4
High biomass production	3.75	2.50	3.00	3.50	2.75	3.50	2.75	3.00	3.50	2.75	2.75	3.00	2.50	2.75	3.00	3.25	3.02	5
Drought tolerance	5.00	4.75	5.00	3.50	5.00	5.00	4.75	3.25	5.00	3.50	5.00	4.75	3.25	3.50	4.50	3.00	4.30	1
Diseases and pests resistance/ tolerance	2.25	1.50	2.50	2.50	1.75	2.00	1.50	2.00	2.50	1.50	2.75	1.75	2.25	2.00	1.50	1.75	2.00	6

Note: Rank: 1 = least preferred, 6 = most preferred.

[a]Gur = Gurage; Sil = Silte; Gfo = GamoGofa; Sdm = Sidama; Som = South Omo; Kon = Konso Special Wereda; Ama = Amaro Special Wereda; Ged = Gedeo; Wol = Wolayta; Daw = Dawro; Kta = Kembata-Tembaro; Hkl = Halabakulito Special Wereda; Shk = Sheka; Kfa = Kefa; Bmj = Bench Maji; Kot = Konta Special Wereda.

3.4. Farmers-preferred traits of sugarcane

The mean ranks of traits of sugarcane cultivars according to farmers' preferences are presented in Table 4. Farmers' preferred traits included drought tolerance, high cane and juice yields, early maturity, marketability, high biomass yield, as well as pest and disease resistance. In most surveyed zones drought tolerance was the most important criterion used in selection of sugarcane varieties. Farmers expressed the recurrence of drought and erratic rainfall conductions.

Recurrent drought impacts smallholder agriculture in east Africa (Salami, Kamara, & Brixiova, 2010; Wortmann et al., 2006). Sugarcane is a long season crop and requires reliable sources of moisture especially during critical growth stages (Ham, Mcguire, & Kingston, 2000). In the relatively wet areas of the SNNPR such as Kefa, Sheka, Sidama and Gedeo Zones; cane yield, juice quality and drought tolerance were the most preferred traits. High yield, which is determined by the number of sellable stalks with good amount of juice, was among the most preferred traits and ranked second after drought tolerance. Farmers responded that cane yield and high number of tillers per plant that can grow to synchronized full maturity were important traits. Additionally, early maturity was ranked as the third most important trait. Most farmers explained that early maturing varieties had good potential for drought escape. Farmers explained that they would market early maturing varieties before their competitors. Across the study zones, smallholder sugarcane farmers ranked sweetness, quantity of cane juice, easiness of chewing (less fiber), good eye appeal (e.g. brown rind color), and softness of the rind for ease of peel among the key traits that increased marketability. Further, high biomass yield which is also influenced by the tillering ability of the variety, number and size of the leaves, and long stalk height were regarded as the high ranking traits. During the survey no major diseases and pests were reported. However, in some zones termites and stalk borers were most prevalent and farmers enquired for resistant sugarcane varieties (Supplemental Table 2).

Farmers and breeders partnership is of paramount importance to develop sugarcane varieties that meets farmers' needs and interests. It is emphasized that farmer participation in breeding of crop varieties for low-resource farmers is important for variety adoption and commercialization in the value chains (Asiedu-Darko, 2014; Ghimire et al., 2015; Gyawali et al., 2007; Meijer et al., 2015; Mekbib, 2006; Nkongolo, Chinthu, Malusi, & Vokhiwa, 2008).

3.5. Sugarcane varieties grown by smallholder farmers

In Ethiopia the history of sugarcane cultivation by smallholder farmers preceded that of commercial cultivation. As documented in the history of a monastery in Northern Ethiopia, sugarcane has been grown in the country since the 16th century (Esayas, 2014). In this study, local sugarcane germplasm exploration and collection were conducted in the SNNPR. A total of 90 local sugarcane genotypes were collected during 2010/2011 and passport data of the genotypes is presented in Supplemental Table 3. The collected germplasm were planted at Wondogenet Agricultural Research Center. The clones have been monitored during the 2011/12 season for symptoms of major diseases and insects. These clones were transferred to commercial sugarcane plantation estates at Wonji and Metehara for further selection and maintenance. No major diseases and insect pests were detected in all the germplasm collected. Most of the sampled germplasm had acceptable levels of juice refractometer readings (expressed in degree brix) relative to the history of the ages of the samples (Supplemental Table 3).

The genotypes collected from the study zones were recorded by their local names. Farmers mentioned a broad range of sugarcane landraces that had been grown in the areas and maintained for generations. Some of the landraces were commonly recognized by most farmers within and across zones, whereas some were rare varieties known only by few farmers. The large number of landraces observed during the current study attests the existence of diverse genetic resources of sugarcane in the SNNPR. The diversity could have evolved presumably due to diverse climatic conditions, low input management systems, high pests and disease pressure, and continuous selection by farmers.

Smallholder farmers face with diverse environment stresses and have multiple production objectives that affect selection of genotypes (Nkongolo et al., 2008). There were no formally released improved sugarcane varieties grown by farmers in the study zones. Some of the known varieties grown by the farmers were informally introduced by seasonal workers employed at Wonji and Metehara sugar estates. These varieties were renamed by the farmers and referred to bear to local names or named after country of origin of the variety. For instance, the variety "Moris" originated from Mauritius by the sugar estates. The variety referred as "Bshe" or "Bishoftu" by the farmers, phenotypically resembled the popular commercial variety "B52298" known for its high cane and sugar yields. Some of informally introduced sugarcane varieties are widely grown by smallholder farmers in the study zones. The sugar industry in Ethiopia is currently establishing sugarcane breeding program. Therefore, collection and efficient characterization of germplasm is a pre-requisite to strengthen the breeding program.

4. Conclusions

Sugarcane production, farmers' perceived production constraints and preferred traits of small-scale sugarcane growers of the southern Ethiopia were assessed using a PRA approach. Further, 90 genetically diverse sugarcane germplasm grown by smallholder farmers were collected for breeding and conservation. Sugarcane production under the smallholder systems is challenged by a number of constraints across the value chain that limits the productivity and income of growers. Main sugarcane production constraints included drought stress, declining soil fertility, limited access to market, land shortage, lack of inorganic fertilizers, and other production inputs, and limited extension service. Participant farmers prioritized drought tolerance (21%), increased cane yield (20%), early maturity (18%), marketability (17%), and high biomass (14%) as the top preferred traits of sugarcane. Findings from this study would serve as baseline information towards sugarcane research and development emphasizing the constraints and preferences of smallholder sugarcane growers in Ethiopia or similar agro-ecologies. This is the first study to report farmers preferred traits and constraints, and genetic resources of sugarcane under smallholder farming systems in Ethiopia. The sugarcane landraces collected though the study are valuable genetic resources for sugarcane breeding and conservation.

Supplementary material
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References

AfDB. (2009). *AFDB/IFAD Joint Evaluation of their agricultural operations and policies in Africa*. Draft Report. Rome: African Development Bank.
Ashby, J. A., & Lilja, N. (2004, Sept 26–Oct 1). *Participatory research does it work? Evidence from participatory plant breeding*. Proceedings of the 4th international crop science congress, Brisbane, Australia.
Asiedu-Darko, E. A. (2014). Farmers' perception on agricultural technologies a case of some improved crop varieties in Ghana. *Agriculture, Forestry and Fisheries, 3*, 13–16. http://dx.doi.org/10.11648/j.aff.20140301.13
Balemi, T., & Negisho, K. (2012). Management of soil phosphorus and plant adaptation mechanisms to phosphorus stress for sustainable crop production: A review. *Journal of soil science and plant nutrition, 12*, 547–562.
Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science, 59*, 39–46. http://dx.doi.org/10.1097/00010694-194501000-00006
Ceccarelli, S., Grando, S., Bailey, E., Amri, A., El-Felah, M., Nassif, F., ... Yahyaoui, A. (2001). Farmer participation in barley

breeding in Syria, Morocco and Tunisia. *Euphytica, 122*, 521–536. http://dx.doi.org/10.1023/A:1017570702689

Central Statistics Agency (CSA). (2011). *Agricultural sample survey: Report on land utilization of private peasant holdings*. Ethiopia: Statistical Bulletin.

Central Statistics Agency (CSA). (2013). *Agricultural sample survey: Area and production: private peasant holdings*. Ethiopia: Statistical Bulletin.

De Groote, H., & Bellon, M. (2000, November 9–11). *Farmers' participatory research: Application for breeders.* Paper presented at a workshop "PRA for IRMA", Kenya.

Diacono, M., & Montemurro, F. (2010). Long-term effects of organic amendments on soil fertility. A review. *Agronomy for Sustainable Development, 30*, 401–422. http://dx.doi.org/10.1051/agro/2009040

Esayas, T. (2014). *Exploration and collection, characterization, genetic diversity analysis and association of traits for yield and yield components of sugarcane (Saccharum spp.) in Ethiopia* (Ph.D. Dissertation). Haramaya University, Ethiopia.

Ethiopia economy profile. (2013). *CIA World Fact book.* Retrieved 2013, December 09 from http://www.indexmundi.com/ethiopia/economy_profile.html

Ethiopian Sugar Corporation (ESC). (2013). Sugar Corporation and Ethiopian Sugar Industry Profile. Retrieved March 12, 2016, from http://www.etsugar.gov.et/index.php/en/

Ghimire, R. G., Wen-chi, H. U., & Shrestha, R. B. (2015). Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal. *Rice Science, 22*, 35–43. http://dx.doi.org/10.1016/j.rsci.2015.05.006

Gininda, P. S., Antwi, M. A., & Oladele, O. I. (2014). Smallholder sugarcane farmers' perception of the effect of micro agricultural finance institution of South Africa on livelihood outcomes in Nkomazi local municipality, Mpumalanga Province. *Mediterranean Journal of Social Sciences, 5*, 2039–2117.

Girei, A., & Giroh, D. (2012). Analysis of the factors affecting sugarcane (Saccharum officinarum) production under the out growers scheme in Numan Local Government Area Adamawa State, Nigeria. Advances in agriculture, sciences and engineering research. *Journal of Education and Practice, 3*, 195–200.

Glyn, J. (2004). *Sugarcane*. Blackwell Science Ltd, Blackwell Publishing Company: UK.

Gyawali, S., Sunwar, S., Subedi, M., Tripathi, M., Joshi, K. D., & Witcombe, J. R. (2007). Collaborative breeding with farmers can be effective. *Field Crops Research, 101*, 88–95. http://dx.doi.org/10.1016/j.fcr.2006.09.013

Ham, G., Mcguire, P., & Kingston, G. (2000). Irrigation of sugarcane. In M. Hogarth & P. Allsopp (Eds.), *Manual of cane growing* (pp. 369–377). Australia: Bureau of Sugar Experiment Stations.

Hawkes, J. G. (1980). *Crop genetic resources field collection manual, International Board for Plant Genetic Resources (IBPGR) and European Association for Research on Plant Breeding (EUCARPIA)*(p. 38). Netherlands: Druk Co PUDOC.

Hawkes, J. G. (1983). *The diversity of crop plants*(p. 184). London: Harvard Univ. Press. http://dx.doi.org/10.4159/harvard.9780674183551

Hellmuth, M. E., Moorhead, A., Thomson, M. C., & Williams, J. (Eds.). (2007). *Climate risk management in Africa: Learning from practice*. New York, NY: International Research Institute for Climate and Society (IRI), Columbia University.

Jayne, T. S., & Mather, D., & Mghenyi, E. (2006). Smallholder farming under increasingly difficult circumstances: Policy and public investment priorities for Africa". *International Development Working Papers 86*. East Lansing, Mi: Michigan State University, Department of Agricultural Economics.

Kamara, A. B., van Koppen, B., & Magingxa, L. (2002). Economic viability of small-scale irrigation systems in the context of state withdrawal: The Arabie scheme in the Northern Province of South Africa. *Physics and Chemistry of the Earth, Parts A/B/C, 27*, 815–823. http://dx.doi.org/10.1016/S1474-7065(02)00070-0

Kimaru, G., & Jama, B. (2005). Improving land management in Eastern and Southern Africa: A review of practices and policies, *ICRAF Working Paper No. 18*. Kenya: World Agroforestry Centre.

Livingston, G., Schonberger, S., & Delaney, S. (2011, January 24–25). *Sub-Saharan Africa: The state of smallholders in agriculture.* Rome; Paper presented at the IFAD Conference on New Directions for Smallholder Agriculture.

Mahala, A., Mokhtar, A., Amasiab, E., & Attaelmnan, B. (2013). Sugarcane tops as animal feed. *International Research Journal of Agricultural Science and Soil Science, 3*, 147–151.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability, 13*, 40–54. http://dx.doi.org/10.1080/14735903.2014.912493

Mekbib, F. (2006). Farmer and formal breeding of sorghum (*Sorghum bicolor* (L.) Moench) and the implications for integrated plant breeding. *Euphytica, 152*, 163–176. http://dx.doi.org/10.1007/s10681-006-9191-7

Mwadzingeni, L., Shimelis, H., Dube, E., Laing, M. D., & Tsilo, T. J. (2016). Breeding wheat for drought tolerance: Progress and technologies. *Journal of Integrative Agriculture, 15*, 935–943. http://dx.doi.org/10.1016/S2095-3119(15)61102-9

Nicolaas Bezuidenhout, C. S., Bodhanya, S., & Brenchley, L. (2012). An analysis of collaboration in a sugarcane production and processing supply chain. *British Food Journal, 114*, 880–895. http://dx.doi.org/10.1108/00070701211234390

Nkongolo, K. K., Chinthu, L., Malusi, M., & Vokhiwa, Z. (2008). Participatory variety selection and characterization of sorghum (*Sorghum bicolour* (L.) Moench) elite accessions from Malawian gene pool using farmer and breeder knowledge. *African Journal of Agricultural Research, 3*, 273–283.

Olsen, S. R., & Sommers, L. E. (1982). Phosphorus. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of soil analysis, part 2. Agronomy Monograph*(pp. 403–430). Madison, WI: *ASA and SSSA*.

Rebeka, G., Shimelis, H., Laing, M. D., Tongoona, P., & Mandefro, N. (2014). A diagnostic appraisal of the sorghum farming system and breeding priorities in *Striga* infested agro-ecologies of Ethiopia. *Agriculture Systems, 123*, 54–61.

Sahlemedhin, S., & Taye, B. (2000). *Procedures for soil and plant analysis, National Soil Research Center*. Ethiopian Agricultural Research Organization. Technical paper no: 74, Ethiopia.

Salami, A., Kamara, A. B., & Brixiova, Z. (2010). *Smallholder agriculture in East Africa: Trends, constraints and opportunities.* Working Papers Series N° 105 African Development Bank, Tunisia.

Singels, A., Schoeman, J., Leslie, G., Mcfarlane, S., Sithole, P., & Miles, N. (2013, August 6–8). *"Review of South African sugarcane production in the 2012/2013 season from an agricultural perspective"*(pp. 1-23). In 86th Annual Congress of the South African Sugar Technologists' Association (SASTA 2013), South Africa.

South African Sugar Association (SASA). (2016). Retrieved 2016, January from http://www.sasa.org.za/HomePage1.aspx

Southern Nations Nationalities and Peoples' Region (SNNPR). (2014). *Regional profile.* Retrieved 2014, June from http://www.snnprs.gov.et/about.html

SPSS. (2005). SPSS, *Fifteenth ed. users guide.* Chicago.

Surat, S. (2009). *Adoption gaps and constraints analysis of sugarcane cultivation in Bulandshahr District of Uttar Pradesh*(PhD Dissertation). C.C.S. University, India.
Verheye, W. (2010). Growth and production of sugarcane. *Soils, plant growth and crop production, 2*, 1–23.
Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science, 37*, 29–38. doi:10.1097/00010694-193401000-00003
World Bank. (2009). *Commercial value chains in Zambian agriculture: Do smallholders benefit? (Report No. 48774-ZM). Washington, DC: World Bank, Agriculture and Rural Development (AFTAR),* Sustainable Development Department, Country Department AFCS2, Africa Region.
Wortmann, C. S., Mamo, M., Abebe, G., Mburu, C., Kayuki, K. C., Letayo, E., & Xerinda, S. (2006). *The atlas of sorghum production in five countries of Eastern Africa*. Lincoln, NE: University of Nebraska.
Yerima, B. P. K. (1993). *Manual for good laboratory practice*. Ethiopia: Food and Agriculture Organization of United Nation.
Zhou, M. (2013). Conventional sugarcane breeding in South Africa: Progress and future prospects. *American Journal of Plant Sciences, 4*, 189–197. http://dx.doi.org/10.4236/ajps.2013.42025

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