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Table of Content

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Full Length Research Paper

Improving agricultural productivity on salt-affected soils in Ethiopia: Farmers' perceptions and proposals

Asad S. Qureshi[1*], Mulugeta Mohammed[2], Ashenafi W. Daba[2], Birhanu Hailu2, Getinet Belay[2], Abeba Tesfaye[2] and Tesfaye M. Ertebo[3]

[1]Irrigation and Water Management, International Center for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates.
[2]Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.
[3]RAMSAP Project, International Center for Biosaline Agriculture (ICBA), Addis Ababa, Ethiopa.

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This paper presents the results of a baseline study carried out to understand farmers' perceptions about the existence of salinity in their farmlands and its impact on agricultural production and household food security. The strategies adopted by farmers to deal with the salinity and food insecurity problems are also discussed. The survey data were collected from a total of 300 farmers from five districts of Ethiopia. Farmers were selected using a random sampling from a household list. Focus Group Discussions were conducted with farmers in each district to investigate their perceptions of the soil salinity, its impacts and their adaptive strategies. Data were collected using a semi-structured questionnaire and analyzed using SPSS descriptive statistics and chi-square test. Farmers' responses showed that they were concerned about increasing soil salinity problems and its impact on their crop productivity and well-being. The results show that observing white crust and dark brown color of the soil are the major indicators used by farmers to identify salinity on their fields. Poor irrigation and drainage management problems are perceived as the main causes for salinity development. Salinity directly effects crop productivity and household incomes, which leads to food insecurity. The crop production losses due to soil salinity ranged from 10 to 70%. Performing off-farm jobs, selling household assets and joining food aid programs are the common coping strategies adopted by farmers. Farmers' perceptions on salinity should be used as an entry point by different stakeholders to develop strategies for the salt-affected areas.

Key words: Soil salinity, food security, crop productivity, coping strategies, rural poverty.

INTRODUCTION

Land degradation due to increasing soil salinization in arid and semi-arid regions of the world is evolving as the major menace for sustainable agricultural production and food security for the rising population (Ventura and Sagi, 2013; Hasanuzzaman et al., 2014). Globally, over 1,000 million ha of land is affected by the twin problems of salinity and sodicity (Wicke et al., 2011). Currently, 33% of the irrigated area (76 million ha) is affected by different levels of salinity and it is estimated that by 2050, more than 50% of the farms around the world will be salt-

*Corresponding author. E-mail: a.qureshi@biosaline.org.ae.

affected (Jamil et al., 2011; Kumar and Shrivastava, 2015). Soil salinization affects 19 million ha of land in sub-Saharan Africa (Tully et al., 2015). They are found largely in the countries of Eastern Africa, along the coast of Western Africa, the countries of the Lake Chad Basin, and in pockets of Southern Africa. Main drivers of salinity development in these regions are poor irrigation practices, rising groundwater levels due to inefficient drainage, and seawater intrusion into coastal farming areas due to the rising sea level and over-pumping of groundwater.

Ethiopia stands first in Africa in the extent of salt-affected soils due to human-induced and natural causes. Although no systematic nationwide data on the extent of salinity problem in Ethiopia is available, many researchers have reported that currently 11 million ha of land is exposed to salinity (Abegaze et al., 2006; Gedion 2009; Frew, 2012; Ashenafi and Bobe, 2016). This corresponds to 9% of the total landmass and 13% of irrigated area of the country (Birhane, 2017). These soils are concentrated in the Rift Valley, Wabi Shebelle River Basin, the Denakil Plains and various other lowlands and valleys of the country, where about 9% of the population lives (Tenalem et al., 2013; Sileshi, 2016). The growing prevalence of these soils is undermining the sustainability of irrigated agriculture, as it reduces natural biodiversity and farm and livestock productivity in the country.

With about 3% population growth, future food security as well as the livelihood for a considerable portion of the population remains a challenge to the government. Since agricultural production in Ethiopia is predominantly rain-fed, it is extremely vulnerable to changes in precipitation patterns and other adverse impacts of climate changes. Mitigating salinity to increase the productivity of existing salt-affected soils and preventing newly developed areas from the spread of salinity is of paramount importance for agricultural development in the country.

Salinity problem in Ethiopia has manifested to the extent that farmers are experiencing huge crop losses while many farms have gone out of production over the last decade. The salinity problems are now spread over a range of landscapes, irrigated lands, rain-fed farming areas and rangelands in the country (Qureshi, 2017). Currently, soil salinity is recognized as the most important problem in the arid and semi-arid lowland areas of the country resulting in reduced crop yields, low farm incomes and increased rural poverty (Gebremeskel et al., 2018). Among others, farmers' poor knowledge about the processes of salinity development and suitable coping strategies is considered as the major reason for rapidly increasing salinity problems in the country. This situation has forced farmers to switch to salt-tolerant legume and forage crops instead of cultivating traditional cereal crops, which has consequences for the household food security (Qureshi et al., 2018).

Salinity management at the farm level depends on the farmer's knowledge of the causes of salinity development and the farming practices they should use to overcome this problem. Understanding farmers' perceptions of salinity and adaptive strategies to cope with this problem could be a good entry point to suggest interventions that can help them tackle this problem (Wickham et al., 2006). Farmers' response strategies are usually based on the timing and severity of the problem perceived and their ability to properly interpret available information to develop the right response for a given situation (Meze-Hausken, 2000; Kassa et al., 2013). For instance, farmers having knowledge of salinity might decide to employ local mitigation and adaptation practices such as improved land and water management practices, planting salt-tolerant crops, diversify cropping patterns and change their investment decisions (Mamba et al., 2015).

In Ethiopia, very limited literature is available on the sources of salts, extent of soil salinization and its spatial distributions. This study was conducted to establish farmers' perceptions of the soil salinity and its impact on agricultural production and household food security. The study has also documented strategies adapted by farmers to cope with the salinity problems. It is anticipated that the information generated through this study will help policy makers, farmers and researchers in formulating appropriate policies and suggesting suitable interventions for the mitigation of salinity problems and improve food security in the salt-affected areas of the country.

Description of the study area

The study was conducted in five districts of Ethiopia. These include Amibara, Dubti, Raya-Alamata, Ziway-Dugda and Kewet districts from the Afar, Tigray, Oromia and Amahara regions, respectively. These areas were selected based on the presence of large tracts of salt-affected soils in the irrigated areas and the demonstrated potential of crop production. General characteristics of the selected districts are given in Table 1.

In Amibara District, about 33% of the total area is saline. In Dubti District, more than 80% of the area is affected by salinity and sodicity. The major reasons of this salinity development are poor irrigation water management practices and lack of drainage facility (Frew, 2012). The Raya-Alamata District of the Tigray Region is characterized by the shallow groundwater levels, which is the main cause of salinity development. In Ziway-Dugda and Kewet districts, soils are sodic in nature. This problem has deleterious impact on soil fertility which, in turn, reduces crop yields and farm income (Farifteh et al., 2006). The location map of the selected districts is given in Figure 1.

METHODOLOGY OF DATA COLLECTION AND ANALYSIS

The survey data were collected from a total of 300 respondents from five districts of Ethiopia, which were selected from a household

Table 1. Characterization of the selected districts.

Districts	Climate	Mean annual rainfall (mm)	Temperature range (°C)	Main crops grown	Salinity problems
Amibara	Semi-arid	570	19-34	Cotton, wheat, maize, vegetables	Wide-spread salinity in irrigated areas
Dubti	Hot and dry	220	23-49	Wheat, sorghum, vegetables	High water table, high salinity in farms
Raya-Alamata	Semi-arid	660	15-28	*teff,* sorghum, cereals, vegetables	Shallow water table, low to medium salinity
Ziway-Dugda	Arid	760	16-25	Fodder, cereals	Shortage of water, wide-spread salinity
Kewet	Hot and humid	1000	17-32	*teff,* maize, tobacco and vegetables	High water table, high salinity, low yields

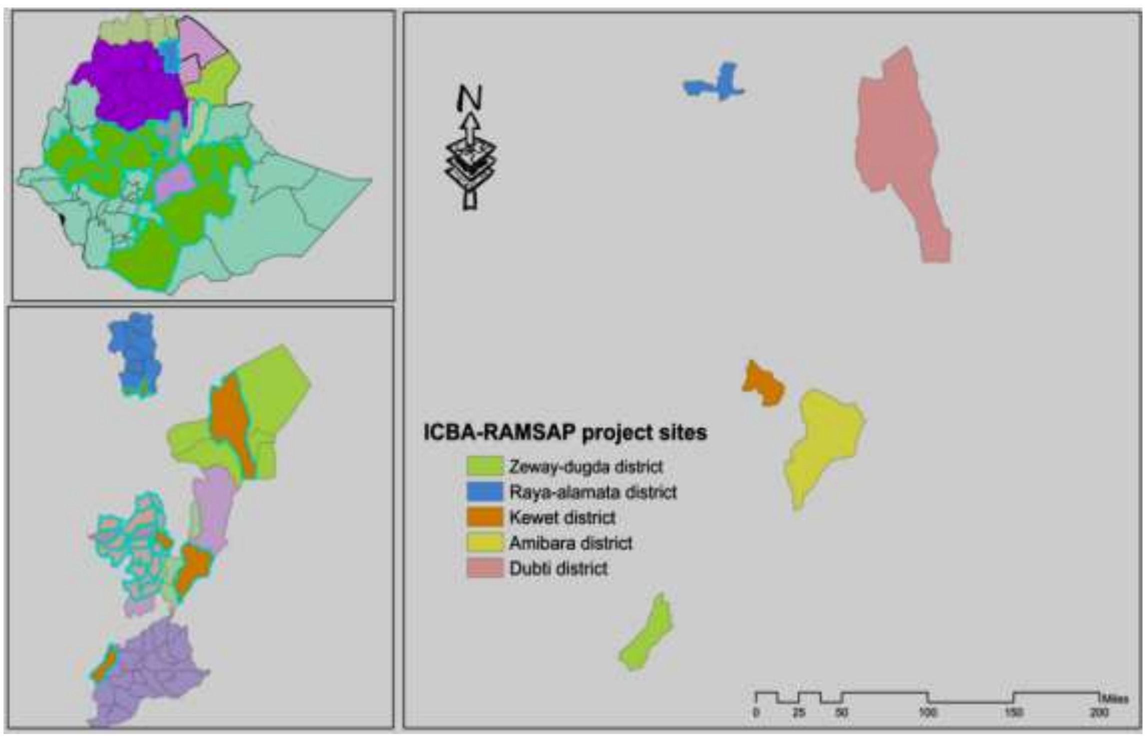

Figure 1. Location of the selected study areas in Ethiopia.

list using multistage random sampling technique. These include 67 respondents from Amibara, 35 from Dubti, 88 from Raya-Alamata, 45 from Kewet and 65 from Ziway-Dugda. The survey was conducted at regional and household levels. The variation in the number of respondents from each district is due to population size of that district. Data were collected using a semi-structured questionnaire. Semi-structured interviews are considered a better strategy to understand farmers' response and coping strategies and practices for the management of salt-affected soils. The questionnaire was pre-tested in the field by trained enumerators and necessary corrections were made based on the obtained feedback. Focus Group Discussions were also conducted with farmers in each district to record their collective views on the causes and extent of soil salinity, its impacts on their well-being and their adaptive strategies.

The selected districts have mixed crop-livestock system therefore the livelihood of most of the respondents is based on both farming and livestock rearing. In addition to survey data, data from secondary sources regarding groundwater quality and levels, soil maps and information on the status of salinity/sodicity were also collected. Secondary data are essential to get baseline information of the selected areas. During the survey, information on farmers' perceptions about the causes and severity of salinity on their fields was collected. Farmers were also asked about the limitations and constraints faced by them in the adoption of innovative technologies and approaches for managing saline soils and improving agricultural productivity. The data collected through household survey, interviews and focus group discussions were used to perform descriptive and econometric analyses using mean, %age, frequency and ANOVA. SPSS Version 20 software was used to carry out statistical analysis. The Chi square test was conducted to verify the significance level of association between farmers' perceptions and their determinants.

RESULTS AND DISCUSSION

Demographic and socio-economic characteristics of respondents

The demographic and socio-economic characteristics of respondents include gender, family size, marital status, education level, land holding and livestock ownership. Table 2 shows that 86.7% of the respondents were males and 13% females. The highest number of female respondents belongs to Raya-Alamata District and the lowest to Kewet District. More than 85% of the respondents were married. About 42% of the respondents have formal education, 17% are educated up to secondary school level whereas the rest 41% were illiterate. The highest number of illiterate respondents was from Raya-Alamata District followed by Amibara and Dubti districts. The average landholding per household is 2.2 ha (with a standard deviation of 1.2 ha) with lowest in Amibara (1.2 ha) and highest in Kewet (4.2 ha).

The *t-test* analysis showed that there is a significant difference ($P < 0.01$) in farmland size among households of different districts. Households at Dubti District have larger farmland than households of Amibara, Raya-Alamata and Ziway-Dugda districts. The farmland size in Kewet District is the highest among all districts. Similarly, the number of land parcels per household differs significantly ($P< 0.1$) between districts with a combined mean of 1.25 and a minimum and maximum of 1 and 3 parcels, respectively. In Dubti, land parcel per household is 1.37 compared to 1.19 parcels in Amibara district.

The livestock ownership is considered a proxy for wealth in rural areas of Ethiopia. Number and type of livestock holding determine the wealth of a household. This is particularly true in Amibara and Dubti districts because livestock is a major source of food, income and security in times of hardship for the pastoral communities of these areas. In this study, the livestock asset of separate households was estimated by tropical livestock unit (TLU) (Storck et al., 1991). The TLU provides a common unit for comparison because households own different species of livestock (cattle, goat, camel, sheep etc.). The average livestock holding per household was found to be 10.4 TLU with highest livestock holding in Amibara District and the lowest in Ziway-Dugda and Kewet districts. The highest livestock holding in Amibara, Dubti and Raya-Alamata districts can be attributed to the presence of pastoral communities. The 3.7 TLU value in Ziway-Dugda and Kewet districts is lower than the minimum threshold value of 4.5 TLU, which is generally considered necessary to sustain traditional pastoral households in East Africa (Davies and Bennett, 2007). This means that the households in these two districts are less dependent on livestock and need off-farm jobs to supplement their incomes. The households in these districts adopt different strategies to earn their livings. These include livestock herding, crop cultivation, off-farm wage employment, petty trade, permanent employment, food aid, and others.

Sources of households' income

The agricultural production system of the selected districts is a mixed farming system in which farmers practice both livestock and crop production. However, farmers give more emphasis to crop production to secure food supply and satisfy cash needs of their families. The different sources of income reported by the sample households include livestock herding, crop cultivation, off-farm wage employment, petty trade, permanent employment, food aid, and others. The survey results show that although livestock and livestock related income sources were the dominant means of living in pastoral and agro-pastoral livelihood systems, farming (crop sale), off-farm employment and permanent employment also contributed significantly to the incomes of the respondents.

Table 3 shows that except in Ziway-Dugda, the share of crop sale was the largest in household incomes followed by livestock. In Ziway-Dugda, the largest contribution in household income comes from livestock farming and less from agriculture. Due to intensive agro-business activities, opportunities for off-farm wages and permanent employment are significant in Amibara and Dubti districts. This makes households of these districts less dependent on food aid programs. Household incomes from permanent employment are substantial (20%) in Ziway-Dugda district. However, in Raya-Alamata, Ziway-Dugda and Kewet districts, chances of off-farm wages and permanent employment are the lowest and more people are dependent on petty trade and food aid programs of national and international organizations. This clearly shows that households of salt-affected areas in these districts cannot rely solely on farming and need to engage themselves in multiple activities to earn their living and meet their daily food requirements. The survey results indicate that to reduce production cost and increase farm income, household in salt-affected areas perform most of the farm activities by themselves. Farm labor activities such as land clearing, ploughing and irrigating are mainly performed by men whereas women contribute more in winnowing and harvesting activities. Other activities such as sowing weeding, bagging, and transporting are largely shared among male and female members of the household (Figure 2).

Table 2. Demographic and socio-economic characteristics of the respondents.

Parameter	Amibara (N = 67)	Dubti (N = 35)	Raya-Alamata (N = 88)	Ziway-Dugda (N = 65)	Kewet (N = 45)	Average (N = 300)	SD
Male (%)	92	88.5	70.4	87.7	95.0	86.7	9.6
Female (%)	8.0	11.5	29.6	12.3	5.0	13.3	9.6
Single (%)	8.4	17.0	27.6	37.0	2.2	18.4	14.1
Married (%)	91.4	83.0	72.4	63.0	97.8	81.5	14.1
Illiterate (%)	50.8	48.6	51.4	16.9	35.6	41.0	14.8
Formal school (%)	33.2	42.9	42.8	50.8	40.8	42.0	6.3
SSC school (%)	16.0	8.5	5.5	32.3	23.4	17.0	11.0
Landholding (ha)	1.2	2.0	2.0	1.6	4.2	2.2	1.2
Livestock (TLU)	15.3	15.0	14.6	3.70	3.70	10.4	6.2

Table 3. Sources of households' income.

Parameter	Amibara (N = 67)		Dubti (N = 35)		Raya-Alamata (N = 88)		Ziway-Dugda (N = 65)		Kewet (N = 45)	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Livestock	56	83.6	28	80.0	19	21.6	37	56.9	29	64.4
Farming (crop sale)	67	100	31	88.5	53	60.2	14	21.5	30	66.7
Off-farm wage	31	46.3	7	20.0	4	4.5	4	6.2	2	4.4
Permanent employment	19	28.4	9	25.7	1	1.2	13	20.0	1	2.2
Petty trade	2	3.0	3	8.57	3	3.4	9	13.8	4	8.9
Food aid	2	3.0	0	0.00	10	11.4	3	4.6	6	13.3

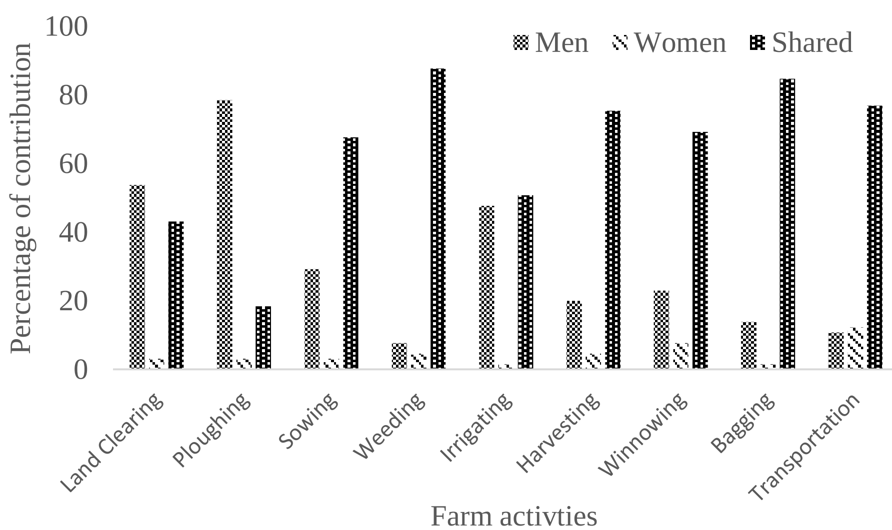

Figure 2. Contributions of men and women in performing different farm activities.

Farmers' perception about the existence and causes of salinity

During this survey, farmers were asked about the indicators they use to identify salinity in their farmlands. According to survey results, 36% of the respondents use white crust on the soil surface, 22% consider dark brown color of the soil whereas 42% use both white crust and

Table 4. Farmers' classification of farmland salinity.

Parameter	Amibara (N = 67)		Dubti (N = 35)		Raya-Alamata (N = 88)		Ziway-Dugda (N = 65)		Kewet (N = 45)	
	N	%	N	%	N	%	N	%	N	%
Classification of farmland salinity										
Low	10	14.9	4	11.4	7	8.0	2	3.1	3	6.7
Medium	28	41.8	13	37.1	28	32.0	10	15.4	16	35.6
High	23	34.3	15	42.9	31	35.0	18	27.7	13	28.9
Very high	6	8.9	3	8.6	22	25.0	29	44.6	6	13.3
Causes of salinity development										
Parent material	12	17.9	17	42.9	10	11.4	58	89.7	30	66.7
Irrigation water quality	59	88.1	29	82.9	76	86.4	29	44.6	14	31.1
Irrigation methods	23	34.3	23	65.7	37	42.0	4	6.2	8	17.8
Climatic conditions	5	7.5	9	25.7	16	18.2	6	9.2	3	5.3
Land leveling problem	32	47.8	15	42.9	8	9.1	7	10.8	6	13.3
Irrigation frequency	5	7.5	4	11.4	40	45.5	4	6.2	4	8.8
Irrigation water quantity	14	20.9	11	31.4	39	44.3	12	18.5	13	28.9
Drainage problem	34	50.8	18	51.4	53	60.2	58	89.2	37	82.2

dark brown color of the soil as an indicator to identify salinity in their fields. Based on these indicators, farmers were asked to classify salinity in their farmlands on a scale of low, medium, high and very high and the results are presented in Table 4.

The results presented in Table 4 shows that most of the farmers believe that salinity levels in their farmlands ranged from medium to high. A considerable percentage of respondents in Raya-Almata (25%) and Ziway-Dugda (44.6) rated salinity levels in their fields as 'very high'. The high salinity levels in Amibara and Dubti districts are attributed to dry and hot weather conditions along with low availability of irrigation water. The presence of parent salts and the addition of excessive salts due to the use of poor quality groundwater for irrigation are also major causes of high salinity in these areas. Furthermore, drainage problems are also more severe in Amibara and Dubti districts where poor irrigation management practices and absence of complimentary drainage system have resulted in rapid rise of groundwater levels leading to soil salinization. In Dubti and Raya-Almata districts, farmers also believe that salinity development is linked to climate changes as the length of dry periods have increased whereas the amount of rainfall has reduced. However, in other three districts, climate change is not considered as the major concern.

The fertility status of farmlands in the 5 districts differs significantly due to various reasons. During this survey, respondents were also asked to categorize fertility status of their farmlands using three indicators, that is, poor (infertile), average and good (fertile). The consolidated results of the survey revealed that majority of the farmlands possessed by respondents of these areas are poor in terms of fertility. About 43% of the respondents consider their farmland poor (infertile), 51% rated their farmland as average and about 6% termed the fertility of their farmland as good (fertile).

Table 4 illustrates that more than 80% of the respondents from Amibara, Dubti and Raya-Alamata districts consider poor irrigation water quality and inadequate drainage facilities as the main causes of salinity development in their farmlands, followed by irrigation methods and land leveling issues. Despite all the scientific progress and mounting water shortages, irrigation applications by farmers are not based on actual crop water demands. Fields are poorly leveled and farmers generally use basin/flooding methods of irrigation. This results in patches of low and high water application after each irrigation event leading to uneven crop growth and consequently low yields.

Farmers' perceptions about crop productivity losses due to salinity

The crop productivity losses due to soil salinization in the study areas ranged from a complete loss to less than 10% loss. The majority of the respondents (54.3%) in Dubti District reported 50% loss in their crop production followed by Amibara (38.8%), Ziway-Dugda (32.5%), Kewet (28.9%) and Raya-Alamata (20.8%). The highest crop productivity losses of 25% were reported in Amibara (35.8%) and Dubti (25.7%) districts (Figure 3). Nearly 15% of the respondents in Amibara District reported a complete loss of their crop production in multiple cropping seasons. However, in other four districts, complete production losses were less than 10%. High productivity losses in Amibara and Dubti districts are understandable

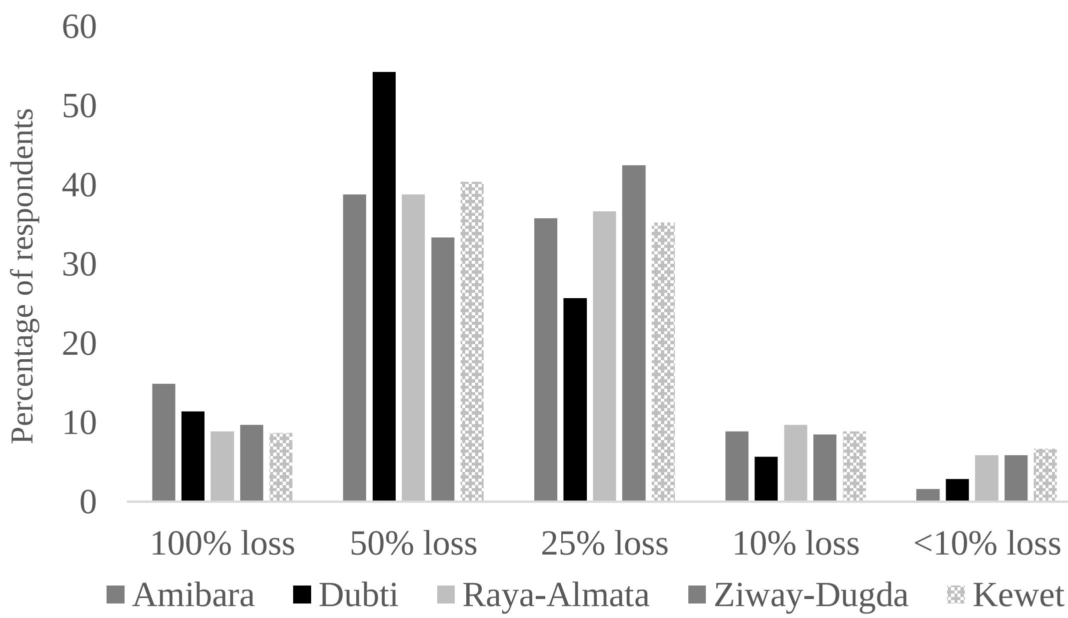

Figure 3. Production losses due to soil salinity in different districts.

given the dry, hot and saline environment of the area.

The low crop productivity in salt-affected areas has direct impact on the income and livelihood of households. In the highly saline areas of Amibara and Dubti, farmers are abandoning their lands and migrating to nearby cities and towns in search of off-farm jobs. Declining farm incomes has forced households to do extra work to earn cash to meet their daily needs, which has created serious health problems especially for women and children. Farmers complain about losing their livestock due to drought and diseases, which is making it impossible for them to nurture their families and we are entirely dependent on food aid programs for more than six months in a year. Due to low productivity in salt-affected areas, farmers send their animals to other areas in search of feed. This situation further increases their vulnerability.

Farmers' perception about production and marketing constraints

The information collected from secondary sources revealed that average crop productivities in the selected districts were consistently low. During this survey, farmers were asked about the major production and marketing constraints faced by them for improving their agricultural productivity. In Raya-Almata District, more than 95% of the respondents consider lack of agricultural inputs such as improved seed, fertilizer and farm machinery, shortage of arable land, lack of technical knowledge, shortage of irrigation water and increasing salinity as the major constraints for low productivity in their fields. In Dubti District, lack of agricultural inputs and technical knowhow, increasing soil salinity and invasion of weeds are reported as the major constraints.

In Ziway-Dugda and Kewet districts, lack of agricultural inputs and shortage of arable land are not reported as the major issues. In these districts, shortage of water, increasing soil salinity are the major concerns followed by invasion of weeds. In all districts, low availability of pesticides results in the expansion of invasive weeds. The farmers of Amibara District were also concerned about the poor quality of surface water. They reported that the mixing of Lake *Beseka* and *Deho* hot spring water to Awash River has deteriorated the irrigation water quality over the last 5 years, which is causing salinity in their farmlands (Table 5).

Consistently lower land productivity in the study areas results in reduced farm incomes, food insecurity and sway in poverty. Due to the above-mentioned constraints, crop yields are generally low and after meeting domestic needs very little is left for sale in market to earn cash for other family needs. In addition to low produce, farmers are also facing many marketing constraints to get true value of their produce. During this survey, lack of market information and poor infrastructure were rated as the major marketing constraints by farmers in Amibara, Dubti and Raya-Almata districts. However this was not the case in Kewet District, where active involvement of brokers was reported as the top market constraint, followed by high transaction costs.

Household's food security in salt-affected areas

Salt-affected lands are directly and indirectly affecting livelihoods of the households. The direct effects of salinity

Table 5. Production and marketing constraints faced by farmers in Ethiopia.

Parameter	Amibara (N = 67)		Dubti (N = 35)		Raya-Alamata (N = 88)		Ziway-Dugda (N = 65)		Kewet (N = 45)	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Production constraints										
Lack of agricultural inputs	64	95.5	27	77.1	86	98.9	13	20	2.0	4.4
Shortage of arable land	50	74.6	15	42.9	86	98.9	1	1.5	1.0	2.2
Lack of tech. knowledge	51	76.1	25	71.4	85	97.7	32	49.2	14	31.1
Shortage of irrigation water	30	44.8	6	17.1	82	94.3	62	92.3	31	68.9
Increasing soil salinity	67	100	34	97.1	83	95.4	43	66.2	30	66.7
Growth of invasive weeds	52	77.6	25	71.4	70	80.5	22	33.8	18	40.0
Marketing constraints										
Lack of market information	53	79.1	29	82.8	77	88.5	4	6.2	3.0	6.7
Lack of infrastructures	38	56.7	19	54.3	32	36.8	32	49.2	5.0	11.1
Involvement of brokers	18	26.8	6	17.1	27	31.0	2	3.1	24	53.3
High transaction costs	35	53.3	19	54.3	43	49.4	5	7.7	7.0	15.6

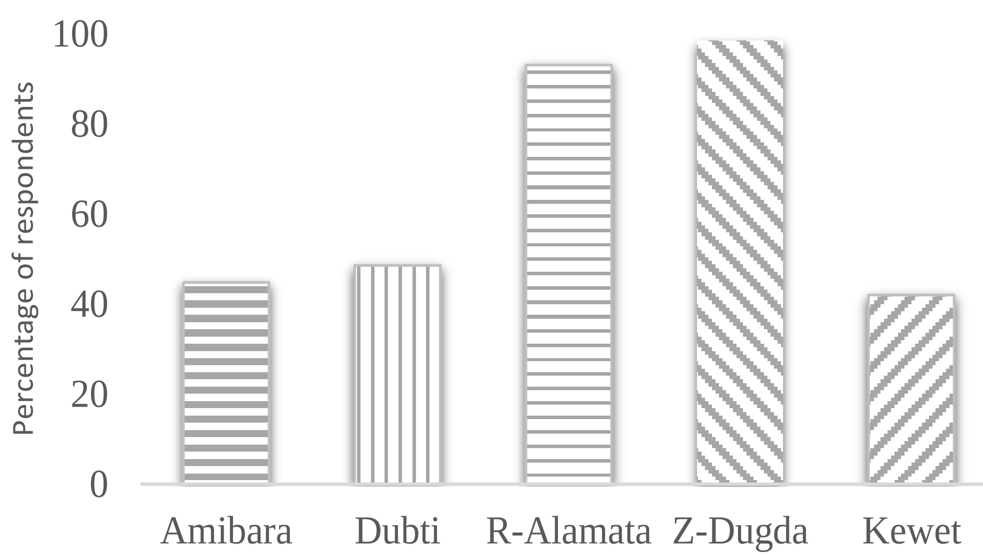

Figure 4. Food security in salt-affected areas of different districts.

are related to decreased farm productivity and household income. The indirect effects are linked to food insecurity and increased dependency on donor aid programs. The survey results indicate that about 93% of the households in Raya-Alamata and 98.5% of the households in Ziway-Dugda are food insecure during different times of the year. In Kewet District, 42% of the households are food insecure for the whole year especially in the months of August and September. The remaining 58% of the households are food secure for most part of the year. About 44.8% of the households in Amibara and 48.6% in Dubti were reported as food insecure for different times of the year especially from March through June as these are the driest and hottest months. During these months, farmers usually shift their livestock to other areas where availability of fodder and water is guaranteed. Therefore households do not have access to milk and other dairy products, which makes it difficult for them to meet their food demands. In addition, crop production is at the lowest due to shortage of water and high temperatures (Figure 4).

Farmers' coping strategies

Households use different adaptive strategies to ensure food security. Traditionally, mutual support system was the most commonly used strategy in pastoral and agro-pastoral communities used at the time of shocks and risks. However, with the weakening of the pastoral traditional system, this mutual support strategy system has broken down in the recent years. As a result, other copping strategies have been adopted by the communities either by themselves and/or with the support of internal and external bodies (governmental and non-governmental organizations). According to aggregate survey results, 42% of the food deficit households of all districts take part in "*food for work activities*" while 13% rely on food aid programs of national and international organizations. The remaining 45% food insecure households cope with this situation by doing off-farm income earning activities and even selling assets such as livestock and different household items.

CONCLUSION AND RECOMMENDATIONS

Understanding salinity status of soils plays a vital role for sustainable agricultural production. This study was initiated to evaluate the impacts of soil salinity on crop productivity, food security and socio-economic conditions of the farming communities in order to develop suitable management strategies for sustainable crop production in the salt-affected areas of Ethiopia. The study results indicate that farmers use different indicators to identify salinity in their lands. Observing white crust and dark brown color of the soil are the major indicators used by households for the identification of salinity in their farmlands. Majority of the households alleged that poor irrigation management and absence of drainage systems are the major causes of salinity development in their fields. Drainage systems are either non-existing or malfunctioning.

The agricultural farming followed by livestock are the major sources of household income in Ethiopia. Salinity affects directly or indirectly the livelihoods of the households. The direct impacts are related to abandoning of land, reduced crop production and declining farm incomes. The indirect impacts are linked to food insecurity and increased dependence on food aid programs. Farmers face number of production and marketing constraints, which include lack of farm inputs including fertilizer and machinery, shortage of irrigation water, lack of market information and heavy involvement of brokers (middleman). The declined household income is increasing poverty in salt-affected areas, which has forced male members of the household to migrate to nearby towns and cities in search of off-farm jobs. This has put an enormous pressure on female members as they have to carry extra burden of household activities.

In salt-affected areas, farmers are witnessing 10 to 70% production losses in different regions due to soil salinity, non-availability of agricultural inputs and management capacity of the farmers. The survey results indicate that majority of the food deficit households take part in "*food for work activities*" and at times depend on food aid programs of national and international organizations. Increasing dependence of farmers on food aid programs is declining the capacity of the food aid organizations, which is forcing farmers to sell their assets such as livestock and household items to buy food and other utilities for their families. Therefore, government needs to take immediate measures to improve situation in salt-affected areas to address food insecurity and poverty issues.

The households have made the following recommendations for raising agricultural productivity in salt-affected areas:

(i) A system of continuous assessment and monitoring should be established to keep an eye on the occurrence and increasing trend of soil salinity in the district.
(ii) Surface and subsurface drainage systems should be installed in the waterlogged areas since more farmlands are abandoned from time to time.
(iii) Crop varieties that have the capacity to grow under salinity and waterlogging conditions should be introduced.
(iv) Marketing mechanism for buying the agricultural products of smallholder farmers at their true value needs to be established. This will encourage farmers to increase crop production and improve their incomes.
(v) Effective extension program should be initiated to disseminate information on soil, water and salinity management practices to farmers. Farmers should also be linked with national research and extension organizations for developing intervention programs for solving increasing salinity problems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ashenafi W, Bedadi B (2016). Studies on Soil Physical Properties of Salt Affected Soil in Amibara Area, Central Rift Valley of Ethiopia. International Journal of Agricultural Sciences and Natural Resources 3(2):8-17.

Abegaze F, Giorgis K, Fanta A, Gebrekidan H, Chekol W, Azeze H, Ayalew A, Fisseha M, Bedel M (2006). Report of the National Task Force on Assessment of Salt Affected Soils and Recommendations on Management Options for Sustainable Utilization.

Birhane H (2017). Salinity Status of Soils of Irrigated Lands, Water Logged Areas and Irrigation Water Quality at Raya Alamata District in Raya Valley, Northern Ethiopia. MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Davies J, Bennett R (2007). Livelihood adaptation to risk: constraints and opportunities for pastoral development in Ethiopia's Afar Region. The Journal of Development Studies 43(3):90-111.

Farifteh J, Farshad A, George RJ (2006). Assessing salt-affected soils using remote sensing, solute modeling and Geophysics. Geoderma 30(2):191-206.

Frew A (2012). Appraisal and mapping of soil salinity problems in Amibara area of middle awash basin. MSc Thesis, School of Graduate Studies, Haramaya University, Ethiopia.

Gebremeskel G, Gebremicael TG, Kifle M, Meresa E, Gebremedhin T, Girmay A (2018). Salinization pattern and its spatial distribution in the irrigated agriculture of Northern Ethiopia: An integrated approach of quantitative and spatial analysis. Agricultural Water Management 206:147-157.

Gedion T (2009). Surface water-Groundwater interactions and effects of errigation on water and soil resources in the Awash Valley. MSc Thesis, Addis Ababa University, Ethiopia.

Hasanuzzaman M, Nahar K, Alam MM, Bhowmik PC, Hossain MA, Rahman MM, Prasad M NV, Ozturk M, Fujita M (2014). Potential use of halophytes to remediate saline soils. BioMed Research International doi:10.1155/2014/589341.

Jamil A, Riaz S, Ashraf M, Foolad R (2011). Gene expression profiling of plants under salt stress. Journal of Plant Science 30(5):435-458.

Kassa Y, Beyene F, Haji J, Lejesse B (2013). Farmers perceptions of the impact of land degradation and soil and water conservation measures in west Hareghe zone of oromia national regional state, Ethiopa. Journal of Bilogy, Agriculture and Healthcare 3(11):12-19.

Kumar R, Shrivastava P (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi Journal of Biological Sciences 22:123-131.

Mamba SF, Salam A, Peter G (2015). Farmers' Perception of Climate Change a Case Study in Swaziland. Journal of Food Security 3(2):47-61.

Meze-Hausken E (2000). "Migration caused by climate change: how vulnerable are people in dryland areas? A case study in Northern Ethiopia." Mitigation and Adaptation Strategies for Global Change 5(4):379-406.

Qureshi AS (2017). Sustainable use of marginal lands to improve food security in the United Arab Emirates. Journal of Experimental Biology and Agricultural Sciences August-2017; Volume–5 (Spl-1-SAFSAW). DOI: http://dx.doi.org/10.18006/2017.5(Spl-1-SAFSAW).S41.S49.

Qureshi AS, Ertebo T, Mehansiwala M (2018). Prospects of alternative cropping systems for salt-affected soils in Ethiopia. Journal of Soil Science and Environmental Management 9(7):98-107.

Sileshi A (2016). Status of salt-affected soils, irrigation water quality and land suitability of Dubti-Tendaho Area, North Eastern Ethiopia. PhD Dissertation, Haramaya University, Ethiopia.

Storck H, Bezabih E, Birhanu A, Borowiecki A, Shimeles W (1991). Farming systems and farm management practices of smallholders in the Hararghe Highlands: Farming systems and resources economics in the tropics. Wissenshafts varlag vauk, Kiel, Germany 11:41-48.

Tenalem A, Gebreegziabher M, Seifu K, Sileshi M (2013). Integrated assessment of hydrogeology and water quality for ground water-based irrigation development in the Raya Valley, northern Ethiopia. Water International 38(4):480-492.

Tully K, Sullivan C, Weil R, Sanchez P (2015). The state of soil degradation in Sub-Saharan Africa: Baselines, trajectories, and solutions. Sustainability 7:6523-6552.

Ventura Y, Sagi M (2013). Halophyte crop cultivation: The case for *Salicornia* and s*arcocornia*. Environmental and Experimental Botany 92:144-153.

Wicke B, Smeets E, Dornburg V, Vashev B, Gaiser T, Turkenburg W, Faaij A (2011). The global technical and economic potential of bioenergy from salt-affected soils. Energy Environmental Science 8:2669e2681.

Wickham JD, Nash MS, Wade TG, Currey L (2006). Statewide empirical modeling of bacterial contamination of surface waters. American Journal of Water Resources 42:583-591.

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Identification of 1-decyne as a new volatile allele-chemical in baobab (*Adansonia digitata*) from Sudan

Yoshiharu Fujii[1*], Hala Sad Alla Maliek Elmadni[1,2] and Maryia Mishyna[1,3]

[1]Department of International Environmental and Agricultural Science, Faculty of Agriculture, Tokyo University of Agriculture and Technology, 183-8509 Tokyo, Japan.
[2]Department of General Administration of technology Transfer and Extension, Federal Ministry of Agriculture and Forest, 461 Khartoum, Sudan.
[3]School of Food Science and Bioengineering, Zhejiang Gongshang University, Hangzhou, China.

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Leaf, fruit, wood, and gum of fifty-five plants collected in Sudan were evaluated by Dish pack method for their allelopathic activity through volatile chemicals using lettuce (*Lactuca sativa*) as a receptor plant. Several potential plants with high allelopathic activity, such as *Terminalia brownie, Euphorbia hirta, Diospyros mespiliformis, Corchorus olitorius, Adansonia digitata, Hibiscus sabdariffa*, were determined. Baobab (*A. digitata*) leaves demonstrated relatively higher inhibition (23.9 and 21.5% of hypocotyl and radicle, respectively) than most of the screened plant species. Identification of the volatile compounds using headspace gas chromatography-mass spectrometry revealed 1-decyne as the main volatile compound naturally released from dried baobab leaves. EC_{50} (50% growth inhibition) of radicle and hypocotyl growth of lettuce seedlings by authentic 1-decyne was determined in the headspace air using by GC-MS with Cotton Swab method at the concentration of 0.5 ng/ml. The obtained results could fully explain the plant growth inhibitory activity of baobab volatiles by the presence of 1-decyne. Thus, in this study, we first identified 1-decyne as a new volatile allelochemical from baobab leaves. 1-decyne might be an important allelochemical for the survival of baobab in Africa and our findings may also offer a potential for future development of new volatile plant growth modulator.

Key words: *Adansonia digitata*, baobab, 1-decyne, allelopathy, volatile, GC-MS, Sudan.

INTRODUCTION

Recent intensification of cropping and rapid conversion of vast areas into intensive agricultural production has led to serious weed problems in all areas in Sudan (Hamada, 2000; Mahgoub, 2014). Another problem of the last decades is rapidly evolving resistance of weeds, for example, *Cyperus rotundus* (Nagulendran et al., 2007) and *Panicum turgidum* (Williams and Farias, 1972), to a number of herbicides (Green and Owen, 2011). As an alternative to synthetic herbicides, allelopathy offers the potential for bio-rational weed control through the production and release of allelochemicals from plant materials (Weston, 1996) along with using allelochemicals as growth regulators, insecticides, and antimicrobial crop protection products (Cheng and Cheng, 2015).

*Corresponding author. E-mail: yfujii@cc.tuat.ac.jp.

Screening of plants is the first essential step in the identification of the allelopathic potential of plant material followed by allelochemicals identification, laboratory bioassays, and field tasting (Cheng and Cheng, 2015). Previous research on the allelopathic activity of African plants has reported about trimethyl allo-hydroxycitrate and β-sitosterol from *H. sabdariffa* (Piyatida et al., 2013; Suwitchayanon et al., 2015) and phenolic antioxidants from *C. olitorius* leaves (Azuma et al., 1999). Aqueous and methanol extracts of *Capparis spinosa* and *Cleome arabica* reduced mitotic index triggered oxidative damage and caused the disruption in membrane permeability (Ladhari et al., 2014). The study of the phytotoxic activity of *Vachellia sieberiana*, *Albizia adianthifolia*, *Buddleja saligna*, *Combretum kraussii*, *Halleria lucida*, and *Rapanea melanophloeos* from South Africa showed significant inhibition in germination, chlorophyll accumulation, and growth of lettuce (Sunmonu and Van Staden, 2014). Despite some studies, African plants remain poorly studied as a source of allelopathic compounds that can be used directly in weed control or be a source for new non-synthetic herbicides. Therefore, the objectives of our study were to evaluate the allelopathic potential of Sudanese plants and to identify volatile allelochemicals from baobab leaves.

MATERIALS AND METHODS

Collection of plant samples

Plant material (fruit, stem, leaves) of 55 species was collected from different places of Sudan (Sinnar, Kassala, Elgezira, Algedaref, and Kordofan) in August 2015 and from the international botanical garden in Khartoum, Sudan in September 2016. All plant species were identified in the international botanical garden (Khartoum, Sudan). The leaves were dried at 60ºC for 24 hrs and stored at room temperature.

Dish pack method

Dish pack method was used to determine allelopathic activity through volatile compounds emitted from plant material (Fujii et al., 2005). Briefly, 200 mg of dried leaves were placed into one of the holes in multi-dish with 6 holes, except control. Filter papers (33 mm) were placed and 0.7 ml of distilled water was added to another five dishes. Seven seeds of lettuce (*Lactuca sativa*), variety great Lakes 366 (Takii seed Co., Japan) were placed on the filter paper. The multi-dish plates were sealed and incubated at 22°C under the dark condition. After 3 days the length of radicle and hypocotyl of lettuce seedlings was measured.

Gas chromatography-mass spectrometry (GC-MS)

1 g of baobab leaves was placed in 20 ml glass vial and sealed. Headspace air was collected after 24 and 48 hrs of incubation at room temperature. The composition of volatile compounds was detected by GC-MS-QP 2010 plus system (Shimadzu, Japan) equipped with EQUITY-5 column (0.25 × 30 × 0.25 mm) with helium gas as a carrier. The oven temperature was increased from 50 to 200°C at a rate of 10°C/min. The injection was set to split modes. Mass spectra were recorded at 70 eV with a mass range of m/z 50 to 400, compared to a mass spectral library (NIST and Wiley), and confirmed against spectra of authentic 1-decyne, 1-nonyne, and 1-undecyne (Tokyo Chemical Industry, Japan).

Cotton swab method

To determine the inhibitory activity of authentic 1-decyne, cotton swab method (Mishyna et al., 2015) was used. Agar solution was prepared at the concentration of 0.75% w/v and sterilized in an autoclave at 115°C for 15min. 10 ml of agar were added to each glass vial and five lettuce seeds were placed on solidified agar. The prepared cotton swab was inserted in the agar and 1-decyne solution at different volumes (0.5, 1, 10, 20, 50 and 100 µl) was added. To identify EC_{50} of volatiles from baobab leaves, 500, 700, and 900 mg of plant material were added instead of the cotton swab. Measurement of the length of radicle and hypocotyl of lettuce seedlings were done after three days of incubation at 22°C. All treatments were replicated three times and repeated twice.

Statistical analysis

ANOVA test (level of significance is $P<0.05$) was used to evaluate the effect of volatiles on the growth of radicles and hypocotyl of tested plants.

RESULTS AND DISCUSSIONS

Screening of allelopathic activity of plant volatiles

Table 1 shows the results of testing of allelopathic activity through volatile compounds of 55 plants from Sudan. Hypocotyl growth of the lettuce seedlings was inhibited from 0.4% (leaves of *Xanthium brasillicum*) to 30.5% (wood of *Terminalia brownii*) compared to control. Top 5 plants with the strongest allelopathic activity (21 - 30.5% and 19.4 - 38.7% for hypocotyl and radicle, respectively) was identified including *T. brownie, E. hirta* (leaves), *D. mespiliformis* (leaves), *A. digitata* (leaves), and *C. olitorius* (leaves).

The volatiles from *shaf* (*T. brownii*) wood showed the strongest inhibition of the hypocotyl growth (30.5%) of lettuce seedlings in this study. It has been previously reported that *shaf* contains antimycobacterial compounds of diverse polarities and can be used for tuberculosis treatment (Salih et al., 2018). Mbiri et al. (2016) demonstrated an antinociceptive activity of the barks of *shaf* and rationalize the traditional use of the barks in the management of pain. The volatiles from *E. hirta* leaves showed secondary strongest inhibition (27.8 and 38.7% of hypocotyl and radicle growth of lettuce, respectively). Very little is known about the allelopathic potential of volatiles of *E. hirta*, but the analysis of essential oil from dried leaves *E. hirta* demonstrated major compounds such as 3,7,11,15-tetramethyl-2-hexadecen-1-ol, 6,10,14-trimethyl-2-pentadecanone, hexadecanal, phytol, and n-hexadecanoic acid and its potential for medication of asthma (Ogunlesi et al., 2009). Volatiles from gogan (*D.

Table 1. Assessment of allelopathic activity of plant volatiles from Sudanese plants.

N	Family name	Local name in Sudan	Scientific name	Parts used	Inhibition (%)	
					Hypocotyl	Radicle
1	Mimosaceae	Shaf	*Terminalia brownii*	wood	30.5	24.1
2	Euphorbiaceae	(Euphorbia)	*Euphorbia hirta*	leaf	27.8	38.7
3	Ebenaceae	Gogan	*Diospyros mespiliformis*	leaf	27.4	19.4
4	Malvaceae	Baobab	*Adansonia digitata*	leaf	23.9	21.5
5	Malvaceae	Nalta Jute	*Corchorus olitorius*	leaf	21.0	24.8
6	Malvaceae	Karkade	*Hibiscus sabdariffa*	fruit	20.1	29.6
7	Lythraceae	Henna	*Lawsonia inermis*	leaf	18.2	13.8
8	Aristolochiaceae	Um Galagel	*Aristolochia bracteolate*	leaf	17.8	11.0
9	Poaceae	Ankoj	*Ischaemum afrum*	leaf	17.4	18.2
10	Cyperaceae	Cyperus	*Cyperus rotundus*	leaf	17.4	15.9
11	Poaceae	Allambri	*Abutilon figarianium*	leaf	16.7	15.1
12	Euphorbiaceae	Tabar	*Ipomoea cardiosepala*	leaf	16.0	12.6
13	Malvaceae	Guddaim	*Grewia tenax*	fruit	16.0	4.26
14	Lythraceae	Henna	*Lawsonia inermis*	leaf powder	15.7	20.6
15	Amaranthaceae	Doneb	*Chenopodium ambrosioides*	leaf	14.6	13.8
16	Convolvulaceae	Dareyah	*Merremia emarginate*	leaf	14.6	9.43
17	Aizoaceae	Rabah	*Trianthema portulacastrum*	leaf	14.2	17.5
18	Malvaceae	Guddiam	*Grewia tenax*	leaf	14.1	-0.5
19	Lythraceae	Henna	*Lawsonia inermis*	leaf powder	13.8	2.8
20	Fabaceae	Pohoniya	*Ceratonia siliqua*	leaf	13.7	19.8
21	Fabaceae	Arad	*Albizzia sericocepala*	leaf	13.7	17.9
22	Poaceae	Shleyma	*Phragmites australes*	leaf	13.5	20.8
23	Euphorbiaceae	(Euphorbia)	*Euphorbia buraspastoris*	leaf	13.5	13.1
24	Malvaceae	Baobab	*Adansonia digitata*	fruit powder	13.2	17.0
25	Fabaceae	Senna Mekka	*Cassia senna*	fruit	12.9	16.4
26	Lamiaceae	Rehan	*Ocimum basilicum*	leaf	12.7	23.6
27	Zygophyllaceae	Hegleg	*Balanites aegyptiaca*	leaf	12.3	16.0
28	Poaceae	Taman	*Panicum turgidum*	leaf	11.9	16.6
29	Acanthaceae	Tgtag	*Ruellia patula*	leaf	11.4	20.1
30	Fabaceae	Senna Mekka	*Cassia senna*	leaf	11.2	3.8
31	Poaceae	(Johnson grass)	*Sorghum halepense*	leaf	11.0	24.9
32	Asteroideae	Sheeh	*Artemisia seiberi*	leaf	10.7	13.7
33	Mimosaceae	Hashab	*Acacia senegal*	gum	10.4	18.1
34	Mimosaceae	Shaf	*Terminala bornii*	leaf	10.3	18.6
35	Poaceae	(Millet)	*Pennisetum glaucum*	leaf	9.3	1.8
36	Mimosaceae	Kiter	*Acacia melofera*	leaf	7.7	3.5
37	Mimosaceae	Telih	*Acacia seyal*	leaf	7.3	2.9
38	Poaceae	Durra	*Sorghum bicolor*	leaf	7.2	19.3
39	Orobanchaceae	Buda	*Striga hermonthica*	leaf	6.8	22.3
40	Mimosaceae	Hashab	*Acaica senegal*	gum	6.0	7.4
41	Mimosaceae	Hashab	*Acacia senegal*	leaf	5.6	0.6
42	Asteraceae	Moleta	*Sonchus comutas*	leaf	5.3	13.4
43	Arecaceae	Doum Palm	*Hyphaena thebaica*	leaf	5.2	3.6
44	Malvaceae	Karkade	*Hibiscus sabdariffa*	leaf	4.5	6.7
45	Malvaceae	Guddiam	*Grewia tenax*	leaf	4.3	-0.8
46	Malvaceae	Baobab	*Adansonia digitata*	leaf	4.1	16.8
47	Rhamnaceae	Sidr	*Ziziphus spinachristi*	leaf	4.1	9.22
48	Leguminosae	Alsurib	*Phyllanthus maderaspatensis*	leaf	3.9	14.3
49	Fabaceae	(Peanut)	*Arachis hypogaea*	leaf	3.0	11.3
50	Fabaceae	Aradeeb	*Tamarindus indica*	leaf	3.0	5.9
51	Asteraceae	Rantook	*Xanthium brasillicum*	leaf	0.4	13.8
52	Zygophyllales	Dresa	*Tirbulus terrestris*	leaf	0	-3.8
53	Poaceae	Um Koaat	*Brachiaria eruciformis*	leaf	-1.1	7.9
54	Salvadoraceae	Arak	*Salvadora peresica*	leaf	-4.3	4.4
55	Pedaliaceae	(Sesame)	*Sesamum indicum*	leaf	-5.2	4.3

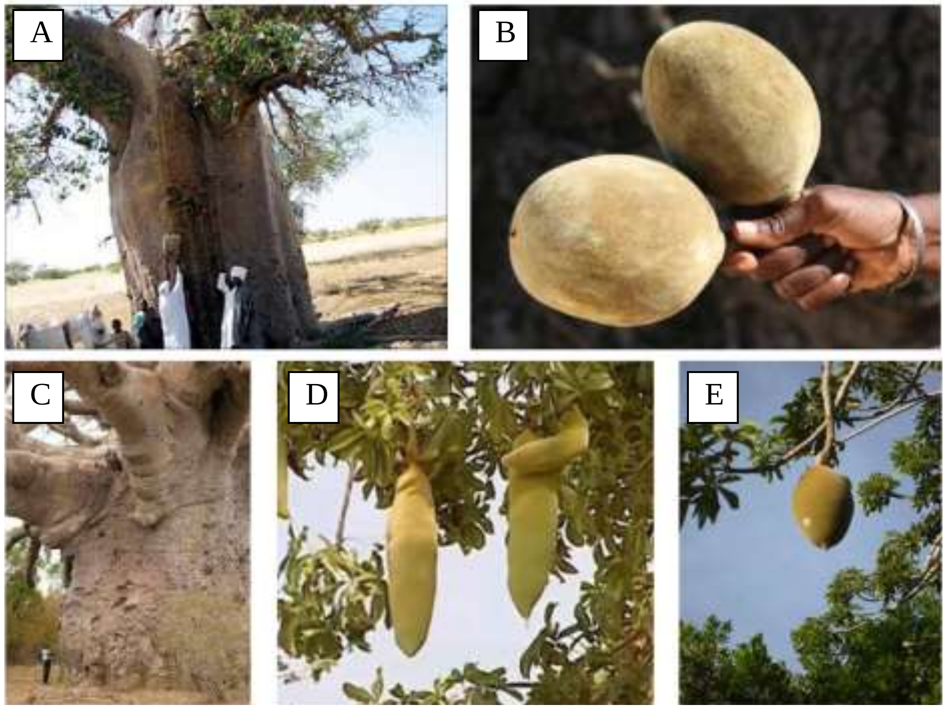

Figure 1. Baobab tree (a, c) and fruits (b, d, e) in Sudan.

mespiliformis) inhibited the growth of hypocotyl and radicle of lettuce seedlings by 27.4 and 19.4% respectively. Leaf volatiles from *C. olitorius* showed the relatively close inhibition of hypocotyl growth to the results observed for baobab leaf volatiles (21 and 23.9%, respectively). Essential oil from flowers and leaf of *C. olitorius* was previously analyzed by gas chromatography/mass spectrometry and main components benzaldehyde (56%), methyl 4-methoxysalicylate (6.55%) and carvacrol (4.75%) were identified (Driss et al., 2015), however there is no information about allelopathic potential of *C. olitorius*.

Fruit volatiles of kardade (*H. sabdariffa*) suppressed the radicle and hypocotyl growth of lettuce by 29.6 and 20.1%, respectively. (Farag et al., 2015) previously identified 104 volatiles from hibiscus flower aroma using solid-phase microextraction coupled to GC-MS. Moreover, it has been previously reported the presence of two allelochemicals, trimethyl allo-hydroxycitrate and β-sitosterol, in hibiscus fruits (Piyatida *et al.*, 2013). Despite not much is known about allelopathy of hibiscus though volatile compounds (Piyatida and Kato-Noguchi, 2011) and (Piyatida et al., 2013) isolated and identified active substance β-sitosterol with I_{50} values of 16.2 and 406.7 μM for cress and lettuce, respectively.

Allelopathic activity of volatiles from baobab leaves

Volatiles from baobab (*A. digitata*) leaves inhibited 23.9% of hypocotyl growth and 21.5% of radicle growth. Plant growth inhibitory activity by baobab through volatile compounds was not previously studied, but it was reported that baobab root extracts may inhibit the germination and seedling growth of *L. sativa*, *H. sabdariffa*, and *S. bicolor* (Suleiman and Banagab, 2016).

Baobab is an indigenous tree of Malvaceae family growing in the arid and semi-arid areas of Africa (Cissé et al., 2013; Rahul et al., 2015) as a solitary plant or occasionally in groups (Gebauer et al., 2016) (Figure 1). In Sudan, baobab is mainly occurring in the southern area, which can be considered as the extreme northern part of the East African distributional range of the species (El Amin , 1990; Gebauer et al., 2016). Baobab was also introduced in India and Sri Lanka centuries ago by Moslem traders, and into Asian and North American countries as an ornamental plant (Sidibe et al., 2002; Rahul et al., 2015). Since ancient time baobab has been widely utilized by indigenous people for medicinal and nutritional purposes (Kamatou et al., 2011; Cissé Ibrahima et al., 2013; Coe et al., 2013); leaves and seeds are used for soups, while locals prepare a drink from baobab pulps dissolving them in water or milk (Becker, 1983; Sidibe et al., 2002).

While there is limited information on volatile allelochemicals for all screened plants and some of them can be considered as the promising source of allelopathic compounds, in this research we focused on the identification of volatile compounds that caused allelopathic activity from baobab leaves due to their

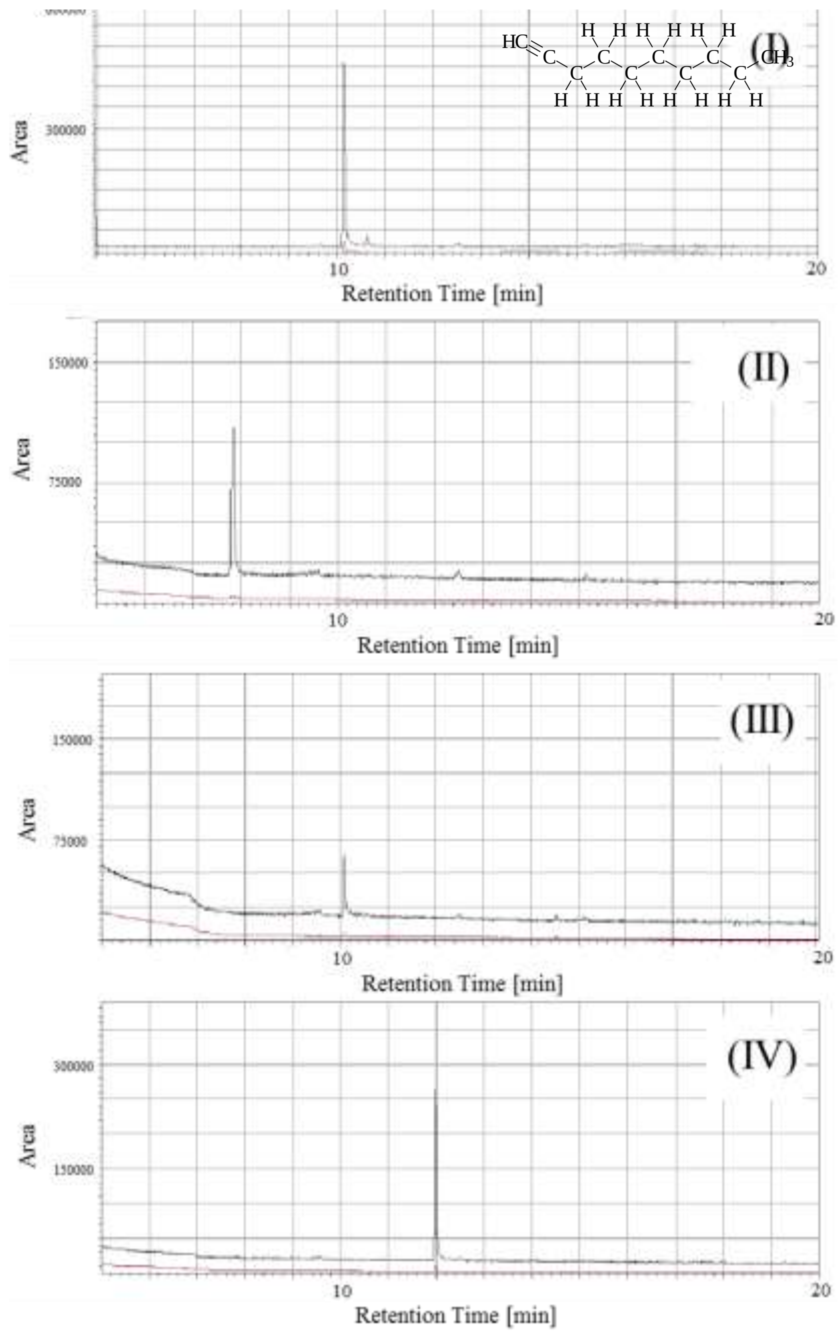

Figure 2. Confirmation of a major peak from baobab volatiles (I) using pure standard compounds: 1-nonyne (II), 1-decyne (III) and 1-undecyne (IV).

availability for locals and high biomass.

Identification of volatile allelochemicals from baobab leaves

Headspace GC-MS analysis of volatiles naturally emitted from baobab leaves showed the presence of one major peak with retention time of 10.00 min, corresponding to 1-decyne from in-house library. The compound was confirmed by using an authentic 1-decyne in comparison with 1-undecyne and 1-nonyne, which revealed a retention time of 11.99 and 7.84 min, respectively. The chromatograms of 1-decyne, 1-undecyne, and 1-nonyne are displayed in Figure 2. The concentration of 1-decyne in the headspace (0.43 ng/ml) was calculated based on the calibration curve of authentic 1-decyne and the peak area of 1-decyne emitted from baobab leaves.

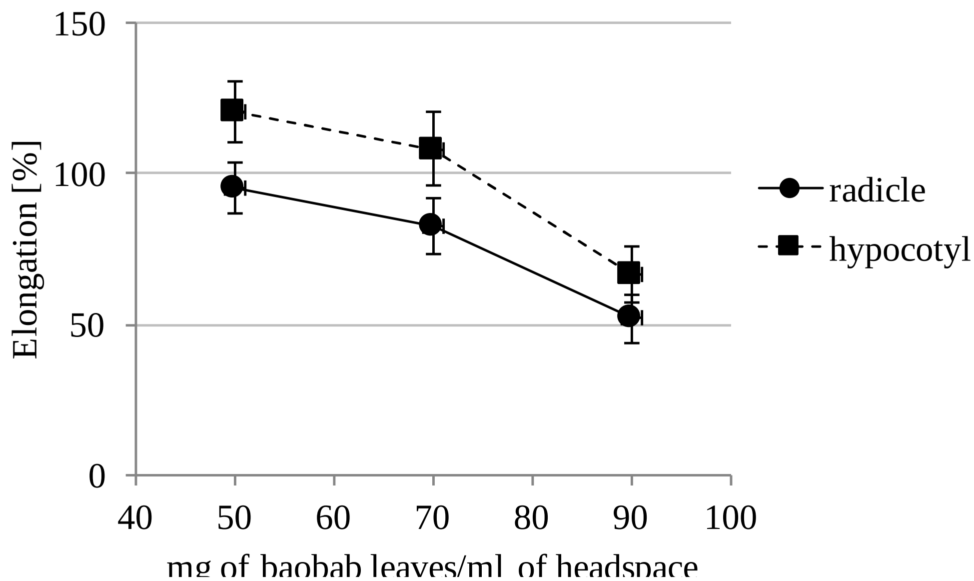

Figure 3. Effect of volatiles from baobab leaves on the radicle and hypocotyl growth of lettuce seedlings.

1-Decyne is an alkyne hydrocarbon with the chemical formula $C_{10}H_{18}$. This compound has been previously identified in the essential oil of *A. racemosa* leaf which showed the larvicidal activity against three mosquito species, *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus* (Arun et al., 2015). (Ahmad et al., 2016) reported 1-decyne as one of 123 components of essential oil from *Rumex hastatus* which possess anticholinesterase and antioxidant potentials. GC-MS analysis of methanol extract of flowers of *Viola odorata* showed the presence of 1-decyne (Jasim et al., 2018). Moreover, 1-decyne was reported as one of the major volatile from photo-oxidized cottonseed oil (Fan et al., 1983) volatile 1-decyne was previously also determined in the defensive secretions of male and female of *Pyrrhocoris tibialis* and *Scantlus aegyptlus* (Krajicek et al., 2016). Despite the fact that 1-decyne has been previously identified as natural chemicals from plants, there was no report on the plant growth inhibitory activity by 1-decyne.

A contribution of 1-decyne into the total inhibitory activity of volatiles from baobab

Naturally released volatiles from dried leaves of baobab significantly inhibited growth of radicle and hypocotyl of lettuce seedlings at EC_{50} > 90 mg of baobab leaves/ml of headspace (Figure 3). The plant growth inhibitory activity of authentic 1-decyne in headspace was expressed as EC_{50} value (50% of radicle or hypocotyl growth inhibition) and was detected at ≈0.5 ng of 1-decyne/ml of headspace (Figure 4). Based on it the contribution of 1-decyne released from baobab leaves into the total inhibitory activity of leave volatiles in shown in Figure 5 and demonstrates that 1-decyne is responsible for the total allelopathic activity. 1-Decyne is a compound with the triple bond (Figure 2), and it is well known that *cis*-dehydromatricaria ester, an allelochemical reported from *Solidago* and *Erigeron* spp, also contains triple bond in their structure.

Our results demonstrated stronger inhibitory activity of 1-decyne compared to the previously published EC_{50} value for volatile allelochemicals octanal and safranal obtained by the same method. So, it was previously reported that *Heracleum sosnowskyi* fruits emit octanal at concentration 20 ng/cm^3 (Mishyna et al., 2015), while EC_{50} of safranal, an allelochemical from *C. sativus* is 1 and 2 µg/l for lettuce radicle and hypocotyl, respectively (Mardani et al., 2015). Moreover, allyl isothiocyanate and methyl isothiocyanate, the major volatiles released form chopped plants as allelopathic green manure crops, completely inhibited the germination of all tested species at a headspace gas concentration of 1 ppm (Vaughn and Boydston, 1997).

Conclusion

Evaluation of allelopathic activity through volatile compounds of 55 plants from Sudan revealed several potential plants with high plant growth inhibitory activity (*T. brownie, E. hirta*, *D. mespiliformis*, *A. digitata*, *C. olitorius*). Allelopathic activity of volatiles emitted from baobab leaves can be explained by the presence of 1-decyne, a newly determined volatile allelochemical. 1-

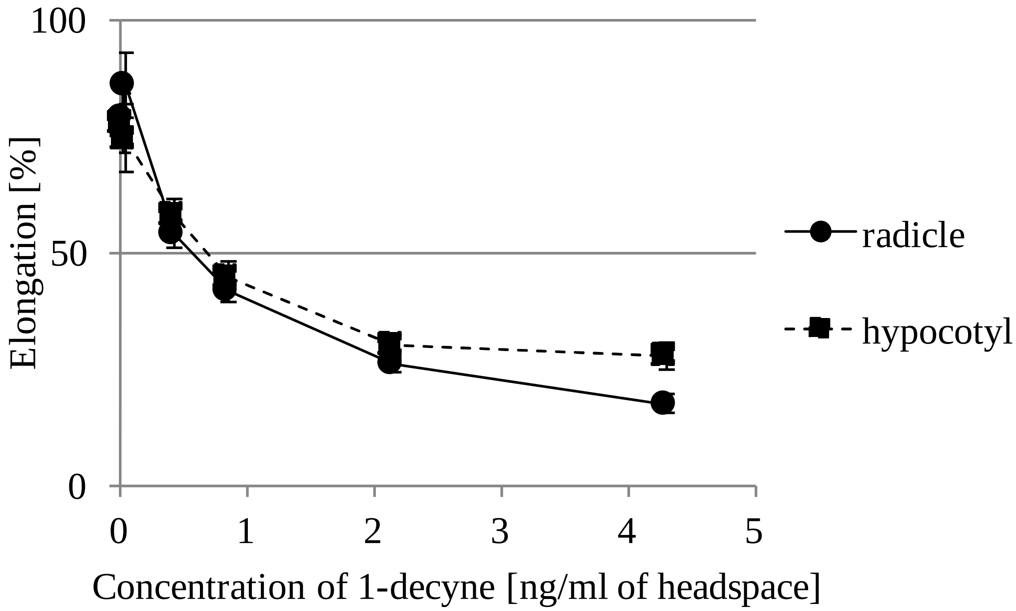

Figure 4. Effect of authentic 1-decyne on the radicle and hypocotyl growth of lettuce seedlings.

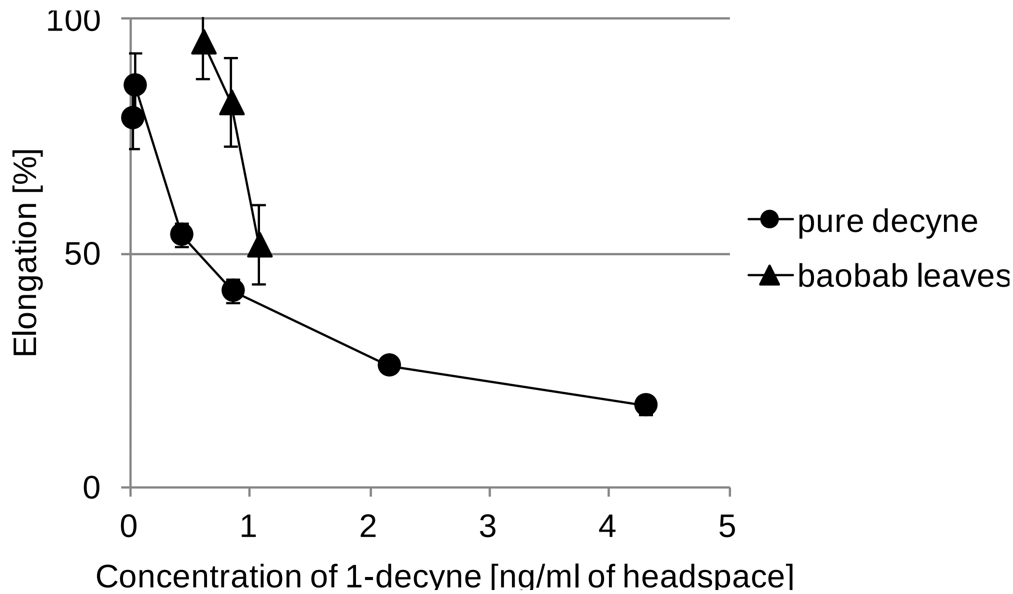

Figure 5. Contribution of 1-decyne to the radicle inhibition of lettuce seedlings by volatiles from baobab leaves.

decyne could be an important allelochemical for the survival of baobab in Africa and may offer a potential for future development of new volatile plant growth modulator.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ahmad S, Ullah F, Sadiq A (2016). Chemical composition, antioxidant and anticholinesterase potentials of essential oil of Rumex hastatus D. Don collected from the North West of Pakistan. BMC Complementary and Alternative Medicine 16(1):29.

Arun K Das, Suresh K, Swamy P (2015). Larvicidal activity and leaf essential oil composition of three species of genus Atalantia from south India. International Journal of Mosquito Research 2(3):25-29

Azuma K, Nakayama M, Koshioka M (1999). Phenolic antioxidants from the leaves of *Corchorus olitorius* L. Journal of Agriculture and Food

Chemistry 47:3963-3966.
Becker B (1983). The contribution of wild plants to human nutrition in the Ferlo (Northern Senegal). Agroforestry System 1:257-267.
Cheng F, Cheng Z (2015). Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. Frontier Plant Science 6:1020. 10.3389/fpls.2015.01020.
Cissé I, Montet D, Reynes M, Danthu P, Yao B, Boulanger R (2013) Biochemical and nutritional properties of baobab pulp from endemic species of Madagascar and the African mainland. African Journal of Agricultural Research 8:6046-6054.
Coe SA, Clegg M, Armengol M, Ryan L (2013) The polyphenol-rich baobab fruit (*Adansonia digitata* L.) reduces starch digestion and glycemic response in humans. Nutrition Research 33:888-896.
Driss D, Kaoubaa M, Mansour R Ben, Kallel F, Abdelmalek B, Chaabouni SE (2015) Antioxidant, antimutagenic and cytotoxic properties of essential oil from Corchorus olitorius L. flowers and leaf. Free Radicals Antioxidants 6:34-43.
El Amin HM (1990). Trees and shrubs of the Sudan. Ithaca Press.
Fan LL, Tang J-Y, Wohlman A (1983) Investigation of 1-decyne formation in cottonseed oil fried foods. Journal of the American Oil Chemists' Society 60:1115-1119.
Farag MA, Rasheed DM, Kamal IM (2015). Volatiles and primary metabolites profiling in two *Hibiscus sabdariffa* (roselle) cultivars via headspace SPME-GC-MS and chemometrics. Food Research International 78:327-335 10.1016/J.FOODRES.2015.09.024.
Fujii Y, Matsuyama M, Hiradate S, Shimozawa H (2005). Dish pack method: a new bioassay for volatile allelopathy. Proc 4th World Congr ess in Allelopath pp. 493-497.
Gebauer J, Adam YO, Sanchez AC (2016). Africa's wooden elephant: the baobab tree (*Adansonia digitata* L.) in Sudan and Kenya: a review. Genetic Resources and Crop Evolution 63:377-399.
Green JM, Owen MDK (2011) Herbicide-resistant crops: utilities and limitations for herbicide-resistant weed management. Journal of Agriculture and Food Chemistry 59:5819-5829.
Hamada AA (2000). Weeds and weed management in Sudan. Journal of Weed Science and Technology 45:131-136.
Jasim SF, Baqer NN, Alraheem EA (2018). Detection of phytochemical constituent in flowers of Viola odorata by gas chromatography-mass spectrometry. Asian Journal of Pharmacy and Clinical Research 11:262.
Kamatou GPP, Vermaak I, Viljoen AM (2011). An updated review of *Adansonia digitata*: A commercially important African tree. South African Journal of Botany 77:908-919.
Krajicek J, Havlikova M, Bursova M, Ston M, Cabala R, Exnerova A, Stys P, Bosakova Z (2016). Comparative analysis of volatile defensive secretions of three species of Pyrrhocoridae (Insecta: Heteroptera) by gas chromatography-mass spectrometric method. (JC Dickens, Ed.). PLoS One 11:e0168827.
Ladhari A, Omezzine F, Haouala R (2014). The impact of Tunisian Capparidaceae species on cytological, physiological and biochemical mechanisms in lettuce. South African Journal of Botany 93:222-230. 10.1016/J.SAJB.2014.04.014.
Mahgoub F (2014). Current status of agriculture and future challenges in Sudan. Nordiska Afrikainstitutet. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A712485&dswid=-7173
Mardani H, Sekine T, Azizi M, Mishyna M, Fujii Y (2015). Identification of safranal as the main allelochemical from saffron (*Crocus sativus*). Natural Product Communications 10(5):1934578X1501000519 10:775-777.
Mbiri JW, Kasili S, Kisangau PD, Musila MN, Piero MN, Mbinda WM (2016). Antinociceptive Properties of Methanolic Bark Extracts of Terminalia brownii in Wistar Rats. Journal of Pain and Relief 5(261):2167-0846.
Mishyna M, Laman N, Prokhorov V, Maninang JS, Fujii Y (2015). Identification of octanal as plant growth inhibitory volatile compound released from Heracleum sosnowskyi fruit. Natural Products Communication 10:771-774.
Nagulendran K, Velavan S, Mahesh R, Begum VH (2007). In vitro antioxidant activity and total polyphenolic content of Cyperus rotundus rhizomes. E-Journal of Chemistry 4:440-449.
Ogunlesi M, Okiei W, Ofor E, Osibote A (2009). Analysis of the essential oil from the dried leaves of Euphorbia hirta Linn (Euphorbiaceae), a potential medication for asthma. African Journal of Biotechnology 8(24):7042-7050.
Piyatida P, Kato-Noguchi H (2011). Evaluation of allelopathic activity of *Hibiscus sabdariffa* L. Advances in Biological Research (Rennes) 5:366-372.
Piyatida P, Kimura F, Sato M, Kato-Noguchi H (2013). Isolation of β-sitosterol from Hibiscus sabdariffa L. Allelopathy Journal 32:289-300.
Rahul J, Jain MK, Singh SP (2015). *Adansonia digitata* L. (baobab): a review of traditional information and taxonomic description. Asian Pacific Journal of Tropical Biomedicine 5:79-84.
Salih EYA, Julkunen-Tiitto R, Lampi A-M (2018). Terminalia laxiflora and Terminalia brownii contain a broad spectrum of antimycobacterial compounds including ellagitannins, ellagic acid derivatives, triterpenes, fatty acids and fatty alcohols. Journal of Ethnopharmacology 227:82-96.
Sidibe M, Williams JT, Hughes A, Haq N, Smith RW (2002). Baobab, Adansonia digitata L. International Centre for Underutilised Crops. ISBN 0854327649 Printed at RPM Reprographics, Chichester, England. https://docplayer.net/56462807-Baobab-adansonia-digitata-l-authors-m-sidibe-and-j-t-williams-editors-a-hughes-n-haq-r-w-smith.html
Sunmonu TO, Van Staden J (2014). Phytotoxicity evaluation of six fast-growing tree species in South Africa. South African Journal of Botany 90:101-106.
Suwitchayanon P, Pukclai P, Ohno O, Suenaga K, Kato-Noguchi H (2015). Isolation and identification of an allelopathic substance from *Hibiscus sabdariffa*. Natural Products Communication 10:765-766.
Vaughn SF, Boydston RA (1997). Volatile allelochemicals released by Crucifer green manures. Journal of Chemical Ecology 23:2107-2116.
Weston LA (1996) Utilization of allelopathy for weed management in agroecosystems. Agronomy Journal 88:860.
Williams JT, Farias RM (1972). Utilisation and taxonomy of the desert grass Panicum turgidum. Economic Botany 26(1):13-20.

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Production performance of sunflower genotypes in Campo Novo do Parecis, Brazil´s main producing region of the oleaginous plant

Flávio Carlos Dalchiavon[1*], Anderson Morais Kimecz[1], Marcelo Marchesini[1], Diego Hahn Machado[1], Wellington Junior Candido da Silva[1], Rosivaldo Hiolanda[1] and Claudio Guilherme Portela de Carvalho[2]

[1]Department of Agronomy, Federal Institute of Education, Science and Technology of Mato Grosso (IFMT), 78360-000, P. O. Box 100, Campo Novo do Parecis MT Brazil.
[2]Brazilian Agricultural Research Corporation, Embrapa Soybean, 86001-970, Londrina - PR, Brazil.

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Sunflower crops have a wide adaptability to several edaphoclimatic conditions, with possible alternative for a second harvest. Crops are diversified and extra profit is collected by the producer. Current assay determines the agronomic characteristics of the sunflower genotype planted in second harvest in Campo Novo do Parecis MT Brazil, the main sunflower producing region in Brazil. The assay was conducted on the experimental field of the Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso, Campus Campo Novo do Parecis MT Brazil, in the agricultural year 2016-2017. Experimental design comprised randomized blocks with 4 replications and 5 treatments from hybrids SYN 045, BRS G40, BRS G49, BRS G50 and BRS G51. The sunflower´s vegetative and reproductive characteristics were evaluated. Hybrids SYN 045, BRS G51 and BRS G40 had good performance in grain and oil. Hybrid BRS G51 showed good performance in grains and oil with reduced cycle and size.

Key words: Production components, performance of varieties, *Helianthus annuus.*

INTRODUCTION

The sunflower (*Helianthus annuus*) is an annual dicotyledon plant of the family Asteraceae, known for its adaptability to different edaphoclimatic conditions making possible its cultivation in all continents. The crop is employed for the production of edible oil and animal feed, among others (Souza et al., 2015; Carvalho et al., 2019).

It is highly common in Brazil to have a second summer harvest in February, when the main crop, planted between October and the start November, is harvested (Porto et al., 2008; Dalchiavon et al., 2015). Sunflower is one of the crops suitable as the second summer crop, mainly cultivated in the central-western region, especially in Campo Novo do Parecis, state of Mato Grosso, Brazil. The area cultivated in Brazil in 2017-18 reached 95.5 thousand hectares, of which 60.5 thousand hectares were in the state of Mato Grosso (CONAB, 2018). In

*Corresponding author. E-mail: flavio.dalchiavon@cnp.ifmt.edu.br. Tel: +00 55 65 996175059.

these areas, the Brazilian production totaled 142.2 thousand tons, with 101.9 thousand tons mainly produced in Campo Novo do Parecis. The region is characterized by adequate temperature and well-defined dry season (Dalchiavon et al., 2016a, b).

Current agricultural system in Campo Novo do Parecis scarcely employs crop rotation, with the subsequent occurrence of pests and diseases. The sunflower is an oleaginous plant, with greater resistance against draught, cold and heat than most of the species cultivated in Brazil. In fact, it features great adaptability to different soil-climate conditions, practically not affected by latitude, altitude and photoperiod (Porto et al., 2008). Consequently, it is a good option in crop rotation systems in the region of Campo Novo do Parecis, since it contributes towards agricultural diversity (Dalchiavon et al., 2016a,b).

Research-based data have been decisive for the technological basis of the crop´s development in Brazil, with greater productivity and competitive economical profits (Dalchiavon et al., 2019). The proper selection of cultivars is one of the main components of the crop´s production system among the several technologies developed for the production of sunflower (Porto et al., 2007; Souza et al., 2014). Cultivars should be adapted to regions and should have features that facilitate cultural practices, decrease risks of production loss and increase the producer´s profits (Dalchiavon et al., 2016a). Current assay determines the agronomic characteristics of the sunflower genotype planted in the second summer harvest in Campo Novo do Parecis MT Brazil.

MATERIALS AND METHODS

The experiment was developed within the experimental area of the Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso (IFMT) - campus Campo Novo do Parecis, during the harvest of the agricultural year 2016-2017, at 13°40'37''S and 57°47'30''W, altitude 564 m. According to the Brazilian Classification of Soils (EMBRAPA, 2013), the region´s soil is typical Red-Yellow Dystrophic Latosol. Initial fertility characteristics for the 0- 0.20 m layer had the following features: pH ($CaCl_2$) = 4.97; MO = 27.02 g dm^{-3}; K^+ = 0.05 $cmol_c$ dm^{-3}; Ca^{+2} = 2.17 $cmol_c dm^{-3}$, Mg^{+2} = 0.85 $cmol_c dm^{-3}$; H^+ = 4.61; H+Al = 4.61 $cmol_c$ dm^{-3}; P = 7.47 mg dm^{-3}; Cu = 1.03 mg dm^{-3}; Zn = 4.19 mg dm^{-3}; Fe = 189.53 mg dm^{-3}; Mn = 15.76 mg dm^{-3}, with V = 39.98%.

According to Köppen´s classification, local climate, referred by Vianello and Alves (2004), is Aw, or rather, tropical climate with a well-defined dry season between May and September. Dry and rainy seasons are well-defined: dry between May and September and rainy between October and April (Dallacort et al., 2011). Figure 1 shows mean rainfall and temperatures during the experimental period. Mean rates comprised 31.0; 23.3 and 18.4°C respectively for maximum, mean and minimum temperatures, with rainfall at 510.4 mm, perfectly fitting the crop´s water demand between 500 and 700 mm, regularly distributed throughout the cycle (Castro and Farias, 2005).

Experimental design comprised randomized blocks with 5 treatments and 4 replications. Treatments consisted of hybrids SYN 045 (control), BRS G40, BRS G49, BRS G50 and BRS G51. Tested hybrids were simple hybrids developed by Embrapa´s improvement program. Experimental plots were formed by four 6 m rows, with 0.45 m spaces and a population of 45,000 plants ha^{-1}. Useful area was defined by two 5.0 m central rows, taking off 0.5 m from each edge, as border, and side rows.

Prior to seeding, the area was sprayed with herbicide Paraquat (20% i.a.) at 1.5 L ha^{-1} to eliminate infesting plants on the experimental area. Seeding, with three seeds per hole, was performed with a sowing rack on 10th March 2017. Thinning occurred 10 days after emergence (DAE) so that only one plant/hole would remain. Base fertilization followed Leite et al. (2007) with a chemical analysis of the soil to attend to crop needs: 10 kg ha^{-1} N; 70 kg ha^{-1} P_2O_5; 60 kg ha^{-1} K_2O; 2 kg ha^{-1} B, distributed previously with seeding, at a row below the seeds, with a 7-row sower. Cover fertilization was done 30 DAE, at 60 kg ha^{-1} N, with urea, and 0.5 L ha^{-1} Boron through the leaves, with borosol (14.6% Boron), with application volume at 200 L ha^{-1}.

Weeds were eliminated by hand at 7, 20 and 35 DAE. Pest and disease controls were undertaken by constant monitoring of the area. Two applications of Tiametoxan + Lambda Cialotrina (141 g L^{-1} + 106 g L^{-1} i.a., respectively), at dose 250 ml ha^{-1}, were undertaken for the control of the cucurbit beetle (*Diabrotica speciosa*), sunflower patch (*Chlosyne lacinia*) and the *Cyclocephala melanocephala* beetle, when plant reached V4 stage (four true leaves) and V6 (six true leaves); an application of Alpha-cypermethrin (1000 g L^{-1} i.a.) at 100 ml ha^{-1} when sunflower reached R1 (visible inflorescence); and one application of acephate (750 g kg^{-1} i.a.) at 1 kg ha^{-1} when the sunflower reached R5 (start of anthesis). Two doses of Difeconazol (250 g L^{-1} i.a.) at 0.3 L ha^{-1} were applied for disease control of plant pathogen *Alternaria helianthi*) when crop reached V6 and R1. Applications were done by shoulder-strapped pump with CO_2, at a constant pressure of 60 pounds.

Hand harvest was undertaken within the useful area when the crop reached the phenological stage of physiological maturity (R9) on June 30th 2017. A mechanized trailer (Maqtron – B 350 STD) was employed to separate achenes from the head and send for laboratory analysis. Achenes were weighed and humidity corrected to 11% (b.u.), following Dalchiavon et al. (2016a).

Evaluated agronomic characteristics at R5.5 (full florescence), in five plants per plot, comprised plant height (PH; m), measured by tape and taking soil level as the highest section of the plant; stalk diameter (SD; mm), measured by digital caliper at 5 cm from soil level; fresh mass of aerial section (FMA; t ha^{-1}) and of root (MFR, t ha^{-1}) and dry mass of the aerial sector (DMA; t ha^{-1}) and of root (DMR, t ha^{-1}), after weighing and drying of plants in a buffer at 105°C. Harvest of fresh and dry mass of the aerial sector was divided into stalk, leaves and head.

Assessment of the following in five head was undertaken at R9: head diameter (HD; cm), measuring its extremities by tape; number of achenes per head (NAH), by grain counter (Model NV-C/01); mass of head (MH; g) and mass of achenes per head (MAH; g) by semi-analytic scale (0.01 g); harvest index (HI), by dividing the mass of achenes by the mass of the head; mass of 1000 achenes (MTA; g) and the productivity of achenes (PA; kg ha^{-1}), based on the harvest of plants of the plot´s useful area.

Assessment was also made for initial florescence days (IFD) and days for physiological maturity (DPM), till plants reached stage R4 (initial florescence) and R9 (physiological maturing), respectively; number of broken plants (NBP) and number of lodging plants (NLP) within the plot´s useful area (R9), for hectare; oil rate (OR; %), forecast by spectroscopy (Grunvald et al., 2014) and oil productivity (OP, kg ha^{-1}), calculated by the product of oil rate of achenes (%) and the productivity of achenes (kg ha^{-1}) / 100. When data complied with the presuppositions of homogeneity and residues´ constant variance, they underwent analysis of variance; when F was significant ($p<0.05$), Tukey´s mean test was applied by SISVAR (Ferreira, 2011); Pearson´s co-relationship analysis was employed between characteristics, by Excel.

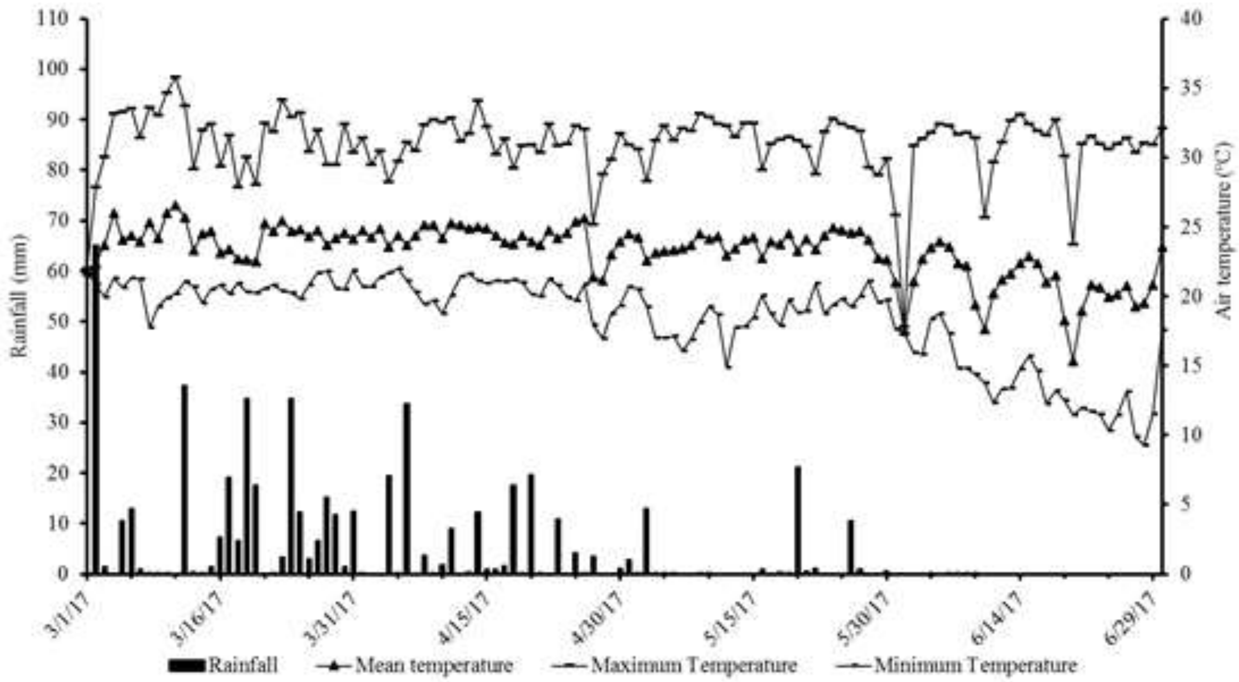

Figure 1. Rainfall and mean temperature in the experimental region between March and June, 2017.

RESULTS AND DISCUSSION

There was significant difference ($p<0.05$) among the characteristics evaluated for physiological maturing days, height of plants, stalk diameter, number of lodging plants, mass of one thousand achenes, mass of achenes per head and productivity of achenes (Table 1). The physiological maturing of genotypes had a general average of 107 days (Table 1). However, the latest material was SYN 045, with 113 days (Table 2), whereas the others did not statistically differ from one another, varying between 105 and 107 days. An assay by Carvalho et al. (2016), conducted in Tangará da Serra MT Brazil, a town with similar edaphoclimatic conditions as that in current study, proved SYN 045 to be the latest, with 106 days, whereas hydrids BRS G40, BRS G49, BRS G50 and BRS G51 did not differ among themselves, with rates between 93 and 94 days. Difference in the hybrid cycle among studies may be the result of severe draught in the municipality of Tangará da Serra. In fact, sowing dates were similar, or rather, March 9th, 2016 for Tangara da Serra and 10th March 2017 for Campo Novo do Parecis. According to Dalchiavon et al. (2016b), very early hybrids are less prone to the occurrence of insect pests, diseases and water deficit in second harvest crop when compared to late hydrids. Risk in production loss and grain quality may be reduced if the management of these factors is not efficient.

According to Kaya et al. (2007), there is a significant co-relationship between physiological maturing and plant height. In current study (Table 2), the latest hybrid (SYN 045) was the highest. Dalchiavon et al. (2016b) also reported such co-relationship in their study in which Genotype GNZ Neon was the latest, featuring 99 days, and the highest, featuring 199.00 cm. Highest averages in plant height were reported for SYN 045 (164.1 cm), BRS G40 (164.7 cm) and BRS G51 (131.9 cm). The first two hybrids differed statistically from the others (Table 2), with averages below 125.8 cm (BRS G50 and BRS G49), corroborating data by Carvalho et al. (2016), who registered SYN 045 as the highest (114 cm) and BRS G50 and BRS G49 as the shortest, featuring 88.0 and 81.0 cm, respectively, and by Dalchiavon et al. (2016a) who also registered highest average for SYN 045 (198.5 cm). The above proved that the hybrid had the plant´s highest height. Plant height is an important characteristic when mechanized agriculture is taken into account since higher plants may make difficult mechanized operations. Shorter and more uniform plants are required for an adequate mechanized harvest, with fewer losses (Pivetta et al., 2012; Dalchiavon et al., 2016a,b; Hiolanda et al., 2018).

With the exception of BRS G49 (16.5 mm), all hybrids had a stalk diameter greater than 18.0 mm and did not differ statistically from control SYN 045 ($p<0.05$) (Table 2). Stalk diameter is an important characteristic for crops. According to Biscaro et al. (2008), their good development causes less lodging, making easier crop treatments and mechanized harvest. In current assay, there was a decrease in final population: 0 (SYN 045); 1.03 (BRS G50); 2.06 (BRS G51) and 3.09% (BRS G49) when compared to initial population of 45,000 plants ha^{-1},

Table 1. Analysis of variance for the characteristics of the sunflower under analysis (Campo Novo do Parecis MT Brazil, 2017).

Characteristics[1]	F[2]	CV (%) [3]	GM [4]
IFD	0.4	5.4	57.0
DPM	6.2*	2.5	107.0
PH	10.8*	8.3	139.4
SD	4.7*	9.4	19.3
NLP	6.8*	76.6	1157.5
NBP	1.1	111.2	1111.2
HD	2.1	9.2	17.8
FMR	1.9	16.9	3.5
FMA	1.8	17.3	36.3
DMR	2.0	20.6	1.7
DMA	0.8	12.4	6.1
MTA	7.8*	18.4	70.5
NAH	1.3	15.8	715.0
MAH	3.8*	27.0	45.7
HI	2.5	7.9	0.6
PA	7.5*	13.0	2185.8
OR	0.9	4.02	41.9
OP	4.61*	13.4	855.7

[1]IFD = initial florescence days (days), DPM = days for physiological maturing (days), PH = plant height (cm), SD = stalk diameter (mm), NLP = number of lodging plants (plants ha^{-1}), NBP = number of broken plants (plants ha^{-1}), HD = head diameter (cm), FMR = fresh mass of roots (t ha^{-1}), FMA = fresh mass of aerial sector (t ha^{-1}), DMR = dry mass of root (t ha^{-1}), DMA = dry mass of aerial sector (t ha^{-1}), MTA = mass of one thousand achenes (g), NAH = number of achenes per head, MAH = mass of achenes per head (g), HI = harvest index, PA = productivity of achenes (kg ha^{-1}), OR = oil rate; OP = oil productivity; [2]* significant at 5%; [3]CV = coefficient of variation; [4] GM = general means.

Table 2. Average of characteristics: days for physiological maturing (DPM, days), plant height (PH, cm), stalk diameter (SD, mm) and the number of lodging plants (NLP, plants ha^{-1}) (Campo Novo do Parecis MT Brazil, 2017).

Genotype	DPM	PH	SD	NLP
SYN 045(T)	113.0^{a}	164.1^{a}	21.8^{a}	0.0^{b}
BRS G40	105.0^{b}	154.7^{ab}	19.0^{ab}	3009.5^{a}
BRS G49	105.0^{b}	120.4^{c}	16.4^{b}	1389.0^{ab}
BRS G50	107.0^{b}	125.8^{c}	18.8^{ab}	463.0^{b}
BRS G51	107.0^{b}	131.9^{bc}	20.0^{ab}	926.0^{b}
DMS	5.9	26.1	4.0	1998.8

*Different letters differ by Tukey´s test at 5% probability. T = control.

due to lodging plants. Against Biscaro et al. (2008), albeit with similar SD, the hybrid BRS G40 had the greatest NLP (6.69% lodging) when compared to SYN 045, BRS G50 and BRS 51. On the other hand, the hybrid BRS G49 had similar NLP when compared to SYN 045, with the lowest SD.

Hybrids BRS G40 (82.1 and 46.6 g) and BRS G51 (80.4 and 46.4 g) provided the mass of 1000 achenes (MTA) and mass of achenes per head (MAH) similar to SYN 045 (86.7 and 64.7 g) ($p<0.05$) (Table 3). On the other hand, hybrid BRS G50 (44.5 and 36.8 g) had lower average rates to control for the two characteristics. Co-relation between MTA and the productivity of achenes (PA) (r = 0.647**) and between MAC and PA (r = 0.649**) were significant and positive, corroborating assays by Amorim et al. (2008), Pivetta et al. (2012) and Stasiak et al. (2018). Results for MTA and MAC may explain the productivity difference between the genotypes, since other characteristics such as the number of achenes per head and head diameter failed to showed any statistical difference between the genotypes.

The productivity of achenes varied between 1731.1 and 2499.3 kg ha^{-1} (Table 3). Rates are above average for Brazil for the 2017-2018 harvest, with 1489 kg ha^{-1}

Table 3. Average of characteristics: mass of 1000 achenes (MTA, g), mass of achenes per head (MAH, g), productivity of achenes (PA, kg ha^{-1}) and productivity of oil (OP) (Campo Novo do Parecis MT Brazil, 2017).

Genotype	MTA	MAH	PA	OP
SYN 045(T)	86.7^{a}	64.7^{a}	2499.3^{a}	1012.2^{a}
BRS G40	82.1^{a}	46.6^{ab}	2427.8^{ab}	912.4^{ab}
BRS G49	58.5^{ab}	33.8^{b}	1731.1^{c}	682.8^{b}
BRS G50	44.5^{b}	36.8^{b}	1792.7^{bc}	689.3^{b}
BRS G51	80.4^{a}	46.4^{ab}	2477.7^{a}	987.5^{a}
DMS	29.2	27.8	640.3	258.8

*Different letters differ by Tukey´s test at 5% probability. T = control.

(CONAB, 2018). SYN 045, BRS G51 and BRS G40 were highlighted, with achene productivity over 2400 kg ha^{-1}. SYN 045 (2499.3 kg ha^{-1}) average was 19 and 29% higher than that given by Dalchiavon et al. (2016a) and Hiolanda et al. (2018), respectively. The two had the same genotype, sown during the same period and in the same region as BRS G40 with 16% higher in achene productivity by Poletine et al. (2013) in an assay in Umuarama PR Brazil, during the 2011-2012 harvest. The existence of positive co-relationships between PA and PH were reported by Kaya et al. (2007) (r = 0.235**), Dalchiavon et al. (2016b) (r = 0.610*) and Stasiak et al. (2018) (r = 0.240*), and also in current assay (r = 0.621**). In fact, SYN 045 provided the highest plant and the highest rate in achene productivity (Tables 2 and 3), whereas hybrids of the shortest plants (BRS G49 and BRS G50) had the lowest averages in achene productivity. However, even with positive co-relationship between PH and PA, the hybrid BRS G51 had the smallest size, with PA similar to SYN 045.

According to Castro and Farias (2005), late cycle genotypes had a greater time period for grain filling and tended towards greater achene productivity rates. Hybrid SYN 045 was the latest and the most productive in absolute value. However, BRS G51 had PA similar to control ($p<0.05$), albeit earliest and shortest.

In current study, there was no significant difference between the hybrids´ oil rates, with a 41.9% average. This rate is higher than that desired by industries (over 40%). In fact, some industries forecast a depreciation of the product when rates are below those expected, or a bonus when rates are above (Porto et al., 2008). Since there was no difference between oil rates, the hybrids (SYN 045, BRS G51 and BRS G40) with greater grain yield were also those with highest oil yield.

Conclusion

(1) Hybrids tested showed similar performances for flowering, number of lodging plants, number of broken plants, head diameter, fresh and dry mass of root and aerial sector, number of achenes per head, mass of achenes per head and harvest index.
(2) Hybrid BRS G51 has good grain and oil yield, adequate plant´s cycle and height when cultivated in Campo Novo do Parecis, the main producing region in Brazil.
(3) As a proposition of this initial study, it is recommended to repeat it in time and in different places.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Amorim EP, Ramos NP, Ungaro MRG, Kiihl T (2008). Correlações e análise de trilha em girassol. Bragantia 67(2):307-316.

Biscaro GA, Machado JR, Tosta VM, Soratto RP, Carvalho LA (2008). Adubação nitrogenada no girassol irrigado nas condições de Cassilândia – MS. Ciência e Agrotecnologia 32(5):1366-1373.

Carvalho CGP, Caldeira A, Amabile RF, Godinho VPC, Ramos NP, Ribeiro JL, Oliveira ACB, Carvalho HWL, Brighenti AM (2016). Informes da Avaliação de Genótipos de Girassol 2015/2016 e 2016. (Série documentos / Embrapa Soja, n.381).

Carvalho CGP, Mazzola LF, Caldeira A, Dalchiavon FC, Mandarino JMG (2019). Quality of Sunflower Oil Obtained in the Main Producing Region of Brazil: Adherence to the Codex Alimentarius. Journal of the American Oil Chemists' Society pp. 1-6.

Castro C, Farias JRB (2005). Ecofisiologia do girassol. In: Leite RMVB de, Brighenti, AM, Castro C de (Ed.). Girassol no Brasil. Londrina: Embrapa Soja, pp. 163-210.

Companhia Nacional de Abastecimento (CONAB) (2018). Acompanhamento da safra brasileira - grãos. v.6, n.1, 2018. Brasília. 129 p. Available at: <http://www.conab.gov.br> on 11/02/2019.

Dalchiavon FC, Carvalho GP, Amabile RF, Godinho VPC, Ramos NP, Anselmo JL (2016b). Características agronômicas e suas correlações em híbridos de girassol adaptados a segunda safra.

Pesquisa Agropecuária Brasileira 51(11):1806-1812.
Dalchiavon FC, Lorenzon LA, Perina R de A, Oliveira RA de, Santos JA dos (2019). Economic Opportunity for Investment in Soybean and Sunflower Crop System in Mato Grosso, Brazil. Journal of Experimental Agriculture International 29(5):1-12.
Dalchiavon FC, Malacarne BJ, Carvalho CGP (2016a). Características agronômicas de genótipos de girassol (*Helianthus annuus* L.) em segunda safra no Chapadão do Parecis: MT. Revista de Ciências Agrárias 39(1):178-186.
Dalchiavon FC, Montanari R, Andreotti M, Dallacort R, Souza MFP (2015). Relationship between sunflower productivity and soil´schemical properties by geo-statistical techniques. African Journal of Agricultural Research 10(35):3525-3532.
Dallacort R, Martins JA, Inoue MH, Freitas PSL, Coletti AJ (2011). Distribuição das chuvas no município de Tangará da Serra, médio norte do Estado de Mato Grosso, Brasil. Acta Scientiarum Agronomy 33(2):193-200.
Empresa Brasileira De Pesquisa Agropecuária (EMBRAPA) (2013). Sistema brasileiro de classificação de solos. 3. ed. Brasília, DF: Embrapa 306 p.
Ferreira DF (2011). Sisvar: A computer statistical analysis system. Ciência e Agrotecnologia 35(6):1039-1042.
Grunvald AK, Carvalho CPG, Leite RS, Mandarino JMG, Andrade CAB, Scapim CA (2014). Predicting the oil contents in sunflower genotype seeds using near-infrared reflectance (NIR) spectroscopy. Acta Scientiarum Agronomy 36(2):233-237.
Hiolanda R, Dalchiavon FC, Biezus E, Iocca AFS, Carvalho CGP (2018). Contributo para o estudo do desempenho agronômico de híbridos na região produtora de girassol no Brasil (Chapadão do Parecis). Revista de Ciências Agrárias 41(1):14-22.
Kaya Y, Evci G, Durak S, Pekcan V, Gücer T (2007). Determining the Relationships between Yield and Yield Attributes in Sunflower. Turkish Journal of Agriculture and Forestry 31:237-244.
Leite RMVBC, Castro C, Brighenti AM, Oliveira FÁ, Carvalho CGP, Oliveira ACB (2007). Indications for sunflower cultivation in the States of Rio Grande do Sul, Paraná, Mato Grosso do Sul, Mato Grosso, Goiás and Roraima. Londrina: Empresa Brasileira de Pesquisa Agropecuária – CNPSo. 4 p.
Pivetta LG, Guimarães VF, Fioreze SL, Pivetta LA, Castoldi G (2012). Avaliação de híbridos de girassol e relação entre parâmetros produtivos e qualitativos. Revista Ciência Agronômica 43(3):561-568.
Poletine JP, Mendes MA, Sapia JG, Maciel CDG (2013). Avaliações morfoagronômicas e teor óleo em genótipos de Girassol nas condições do Arenito Caiuá. Journal of Agronomic Sciences 2(2):105-117.
Porto WS, Carvalho CGP, Pinto RJB (2007). Adaptabilidade e estabilidade como critérios para seleção de genótipos de girassol. Pesquisa Agropecuária Brasileira 42(4):491-499.
Porto WS, Carvalho CGP de, Pinto RJB, Oliveira MF de, Oliveira ACB de (2008). Evaluation of sunflower cultivar for central Brazil. Scientia Agricola 65(1):139-144.
Souza FR, Silva IM, Pellin DMP, Bergamin AC, Silva RP (2015). Características agronômicas do cultivo do girassol consorciado com *Brachiaria ruziziensis*. Revista Ciência Agronômica 46(1):110-116.
Souza LHB, Peixoto CP, Silveira PS, Ledo CAS, Lima VP, Santos APSG (2014). Características agronômicas e rendimento de girassol em diferentes épocas de semeadura e populações de plantas no Recôncavo da Bahia. Bioscience Journal 30(1):90-100.
Stasiak D, Dalchiavon FC, Birck M, Hiolanda R, Iocca AFS, Coletti AD, Carvalho CGP (2018). Agronomic characteristics of sunflower genotypes according to plant population. Revista de Ciências Agrárias 41(1):4-13.
Vianello RL, Alves AR (2004). Meteorologia básica e aplicações. Viçosa: UFV. 449 p.

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Construction and evaluation of soybeans thresher

Adeyeye O. A.[1*], Sadiku E. R.[1], Osholana T. S.[1], Reddy A. B.[1], Olayinka A. O.[1], Ndamase A. S.[1], Makgatho G.[1], Selvam P.[2], Perumal A. B.[2], Nambiar R. B.[2], Fasiku V. O.[3], Ibrahim I. D.[4] and Areo K. A.[4]

[1]Institute of Nano Engineering Research (INER), Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, Pretoria, RSA.
[2]Department of Food Process Engineering, School of Bio-Engineering, SRM University, Kattankulathur-603203, Tamilnadu, India.
[3]Department of Biological science, North West University, Private bag X2046 Mmabatho 2735, Mafikeng Campus, South Africa.
[4]Department of Mechanical Engineering, Mechatronics and Industrial Design, Faculty of Engineering and the Built Environment, Tshwane University of Technology, Building 2 Room 347 Pretoria Campus, South Africa.

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In order to resuscitate soybean production and post-harvest processing, especially in terms of threshing, there is a need to develop an affordable threshing machine, which will reduce drudgery associated with manual soybean threshing. Soybean thresher was fabricated and evaluated at the Institute of Agricultural Research and Training (IAR&T), Apata, Ibadan. The machine component parts includes: hopper, threshing unit, shaker, cleaning unit and the seed outlet; all working together to achieve the main objective of threshing and cleaning. TGX1835-10E variety was used for the evaluation because of its high resistance to pests, rust and pustules. The final moisture content of the sample used was about 15%. The sample was weighed and introduced to the machine. The parameters evaluated includes: Moisture content, threshing efficiency, cleaning efficiency, machine capacity and speed. The threshing efficiency and capacity are: 74% and 65.9 kg/h, respectively. All materials used were sourced locally, which makes the cost of production of the machine to be considerably cheaper than the imported soybean thresher.

Key words: Construction, efficiency, evaluation, soybean, threshing.

INTRODUCTION

Soybean (*Glycine max* (L.) merril) is an annual leguminous plant which belongs to the family of Papiliondea. Its origin can be traced back to China and it has spread all over the world. It is an erect branching plant, which produces pods. The pod may be straight or slightly curved and it is usually covered with hair. It ranges in color from very light to various shades of grey and brown to nearly black. Each pod measures about 2.5 to 5 cm long. As many as 300 to 400 pods can be produced by one plant and one pod may contain between 1 to 5 seeds. The seeds are round and sometimes oval in shape.

*Corresponding author. E-mail: yeyedeemzon@gmail.com; sadikur@tut.ac.za

Production of soybean has steadily increased around the world, it forms an integral part of both human and animal diets. Coalition of high yields per hectare in soybean farms (especially in the leading soybean producing areas) together with favorable soybean prices has made gross incomes per hectare for soybean producers to improve significantly (BFAP, 2013). For farmer to meet up with the demand of soybean in today's market, alternative and effective means of post-harvest handling must be developed which will increase production, reduce drudgery, maximize time of operation and less labor intensive. It must also be designed such that all steps involved will be combined in a single operation (Yang et al., 2016).

All soybean varieties examined by Beliavskaya (2017) were confirmed to have high economic value coefficient of agronomic stability higher than 70%. Animal agriculture is the largest consumer of soy protein and it is a growing industry around the world. Soybean is an excellent protein resource and also an efficient feed ingredient (NSRL, 2010). Soybean is the largest single source of edible oil and it accounts for roughly 50% of the total seed oil production, worldwide. Global production of soybean was approximately 219.8 million metric tons, in 2005 from which India produced about 9.3 million metric tons (FAO, 2007). This accounts for about 4% of the total world production. From this, less than 10% is consumed directly by human (Gandhi, 2006). In 2016, the Global Soybean Production was about 313.02 million tons, according to United States Department of Agriculture (USDA, 2017) global production will be about 345.96 million tons. This could account for an increase of 32.94 million tons or a 10.52% in soybean production around the globe from the previous year.

Deshpande et al. (1993) reported that soybean contains 35% total carbohydrate, 40% protein and 20% cholesterol-free oil. Soybean can be processed into varieties of products, such as vegetable oil, soy-milk and soy-cheese, soybeans cake for animal nutrition and also as "Soy-gari" (soybean fortified with gari). This is recommended for use in the fight against malnutrition in areas where cassava is consumed and protein intake is inadequate. As a legume crop, soybeans Improve yields by enhancing soil health, prevent soil erosion, conserve soil moisture and protect water quality. Merwe et al. (2013) reported that that the yield in production is connected to commercial farmers becoming aware of the importance of soybean in crop rotation systems with maize.

Threshing is the removal of grain from pod. It is also a post-harvest operation that must be given adequate concentration. It must be carefully carried out in order to ensure that the seeds are not damaged. A bad threshing operation will reduce the quality of the seeds or render them completely useless. The primitive system of threshing, which is usually done by beating soybeans with a flail or trampling on it by animal hooves, is usually energy-intensive (Shannon, 1984), that is, drudgery, increase in loss and wastes time. This has been replaced by modern day thresher, which is able to combine the processes together in a single operation. Mechanical threshing is expensive because it requires high technology; however, it helps to improve the quality of final product and removes all the problems associated with the old method of threshing (Olaoye, 2011). An effective threshing operation depends on type of crop, condition of crop in terms of available moisture content, maturity, rate at which materials are fed into the cylinder, speed of the threshing drum and the number of rows of concave clearance, amongst others (Bainer et al., 1960).

MACHINE COMPONENT PARTS AND THEIR FUNCTIONS

Each of the machine member parts was measured according to the working diagram specification. They were cut and joined together to form the complete machine. The machine was fabricated in order to serve as a soybean thresher for small- and medium-scale industries. It is designed to be powered by electric motor. It consists of the following parts: the hopper, shelling unit, blower, grain outlet, shaft, the spout, frame and base, pulley and bearing.

The hopper

This is the receptive part of the machine for onward transportation into the shelling compartment. It is a trapezoid in shape in order to allow easy flow of materials (soybeans) into the machine.

Shelling unit

This comprises the sieve spiels and it carries the hopper at the top. This unit is cylindrical in shape and it is divided into two equal parts, with the sieve/screen at the bottom. The sieve aids the transportation of the threshed soybeans to the sieve. It also reduces the amount of chaff that passes through the fan housing.

Spout

The sieve is embedded inside the spout. It is hollow and opens to the fan housing, which is the cleaning unit. The spout transfers the thresher compartment into the cleaning unit.

Grain outlet

The grain outlet is an opening which collects the clean grain as they drag from the concave into the collecting tray.

Blower

This is an enclosure of the cleaning unit, where the cleaning operation is carried out. It also helps to remove dust and high thrash materials from the desired grain.

Frame

The frame is a structural member of the thresher into which fittings

Figure 1. Soybeans threshing machine.

of the new component is directly attached on. The frame is very strong because of the distortion and its flexibility will affect the stability of the machine, which can lead to personal hazards.

Pulley

This transmits power from the source (electric motor) to other moving parts of the machine through the use of a belt.

CONSTRUCTIONAL DETAILS

The hopper was formed from metal sheet of gauge, 16 cm. It measured 460 by 250 mm at the top and 365 by 260 mm at the base. These were mulled into a concave shape in order to form the feeding tray of the machine. The hopper is trapezoidal in shape to enhance easy feeding of materials.

Threshing drum

Gauge 12 (3 mm thick) metal sheet was cut into a length of 4 and breadth of the sheet was rolled into a cylindrical shape of 750 mm diameter. Two 3 mm diameter and circumference 62 cm to cover the open ends were then welded to form a closed end cylindrical shape. The two ends of the drum were perforated at the center in order to allow the shaft pass through it. At both ends, the shaft was welded to the drum, such that when the shaft rotates the drum equally rotates. The cylinder was then divided into 5 equal parts (12 cm long each) and the spikes of 4 cm long were welded to the drum at a spacing of 5 cm apart.

Cylinder housing

Two gauge 14 mm metal sheets were measured, cut and labeled A and B; each of them was folded into a semi-circle shape of 25 mm diameter. The edges were then bent square to each other. At the bottom of B, a hole of 50 by 50 mm was cut as an outlet for the threshed materials to come out of the threshing unit. The circle rods, each of 1.5 mm diameter and 7 mm long were welded to the inner side. They were arranged in four rows and covered one third (⅓) of the semicircular circumference of the cylinder. The spacing between each rod was 0.65 cm.

Cleaning unit

Gauge 16 sheet metal were measured 42 × 364 mm and another two were measured (260 × 108 mm) and cut. The four were welded together to form a rectangular box having two point ends. The shaft is allowed to pass through the blower and 3 pieces meter sheet of 18 x 140 mm welded to the shaft to form the fan blade of the blower. The parts were joined together to form a complete soybeans threshing machine as seen in Figure 1.

Machine specifications

Machine specifications are as shown in Table 1.

RESULTS

Performance evaluation of the machine was carried out on mass basis. A known mass of the sample (soybean) at a moisture content of 15% was fed through the hopper and was conveyed into the threshing drum, where threshing takes place, by gravitational force. Threshed sample from seed outlet, chaff outlet and other outlets, were collected and mainly separated into: threshed, unthreshed, chaff and losses. The samples were weighed using an electronic weighting machine. The performance data and analysis of results are shown in Table 3.

Analysis

Performance data were analyzed by using the following equations

$$w_{te} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (1)$$

$$w_{ce} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (2)$$

$$w_{le} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (3)$$

Where, w_1 = weight of threshed grain (g); w_2 = weight of unthreshed grain (g); w_{te} = threshing efficiency (%); w_{ce} = cleaning efficiency (%); w_{le} = loss efficiency (%).

Table 2 indicates parts of the machine, material used and specification used for construction of the soybean thresher. Figure 2 shows the front and side views of the

Table 1. Machine specifications.

Power	5 hp electric motor
Length	650 mm
Width	580 mm
Height	10.15 mm
Material for construction	All steel
Drum speed	Between 154 to 222 rpm

Table 2. Materials specification details.

Item no.	Name	Material	Specification
1	Hopper	MS	250 × 450 Top, 75 × 450 Bottom
2	Concave	MS	⌖ 300 500 Long, 3 thick
3	Cylinder/drum	MS	⌖ 200, 460 Long, 3 thick
4	Cylinder shaft Veering house	MS	⌖82 5 Thick (6308)
5	Cylinder shaft 1	MS	⌖ 42, 700 Long
6	Reciprocator shaft Bearing housing	MS	⌖72 5 Thick (6308)
7	Reciprocator	MS	⌖ 32 650 long
8	Frame	MS	550 × 400 × 650 (main); 550 × 185x (Engine seat)
9	Seed	MS	550 × 165 × 240
10	Fan	MS	032, 670 long (shaft); 485 x 115, 2 thick (blade)
11	Fan pulley	MS	⌖45
12	Fab belt	Rubber and Tread	A-60
13	Driving cylinder pulley	MS	⌖ 140
14	Fan driving cylinder pulley	MS	⌖200
15	Sieve	MS	490 × 170 15 thick
16	Sieve guard	MS	490 × 170 15 thick
17	Bolt and nut	MS	M 8 × 20 (18)
18	Bolt and nut	MS	M 10 × 70 (52)
19	Reciprocator belt	MS	A-33
20	Reciprocator pulley	MS	⌖162
21	Reciprocator	MS	⌖ 82 5 thick (6308) 80 long (arm); ⌖ 20, 5 thick (head)
22	Fab housing	MS	⌖260 × 495 12 thick; 490 × 75 (air exit)

threshing machine, while Figure 3 shows its orthographic view.

Moisture content

From the material, 2 samples were taken. The first sample was weighed and the mass recorded. Water was added to the second sample and it was oven dried for 3 h and then reweighed and the mass recorded. The final moisture content was determined from Equation 4.

$$\text{Moisture content} = \left(\frac{weightofwetsample - weightofdrysample}{weightofdrysample}\right) \bullet 100 \quad (4)$$

Weight of wet sample = 98 g;
Weight of dry sample = 85g

$$\text{Moisture content} = \left(\frac{98-85}{85}\right) \bullet 100$$

= 15%

DISCUSSION

From Tables 3 and 4 and Figure 4, it was observed that the threshing efficiency increased, cleaning efficiency increased, losses were at minimum, machine capacity increased as the speed of the machine increased. The

Table 3. Machine performance data.

Speed (rpm)	W_1 (g)	W_2 (g)	W_3 (g)	W_4 (g)	W_5 (g)	Time taken (sec)
42	1079	280	89	440	83	42
86	1190	420	98	565	92	78
78	1205	428	93	583	67	86

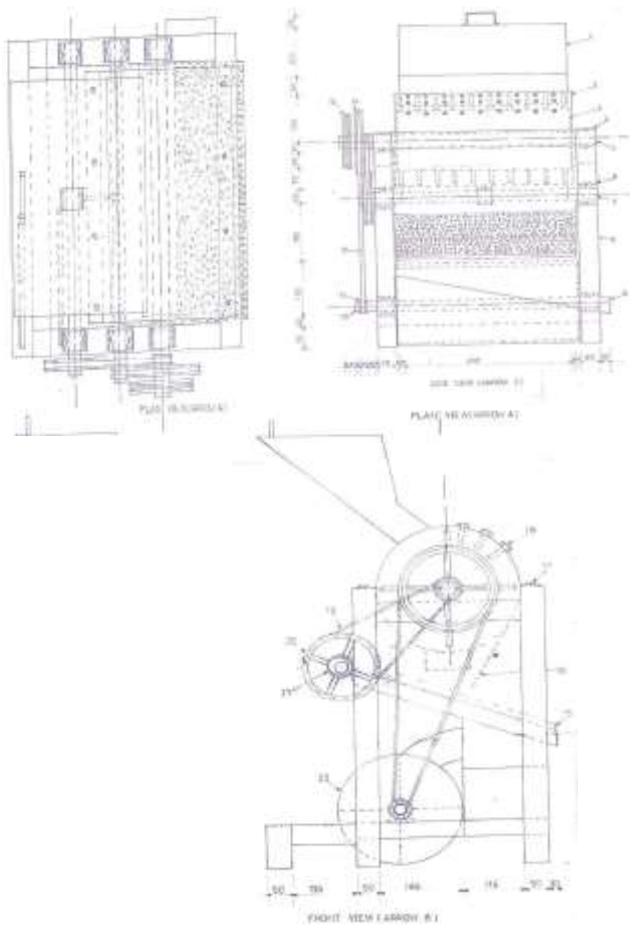

Figure 2. Machine front and side views.

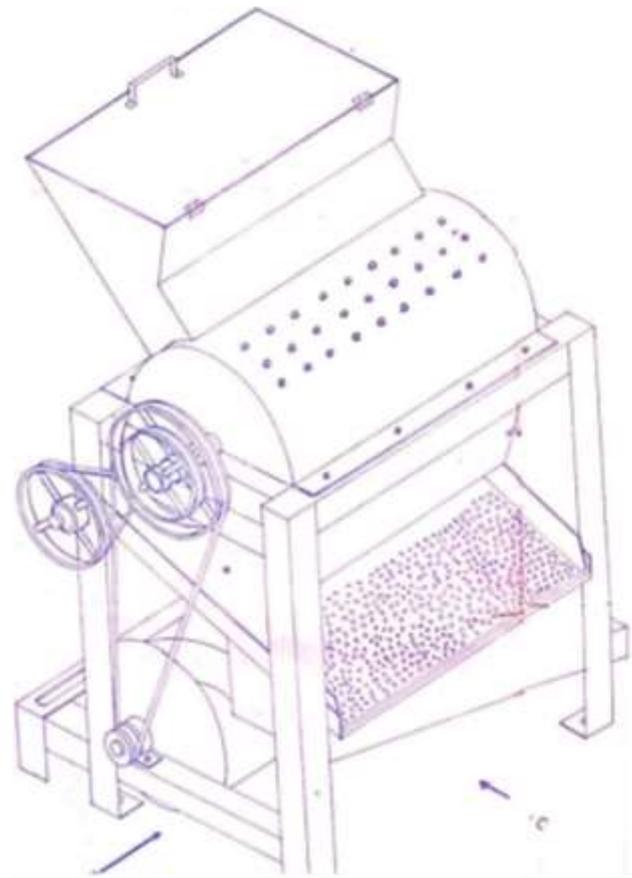

Figure 3. Orthographic view of the thresher.

threshing efficiency increased with increase in the speed of the cylinder. This is because at high speed, more kinetic force is impacted on the material. This is in line with what was stated by Bainer el al. (1960) and Sharma and Devnanl (1980). Lose efficiency increased from 42 to 43% when the speed was increased from 154 to 170 rpm, therefore increase in speed led to loss as reported by Sinha et al. (2014). The increase in cleaning efficiency at high speed might be due to the fact that the blower blows-off the chaff adequately, thereby improving the cleaning efficiency. At high speed, the machine was able to thresh more material, hence, increasing the machine capacity per hour. The loss efficiency is at minimum and increases thereafter. This may be due to the excess vibration from the machine. Therefore, threshing at high speed is advised in order to improve the threshing and cleaning efficiencies, and reduce losses.

Conclusion

From the result obtained, the following conclusions were made:

(i) A designed soybean thresher was constructed and evaluated. The main parts of the machine are: feeding unit, threshing unit, cleaning and grain outlet units. Machine performance evaluation was carried out with TGX1835-10E soybean variety.

Table 4. Soybean thresher analysis result.

Speed (rpm)	Threshing efficiency (%)	Cleaning efficiency (%)	Loss efficiency (%)	Machine capacity (kg/hr
154	68	26	42	92.5
170	76	36	43	54.9
222	78	37	33	50.4

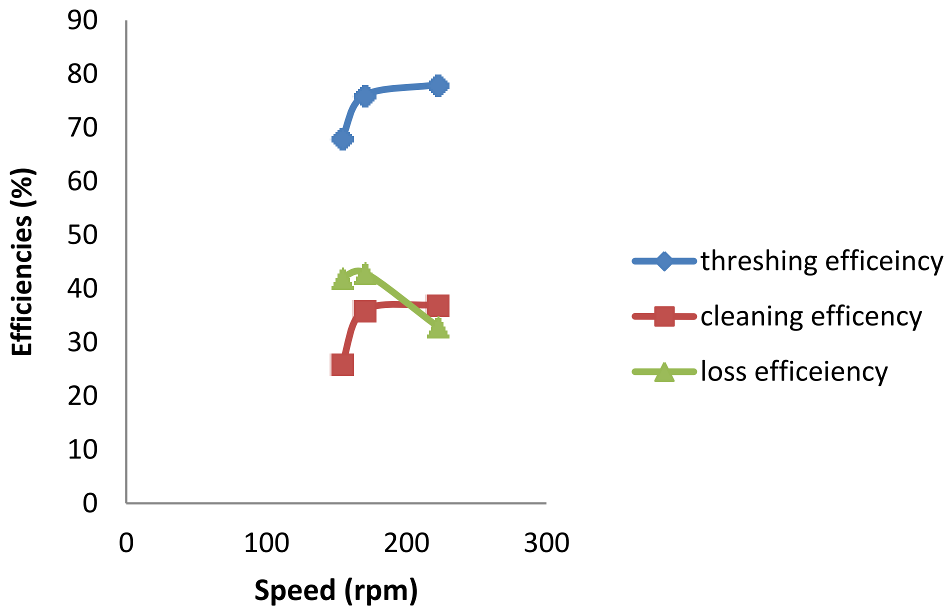

Figure 4. Machine efficiencies against speed.

(ii) The machine was developed in order to replace manual labor associated with soybean threshing.

Evaluation of the machine gave threshing efficiency as 74%, cleaning efficiency was 33% and the machine capacity was determined to be 65.9 kg/h. Feed rate affects threshing efficiency; this is due to inability of the machine to run effectively because of excess of materials within the cylinder and the spikes, this is in line with results obtained by Abdel-wahab et al. (2007). Machine capacity increased as the speed increased. Processing soybean with threshing machine increases market price as compared to manual threshing because loses and damages to seeds will be at minimum.

In order to obtain an optimum threshing and cleaning efficiencies, soybean should be threshed with low moisture content because moisture content state during threshing is an important measure in determining mechanical damage of crop (Allen et al., 1997; Dauda, 2001).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdel-Wahab,El-Shazly M, Afif M, El-Maghawry M (2007). Effectof some operational factors on the Efficiency of Wheat Milling Processes. Farm Machinery and Power, Misr Journal Of Agricultural Engineering, 24(4):688-698

Allen CAW, Watts KC (1998). Design of a belt thresher for cowpea beans. Agricultural Mechanization in Asia, Africa and Latin America, 29(3):42-46.

Bainer R, Kepner RA, Barger EL (1960), Principle of farm machinery. John Coiling and son inc. pp. 370-371; 390-401.

Beliavskaya L (2017). The results of study of ecological stability and plasticity of Ukrainian soybean varieties. Annals of Agrarian Science, Doi: 10.1016/j.aasci.2017.05.003.

BFAP (2013). The Bureau For Food and Policy Research. 10th BFAP Baseline Agricultural Outlook pp. 2013-2022. Pretoria.

Deshpande SD, Bal S, Ojha TP (1993). Physical properties of soybean. Journal of Agricultural Engineering Research, 56(2):89-98.

FAO (2007). Agricultural Enginerring In Development Selecting Of Mechanization Input Agric Service Bulletin Inc 84. Food for Agric. Organization of the United Nation Rome.

Gandhi AP (2006). Soybean-the greater bean, World Grain (USA), February issue pp. 59-62.

Global Soybean Production (2017). United States Department of Agriculture (USDA). Available at: http://www.globalsoybeanproduction.com/ (Accessed on 07/05/2017).

Merwe De Van R, Van Biljon A, Hugo A (2013). Current and potential usage of soybean products as food in South Africa. Abstract 333. Bloemfontein: University of the Free State.

National Soybean Research Laboratory (NSRL) (2010). Soybean Processing. Threshing and Transport. Available at: www.nsrl.illinois.edu. (Accessed 25/04/2017).
Olaoye JO (2011). Development of a treadle operated abrasive-cylinder for threshing cowpea. International Journal of Engineering, Science and Technology, 3(12):8548-8557.
Shannon DA (1984). Prospect for commercial soybean production in Nigeria Proceeding of the 4th National meeting of Nigeria Soybean Scientist at NCRI. Ibadan pp. 46-48.
Sharma KD, Devananl RSA (1980). Threshing studies on soybean and cowpea. Agricultural Mechanization in Asia, Africa and Latin America, 33(2):65-68.
Sinha JP, Manes GS, Anoop D, Arshdeep S, Manpreet S, Bhupinder PS (2014). Performance Evaluation of Axial Flow and Tangential Axial Flow Threshing System for Basmati Rice. International Journal of Research in Agricultural Sciences, 1(2):44-49.
Yang L, Cui T, Qu Z, Li K H, Yin X W, Han D D (2016). Development and application of mechanized maize harvesters. International Journal of Agricultural and Biological Engineering, 9(3):15-28.

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