Turkish Journal of Agriculture - Food Science and Technology, 7(2): 166-172, 2019
DOI: https://doi.org/10.24925/turjaf.v7i2.166-172.1888

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology

Assessment of The Effects of Winter Condition on Sweet Sorghum Yield and Sugar Content

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ARTICLE INFO

Research Article

Received : 05/03/2018
Accepted : 09/11/2018

Keywords:
Winter
Sweet sorghum
Brix
Juice
Maturity

ABSTRACT

Sweet sorghum is an important crop which is produced for food, energy and feed (Almodares and Hadi, 2009). The crop prefers warm moist soil for germination and emergence. However, it would be more beneficial if it can be grown in different seasons. A field experiment was carried to evaluate sixteen sweet sorghum genotypes [*Sorghum bicolor* (L.) Moench] under winter conditions in order to assess the possibility of producing the crop throughout the year since the crop consumes less water and has a short life cycle when compared with sugarcane. The genotypes we recollected from different areas of Sudan. The experiment was planted using a Randomized Complete Block Design with three replications. There were significant differences among genotypes with respect to the number of days to germination, plant height, number of leaves per plant, chlorophyll content, stem diameter, head weight, shoot fresh weight, head to shoot ratio, brix value, juice weight and number of days to maturity. A highly positive correlation (0.92) was observed between juice and shoot weight, and there was a negative correlation (-0.14) between brix value and head weight. The genotypes showed high variability in all mentioned parameters, hence, could be useful genetic resources for breeding winter adaptation.

Introduction

Sorghum [*Sorghumbicolor* (L.) Moench] is an important crop in the Great Plains of Sudan, as well as in many other regions of the world because of its drought resistance, low-input requirements and suitability in crop rotation. Sorghum grow well on wide range of soils but performs best on deep fertile sand loams soils with a pH 5.0-5.8 (Saballos, 2008; Wright and Turhollow, 2010). The crop is used for food, livestock feed and ethanol production. Some sorghum types are suitable for sugar extraction for ethanol production and the Stover can be used for the manufacture of plastics (Janssen et al., 2010).

Sweet sorghum is used extensively for alcohol production (Kundiyana, 2006; Bulawayo et al., 1996; Smith and Frederiksen, 2000; Gnansounou et al., 2005). Sweet sorghum is an efficient converter of solar energy to high carbohydrate and has high concentration of sugar (Almodares et al., 2008).

Sweet sorghums are distributed in the sorghum growing areas of Africa and India (Ramadan, 2011). Studies on sweet sorghum world collection, documented at ICRISAT (The International Crops Research Institute for semi- Arid Tropics), showed that sweet stalk sorghum types are widely distributed in Botswana, Cameron, Chad. Ethiopia, Kenya, Malawi, Niger, Sudan, U.S.A., Zambia and Zimbabwe (Damon, 1962).

Studies on the potential use of sweet sorghum as raw material for ethanol in the USA and Europe started in the 70`s and 80`s, respectively (Tsuchihashi and Goto, 2004). In recent years, there has been increased interest in the use of sweet sorghum for ethanol production in India, Philippines, China and USA (Godoy, 2011). The sugars present in the stalk of sweet sorghum can be fermented and converted to ethanol using relatively simple techniques (Smith and Reeves Jr., 1981; Hill et al., 1987; Smith et al., 1987).

Generally, Sorghum is tolerant to drought, water logging, salinity, soil infertility and high temperature. Sweet sorghum has wider adaptability, rapid growth and high sugar accumulation associated with high biomass production in the semi-arid tropics (Smith et al., 1987).

Therefore, sweet sorghum is a good alternative crop to sugar cane since it requires only one third of the amount of water that sugar cane needs. Sorghum matures in 100-120 days, while first sugar cane crop takes one year to mature. Similarly, on volume basis, sweet sorghum has higher sugar content compared to sugarcane (Almodares et al., 2008). It can be cultivated in temperate and sub-tropical climates.

Sweet sorghum carbohydrates are stored in the stalk, with sugar concentrations of 8-20% (Rains et al., 1989). In Louisiana U.S.A., stalk sugar concentration was recorded at 8.3 to 14.0% during flowering and 12.8 to16.6% during the soft dough stage (Wortmann and Regassa, 2011). Considerable progress has been made in breeding improved sweet sorghum lines with higher mill able cane and juice yield in India (Reddy et al., 2008). The International Crops Research Institute for semi- Arid Tropics (ICRISAT) has developed several improved lines with high stalk sugar content and a few of these lines are being tested in pilot studies for sweet sorghum-based ethanol production in India, Philippines and Uganda.

In Sudan sweet sorghum is grown in areas South of Gadarif, Blue Nile area, Senar, Gezira White Nile, Kurdfan and Darfur. In these areas it is mainly used for chewing. The crop is adapted to a wide range of soil pH (5.0-8.5). The suitable temperature for growth is about 28ºC.

Although sorghum is more tolerant to cool temperatures than other warm-loving cereals, it is still sensitive to temperatures lower than 15ºC. These temperatures occur in the Great Plains primarily during germination and early stages.

Some studies have shown that cold-tolerant sorghum cultivars had requires temperatures 6 to 10ºC less than those of cold–susceptible ones and they maintain respiration rates that are 20 to 25% higher. The limiting factor for sorghum production in the temperate Zone is the vulnerability to low temperatures (Bacon et al., 1986; Tiryaki and Andrews, 2001).

Although low temperatures may reduce the carrying capacity of the phloem of sorghum this unlikely to be an important factor in regulating plant growth at low temperatures (Wardlaw and Bagnall, 1981). Low temperatures throughout the growing season lengthen the growth cycle of genotypes and delay flowering (Zinn et al., 2010). Osuna-Ortega et al. (2003) found that the effect of genotypes, environment and their interaction were highly significant. Quinby et al. (1973) and Zinn et al. (2010) showed that cold stress often delays phonological development (flowering and maturity). Cold stress causes spikelet sterility, flower abortion and reduction in the number of pollen grains intercepted by the stigma in several crop species resulting in poor seed-set and ultimately low grain yield (Khan et al., 1986; Singh, 1985; Maulana and Tesso, 2013; Lee, 2001; Gunawardena et al., 2003; Oliver et al., 2005; Thakur et al., 2010). Moreover, tremendous yield losses due to cold temperature stress on major grain crops have also been reported in sub-tropical and temperate regions (Thakur et al., 2010). The most visible effect of cold temperature early in the season seems to be on the establishment of the crop. Reports from earlier studies showed that germination, emergence and seedling vigor are highly compromised when the crop is subjected to the stress early in the season (Pinthus and Rosenblum, 1961; Singh, 1985; Prasad et al., 2006; Prasad et al., 2008). These reports are substantiated by more recent studies where the effect of early-season cold stress has been noted to reduce plant population with the effect being variable between genotypes (Tiryaki and Andrews, 2001; Franks et al., 2006). Low soil temperature during early growing season severely reduces germination, emergence and seedling growth (Franks at al., 2006). Maulana (2011); Burow et al. (2011); Patanè et al. (2012); Kapanigowda et al. (2013) found that seedling height, leaf chlorophyll content, days to flowering and days to maturity were also significantly affected by the early season cold stress. However, overall number of leaves per plant and plant height were not affected by early stress therefore, is need to screen different genotypes for cold tolerance, yield and yield attributes including sugar content. The development of hybrids with increased cold tolerance and early plant growth would create sweet sorghum production adapted to wider range of climatic conditions.

Sorghum hybrids with improved cold tolerance will not only result in increased yield but also lead to expansion of sorghum production into areas traditionally considered too cold for the crop. This will also enhance yield by allowing early planting in current production areas and 3-4 cultivation seasons. Assessment of the ultimate effects of both early and mid-season cold temperature stress is important to justify investment for improvement of the trait.

There, the objective of this study was to evaluate local sweet sorghum genotypes from different areas of Sudan and assess the effects of winter season cold stress on their yield performance and sugar content.

Materials and Methods

Experimental Site and Plant Materials

A field experiment was conducted at the Demonstration Farm, Faculty of Agriculture, University of Khartoum, Shambat, to evaluate the performance of sixteen genotypes of sweet sorghum [*Sorghum bicolor* (L.) Moench]. The farm is located in semi desert zone (Latitude 15° 39′N, longitude 32°31′E and altitude 380 m above sea level). The soil of the experimental site is heavy clay with alkaline pH. Average, minimum and maximum temperatures range between 14ºC and 27ºC during the winter season and between 25ºC and 41ºC during the summer season. The relative humidity ranges between 31% and 51% during the wet month of the year. Data on the temperature and relative humidity were recorded during the experimental period. The planting material used in this study consisted of sixteen genotypes collected from different areas of Sudan, they are: BE, RNF 1107, RagbtDohElbeit H, Barshoom 1, RagbtDohElbeit K, KB103, Nyala, Barshoom 2, Zakaria 4, NF1100, KBK1101, G1121, Junina, WNB105, Elroseiris, WNBK.

Land Preparation and Planting

The field was disc ploughed, disc harrowed, levelled and ridged (70 cm spacing between ridges). The design of the experiment was randomized complete block design

(RCBD) with three replications. Each of the sixteen genotypes was planted in two ridges of 4m length. The genotypes were planted for one season in winter 2012. The crop was irrigated immediately after sowing and then every ten days during the experimental period. Weeding was done manually at 30 days and then 50 days. The pesticide Furadan (carbofuradan) was applied for the control of stem borers (*Chilo sp*.). Urea (46%N) was applied at a rate of 21.6 kg/ha at 37 days from sowing and 21.6 kg/ha at 60 days from sowing.

Data Collection

Five plants were randomly selected and tagged from each genotype to study the following parameters. Data was collected on mean emergence time (MET) in days, and final emergence (%). Plant height (cm) was measured four times by using ruler at 36, 54, 64 and 84 days after sowing. Stem diameter (cm) at milk stage by using digital Vernier number of days to harvest were also recorded. In addition to these, the following yield and yield-related traits were also recorded.

Chlorophyll content (SPAD unit) it was measured on flag leaf 45, 71, 77 and 96 days after sowing, using portable chlorophyll meter (SPAD, Konica Minolta, Japan). Head weight (g) and shoot fresh weight (g) were recorded at milk stage. Head to shoot ratio was calculated and brix value measured two times at anthesis for the third internodes from the top of the plants for three randomly selected plants and then at milk stage from three randomly selected plants out of the five selected plants after juice extraction using Sugar Cane Presser. Model NO ET-ZZJ80. Brix was measured using a hand refractometer (ATAGO R-Japan). Juice weight was recorded as the average of juice extracted from three plants using Sugar Cane Presser. Model NO ET-ZZJ80.

Statistical Analysis

Analysis of variance (ANOVA) was performed on the data according to the method described by Gomez and Gomez (1984) for a randomized complete block design. Means were then separated using Duncan's Multiple Range Test (DMRT). Simple linear correlation coefficient was estimated between juice weight, head weight, fresh weight, brix value and chlorophyll content measured at the milk stage.

Results

Significant differences ($P<0.05$) in number of days to germination were observed among the genotypes. The highest mean number of days to emergence (5.66) was scored on BE, RagbtDohElbeit K, KB 103, Nyala, NF 1100 and WNBK. The lowest means number of days to germination (5.00) was scored on RNF 1107, RagbtDohElbeit H, Barshoom 1, Barshoom 2, Zakaria 4, KBK1101, G 1121, Junina,WNB 105 and Elroseiris (Table 1).

Significant differences in plant height were shown among the genotypes. Highest mean plant heights were 34.46, 113.73, 158.1 and 173.6 cm for sample taken 35 50, 65 and 80 days after sowing and were scored by Elroseiris, Zakaria 4 and G1121, WNB105 and RNF1107, respectively. Whereas the lowest means plant height was 19.06, 71.87, 121.63 and 134.40 cm scored by RagbtDohElbeit K, B E, RagbtDohElbeit K and Junina, respectively for the same sampling occasions. At 84 days after sowing most of the genotypes scored more or less the same mean plant height albeit the significantly different plant height at earlier stages (Table 2).

Statistical analysis showed significant differences among the genotypes in chlorophyll content at all sampling occasions. The highest chlorophyll content, 56.93, 60.00, 61.26, and 54.83 were scored on Elroseiris, Elroseiris, Barshoom2 and Barshoom2, respectively for samples taken at 45, 71, 77 and 96 days after sowing, respectively. The lowest values of the same parameter were 40.00, 51.10, 50.33 and 43.26 recorded for RNF1107, KBK1101, KBK 1101 and WNB 105, respectively for the same sampling occasions. Most of the genotypes showed lower chlorophyll content at 96 days after sowing compared to the earlier samples (Table 3).

Table 1 Mean emergence time of sixteen sweet sorghum genotypes sown in season 2012/2013

Genotypes	Number of days to germination
B E	5.66[a]
RNF1107	5.00[b]
RagbtDohElbeit H	5.00[b]
Barshoom 1	5.00[b]
RagbtDohElbeit K	5.66[a]
KB103	5.66[a]
Nyala	5.66[a]
Barshoom 2	5.00[b]
Zakaria 4	5.00[b]
NF1100	5.66[a]
KBK1101	5.00[b]
G1121	5.00[b]
Junina	5.00[b]
WNB105	5.00[b]
Elroseiris	5.00[b]
WNBK	5.66[a]

Means followed by the same letter are not significantly different at $P<0.05$ according to Dunant's Multiple Range Test

Table 2 Mean plant height (cm) of sixteen sweet sorghum genotypes at 35, 50, 65 and 80 days sown in season 2012/2013

Genotypes	Plant height (days after sowing)			
	35 days	50 days	65 days	80 days
B E	22.26^{bc}	71.87^{c}	124.20^{bc}	151.76^{a}
RNF 1107	22.67^{bc}	75.27^{bc}	148.667^{a}	173.6^{a}
RagbtDohElbeit H	26.46^{abc}	104.53^{abc}	137.73^{abc}	144.7^{a}
Barshoom 1	28.13^{abc}	103.40^{abc}	143.667^{abc}	153.2^{a}
RagbtDohElbeit K	19.06^{c}	97.53^{abc}	121.63^{c}	136.7^{b}
KB103	30.40^{ab}	88.20^{abc}	139.30^{abc}	139.97^{a}
Nyala	24.40^{bc}	81.50^{abc}	145.73^{ab}	158.3^{a}
Barshoom 2	22.66^{bc}	82.43^{abc}	135.76^{abc}	144.73^{a}
Zakaria 4	30.60^{ab}	113.73^{a}	142.06^{abc}	151.33^{a}
KBK1101	22.73^{bc}	77.43^{abc}	146.53^{ab}	152.03^{a}
NF1100	31.66^{ab}	113.63^{a}	147.46^{a}	146.37^{a}
G1121	31.53^{ab}	113.73^{a}	138.53^{abc}	152.97^{a}
Junina	22.93^{bc}	74.40^{bc}	124.43^{bc}	134.4^{b}
WNB105	24.73^{bc}	79.33^{abc}	158.10^{a}	173.53^{a}
Elroseiris	34.46^{a}	110.67^{ab}	141.80^{abc}	142.83^{a}
WNBK	26.33^{abc}	79.7^{abc}	140.00^{abc}	150.8^{a}

Means followed by the same letter are not significantly different at P<0.05 according to Dunant's Multiple Range Test

Table 3 Mean chlorophyll content of sixteen sweet sorghum genotypes sampled at 45, 71, 77 and 96 days from sowing sown in season 2012/2013

Genotypes	Chlorophyll content			
	45 days after sowing	71 days after sowing	77 days after sowing	96 days after sowing
B E	52.30^{ab}	53.60^{bcd}	53.00^{cbd}	48.76^{abc}
RNF1107	40.00^{c}	52.83^{cd}	55.36^{abcd}	50.20^{abc}
RagbtDohElbeit H	52.26^{ab}	58.26^{abc}	57.80^{abcd}	46.13^{abc}
Barshoom 1	48.80^{abc}	59.56^{ab}	58.86^{abc}	50.90^{abc}
RagbtDohElbeit K	47.10^{bc}	57.20^{abcd}	55.90^{abcd}	50.40^{abc}
KB103	50.83^{abc}	53.36^{cd}	51.60^{cd}	47.86^{abc}
Nyala	50.33^{abc}	56.80^{abcd}	59.56^{abc}	44.86^{cb}
Barshoom 2	51.40^{abc}	58.66^{abc}	61.26^{a}	54.83^{a}
Zakaria 4	51.93^{abc}	58.63^{abc}	51.80^{cd}	53.53^{ab}
NF1100	49.96^{abc}	58.63^{abc}	53.73^{abcd}	45.16^{cb}
KBK1101	51.73^{abc}	51.10^{d}	50.33^{d}	43.46^{c}
G1121	52.26^{ab}	55.33^{abcd}	54.83^{abcd}	50.23^{abc}
Junina	47.40^{bc}	56.36^{abcd}	59.03^{abcd}	49.93^{abc}
WNB105	48.20^{bc}	55.70^{abcd}	55.30^{abcd}	43.26^{c}
Elroseiris	56.93^{a}	60.00^{a}	60.60^{ab}	50.36^{abc}
WNBK	43.b^{c}	55.06^{abcd}	53.46^{abcd}	50.06^{abc}

Means followed by the same letter are not significantly different at P<0.05 according to Dunant's Multiple Range Test

The result of analysis of variance showed significant differences among genotypes in stem diameter. The highest mean (1.33) was obtained by Zakaria 4, whereas the lowest mean (0.94) obtained by RNF 1107. WNB105 and RNF1107 produced significantly lower stem diameter compared to other genotypes (Table 4).

The differences among the genotypes on shoot weight (g), head weight (g) and head to shoot ratio revealed by the analysis of variance were significant. The highest mean shoot weight (235.37 g) was obtained by Barshoom 1, the lowest mean (97.63 g) was obtained by WNB105 (Table 4). The highest mean head mass (81.2 g) was obtained by Barshoom 1, while the lowest mean (25.26 g) was obtained by Elroseiris (Table 4). The highest mean head to shoot ratio (0.41) was obtained by Barshoom 2, while the lowest mean (0.16) was obtained from RagbtDohElbeit K (Table 4).

The analysis of variance showed significant differences among genotypes on brix value at anthesis and milk stage. At anthesis the genotype Elroseiris was scored the highest brix value (12.23) while at milk stage the highest value (17.66) was scored by RNF1107. At milk stage all genotypes produced higher value compared to the value at anthesis (Table 5).

Statistical analysis showed significant differences among the sweet sorghum genotypes for juice weight. The highest mean juice weight (54.73 g) was obtained by WNBK; however the lowest mean (3.1 g) was obtained by WNB105. WNBK produced significantly higher juice weight compared to other genotypes except Barshoom1 (Table 6).

Analysis of variance showed significant differences in the number of days to harvest among the genotypes. The highest mean number of days to harvest (93) was scored by Nyala and NF1100, and the lowest mean value (88.66) was obtained by Elroseiris (Table 6).

Table 4. Mean stem diameter, shoot mass (g), head mass (g) and head to shoot ratio of sixteen sweet sorghum genotypes sown in season 2012/2013

Genotypes	Stem diameter (cm)	Shoot mass (g)	Head mass (g)	Head to Shoot ratio
B E	1.08^{abc}	147.00^{bcde}	38.40^{cde}	0.25^{bcd}
RNF 1107	0.94^{c}	161.67^{bcd}	38.33^{cde}	0.24^{bcd}
RagbtDohElbeit H	1.13^{abc}	157.77^{bcde}	37.96^{cde}	0.27^{abcd}
Barshoom 1	1.20^{abc}	235.37^{a}	81.20^{a}	0.34^{abc}
RagbtDohElbeit K	1.16^{abc}	151.83^{bcde}	26.00^{de}	0.16^{d}
KB103	1.15^{abc}	121.73^{def}	44.30^{bcd}	0.36^{ab}
Nyala	1.06^{abc}	179.27^{b}	60.26^{b}	0.33^{abc}
Barshoom 2	1.21^{abc}	130.43^{cdef}	50.20^{bc}	0.41^{a}
Zakaria 4	1.33^{a}	151.73^{bcde}	45.86^{bc}	0.30^{abcd}
NF1100	1.10^{abc}	134.87^{bcdef}	39.86^{cde}	0.28^{abcd}
KBK1101	1.17^{abc}	171.50^{bc}	51.26^{bc}	0.29^{abcd}
G1121	1.13^{abc}	133.87^{cdef}	36.96^{cde}	0.27^{bcd}
Junina	1.04^{abc}	114.00^{ef}	35.43^{cde}	0.30^{abcd}
WNB105	1.03^{bc}	97.63^{f}	35.76^{cde}	0.30^{abcd}
Elroseiris	1.10^{abc}	120.87^{def}	25.26^{e}	0.20^{cd}
WNBK	1.30^{ab}	226.63^{a}	48.13^{bc}	0.21^{cd}

Means followed by the same letter are not significantly different at P<0.05 according to Dunant's Multiple Range Test

Table 5 Mean brix value of sixteen sweet sorghum genotypes sampled at anthesis and milk stage sown in season 2012/2013

Genotypes	Brix value	
	at Anthesis	at Milk stage
B E	7.66^{bc}	12.83^{abc}
RNF 1107	10.33^{ab}	17.66^{a}
RagbtDohElbeit H	8.43^{abc}	13.66^{abc}
Barshoom 1	11.43^{ab}	12.33^{abc}
RagbtDohElbeit K	7.83^{bc}	12.66^{abc}
KB103	7.73^{bc}	8.66^{cd}
Nyala	7.83^{bc}	12.33^{abc}
Barshoom 2	8.50^{abc}	14.66^{ab}
Zakaria 4	11.00^{ab}	11.66^{bcd}
NF1100	7.33^{bc}	9.33^{bcd}
KBK1101	5.43^{c}	6.66^{d}
G1121	9.66^{abc}	11.66^{bcd}
Junina	9.00^{abc}	10.50^{bcd}
WNB105	8.33^{abc}	9.33^{bcd}
Elroseiris	12.23^{a}	12.83^{abc}
WNBK	9.93^{ab}	13.16^{abc}

Means followed by the same letter are not significantly different at P<0.05 according to Dunant's Multiple Range Test

Table 6. Mean juice weight (g) and number of days to harvest of sixteen sweet sorghum genotypes sown in season 2012/2013

Genotypes	Juice weight (g)	Time to harvest
B E	27.63^{c}	89.00^{ab}
RNF 1107	28.63^{c}	90.33^{ab}
RagbtDohElbeit H	31.96^{bc}	90.33^{ab}
Barshoom 1	46.10^{ab}	91.33^{ab}
RagbtDohElbeit K	26.03^{c}	90.66^{ab}
KB103	20.20^{c}	91.33^{ab}
Nyala	33.40^{bc}	93.00^{a}
Barshoom 2	30.50^{bc}	90.33^{ab}
Zakaria 4	30.06^{c}	90.33^{ab}
NF1100	19.53^{c}	93.00^{a}
KBK1101	26.76^{c}	90.00^{ab}
G1121	22.66^{c}	92.33^{ab}
Junina	16.63^{dc}	89.33^{ab}
WNB105	3.10^{d}	92.00^{ab}
Elroseiris	22.76^{c}	88.66^{b}
WNBK	54.73^{a}	91.00^{ab}

Means followed by the same letter are not significantly different at P<0.05 according to Dunant's Multiple Range Test

Correlations Between Juice Weight, Head Mass, Shoot Mass, Brix Value and Chlorophyll Content

The result showed that there were positive correlations between above mentioned attributes at milk stage, and there was a highly positive correlation (0.92) between juice and shoot weight. However there were negative correlations between head weight and chlorophyll content (-0.23) and between head weight and brix value (-0.14).

Table 7 Correlation coefficients between juice weight, head mass, shoot weight, brix value and chlorophyll content of sixteen sweet sorghum genotypes sown in season 2012/2013

Parameter	Juice weight	Chlorophyll content	Shoot weight	Head weight
Chlorophyll content	0.363			
Shoot weight	0.92	0.105		
Head weight	0.102	-0.23	0.15	
Brix value	0.415	0.570	0.24	-0.14

Discussion

Cold season affected the growth and yield performance of sweet sorghum. In this study, there were significant differences among sweet sorghum genotypes in all parameters studied. The genotypes showed significant differences in number of days to emergence. This could be attributed to the effect of low temperature on emergence. Similar results were reported by Franks et al. (2006) they found that low soil temperature during early growing season can severely reduce emergence. The variable response of the genotypes to low temperature observed in this study might be attributed to the genetic background of each genotype since they were collected from different locations. During the winter there was a significant effect on plant height of sweet sorghum genotypes. This might be due to genetic factors. This result is disagreeing with Burow et al. (2011) who reported that the response of genotypes under cold stress was not significant. The genotypes showed significant differences in number of days to harvest. This might be attributed to the effect of temperature on the developmental stages of sweet sorghum. Similar results were reported by Zinn et al. (2010) who found that low temperatures throughout the growing season lengthen the growth cycle of genotypes and cause delay in flowering. Similarly Maulana (2011) showed that number of days to maturity was significantly affected by the early season cold stress.

Further, there were significant differences among genotypes with respect to chlorophyll content. Similar results were reported by Kapanigowda et al. (2013) who reported that leaf chlorophyll content significantly affected by the early season cold stress. The significant differences among the genotypes found in this study, might be due to the fact that the genotypes differ in their adaptability to low temperature. However, Wardlaw and Bagnall (1981) indicated that low temperatures are unlikely to be an important factor in regulating plant growth. In this study, there were significant differences in head mass (g), shoot fresh mass and head to shoot ratio at milk stage. These differences might be due to fact that these genotypes had different growth responses that lead to different dry matter accumulation. This finding is in line with the finding of Burow et al. (2011) who found that genotypes had significantly variable yield components.

The significant differences in Brix value and juice weight might be due to the differences in genetic factors as a main reason which it can effect on growth parameters and dry matter accumulation and finally Brix value. The differences in Brix value between anthesis and milk stage is because Brix value increases with plant development. Similar results were reported by Reddy et al. (2008) as they found that Brix and starch increased with advancement of the growth stage. Concerning juice weight, it also increased at milk stage, this result is similar to the finding of Almodares et al. (2008). Those workers observed that syrup yield was maximized by harvesting during the late milk to hard dough stage. Similar results were also reported by Rains et al. (1989) whom indicated that sugar yield is dependent on length of growing season and the amount of radiation intercepted.

Conclusions

Sweet sorghum genotypes significantly differed in all parameters measured. These genotypes will be good source for breeding programs.

The results also showed that there was a highly positive correlation (0.92) between juice weight and shoot weight, and a negative correlation between brix value and head weight.

Since this experiment was conducted for only one season, it's recommended that more seasons and locations should be used to obtain more reliable results.

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