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Bioethanol And Sugar Yields Of Sweet Sorghum

Cengiz Erdurmus[1], Celal Yucel[2], Orcun Cınar[1], Arzu Bayır Yegin[1], Mehmet Oten[1]

[1] Batı Akdeniz Agricultural Research Institute, Antalya, Turkey,
[2]ŞırnakUniversity Faculty of Agriculture, Siirt, Turkey
Corresponding Author: Cengiz Erdurmus

ABSTRACT

This study was conducted at Adana and Antalya provinces which are in the Mediterranean coastal zone of Turkey in 2016. The study was done with 9 sweet sorghum genotypes and 4 sorghum variety in the randomized blocks design of experiment as 4 replicates. As a result of the analyses in Adana location, the juice yield was between 8728 and 35143 Lha^{-1}, Brix value was between 13.25 and 17.38%, total sugar content was between 1245 and 5909 kg ha^{-1}, ethanol yield was between 738 and 3146 L ha^{-1}, sucrose content was between 8.02 and 13.89%, glycose content was between 1.73 and 2.69%, fructose content was between 1.22 and 2.78%. As a result of the analyses in Antalya location, the juice yield was between 5353 and 37018 L ha^{-1}, Brix value was between 11.08 and 17.73%, total sugar content was between 612 and 6381 kg ha^{-1}, ethanol yield was between 439 and 3397 L ha^{-1}, sucrose content was between 7.08 and 14.02%, glycose content was between 0.96 and 2.72%, fructose content was between 0.87 and 3.04%. When all of the results were evaluated, genotype number 3 in Adana location and genotypes number 1 and 9 in Antalya location were determined as hopeful.

KEYWORDS;*Bioethanol, brix, sorghum, sugar*

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I. INTRODUCTION

The fossil fuel sources are decreased day by day in the world, the demand to these energy sources is increased day by day. In the world, 63 million barrel of oil was consumed in 1980, 84 million barrel of oil was consumed in 2005, 87.8 million barrel of oil was consumed in 2011(Pandey, 2009). Because of the fosil fuels cause to the air pollution, greenhouse gas, global climate change, it makes significant ecological problem around the world (Demirbas, 2005;Searchingeret al., 2008).

Because of the environmental concerns and consumption problems of the fossil sourced non-renewable energy sources in the future, the alternative energy source searching is increased. The main renewable energy sources are water, wind, solar, geothermal and biomass. The production of the biomass energy source is based on the agricultural products. Sugar beet, molasses cane, corn, wheat, sweet sorghum, potato, ligneous, agricultural wastes are used in the production of bioethanol (Kavruk and Atalay, 2007). The ethanol yield values of various field crops are seen in Table 1.

Plant species	Yield (tha^{-1})	Sugar/starch (t ha^{-1})	Ethanol yield (L ha^{-1})
Sugar beet(Beta vulgaris var.altissima L.)	7.4	9.18	5600
Sweet sorghum(Sorghum bicolor var.saccharata)	90.0	9.00	5400
Molasses cane (Saccharum officinarum L.)	80.0	8.00	5400
Potato (Solanum tuberosum L.)	32.4	5.77	3693
Corn (Zea mays L.)	6.9	4.49	2874
Wheat (Triticum aestivum L.)	7.2	4.46	2854
Barley (Hordeum vulgare L.)	5.8	3.36	2150

Table 1. Biomass, sugar/starch and ethanol yields of some field crops. *Reference: El Bassam,1998, Emeklier, 2014

There are many advantages of bioethanol like native and renewable, reduction to the dependence of the clean and fossil fuels, low cost, easiness of the production and conservation (Melikoglu and Albostan, 2011).
The studies about the ethanol production from agricultural products increased highly in the world in recent years. In the study which was made in Canada about obtaining ethanol from lignosellulosic plants, it was emphasized that these materials are a good bioethanol production source. It is estimated that bioethanol which will be obtained from lignocellulosic plant wastes, will be equal to the half of the fuel used in the transportation in Canada (Mabee and Saddler, 2010). The 44% of the energy sources of Brazil is obtained from the renewable

energy sources, 13.5% of this is ensured from sugar cane. The bioethanol amount obtained from the sugar cane in one ha area, is 6000 L, it is planning to increase up to the 10.000 L (Soccol et.al., 2010). Besides using in transportation, bioethanol can be used in the production of electricity, small house appliances and chemical materials (Ar, 2007).

Sweet sorghum can be adapted to the environmental conditions, it has lower manure and water requirement according to the alternatives, it can be grown in marginal areas, it has higher yield of sugar/ethanol, so these factors show that it is a good energy plant. It was reported that sweet sorghum can be grown as forage crop or energy plant in the summer in free areas in inclined agricultural lands with erosion potential for preventing the wind and water erosion, it can be used for decreasing the diseases and pests in sugar beet areas, it can be used in the crop alternation with sugar beet for producing sugar and ethanol from sugar (Akdogan 2004). In this study, the sugar and ethanol yields of sorghum genotypes and varieties which are in the Adana and Antalya provinces in the Mediterranean coastal zone of Turkey were determined and the yield potentials were revealed.

II. MATERIAL AND METHOD

Material

Nine sweet sorghum genotypes, 3 sorghum varieties belong to the Batı Akdeniz Agricultural Research Institute and 1 variety belong to the Uludag University were used as material in the study. The information about the sweet sorghum genotypes which were provided from the world gene center and the varieties used in the testing is given in the Table 2. The soil structure of Adana location was determined as mild alkaline, state loamy. The soil structure of Antalya location was determined as alkaline, high lime and state loamy. The average temperature values were determined as 25.04°C between June and October in Adana location in 2016. The long years average temperature between June and October was 23.54°C. The average temperature value of this location was higher than the long years average. The total precipitation was occured under 10 mm in the testing period and long years average in Adana location. The average temperature values were determined as 25.12°C between June and October in Antalya location in 2016. The long years average temperature between June and October was 23.34°C. The average temperature value of this location was higher than the long years average. The total precipitation was 104 mm in the testing area, 107.1 mm in the long yeras average.

Genotype number	Code	Gene center	Gene center number	Country
1	PI	USDA	170787	Turkey
2	PI	USDA	175919	Turkey
3	PI	USDA	196049	Ethiopia
4	PI	USDA	586541	Australia
5	PI	USDA	641807	-
6	PI	USDA	641821	-
7	PI	USDA	651495	United States,Mississippi
8	IS NO	ICRISAT	24453	South Africa
9	IS NO	ICRISAT	29187	Swaziland
Variety name	Breeder instution			
E.Sumac	Batı Akdeniz Agricultural Research Institute			
Rox	Batı Akdeniz Agricultural Research Institute			
Gozde 80	Batı Akdeniz Agricultural Research Institute			
Gulseker	UludagUniversity			

Table 2. The information of the genotypes and varieties used in the study

Method

The research was conducted in the Antalya (36°53′N, 30°42′E), and Adana (36°59′N, 35°19′E) provinces which are in the Mediterranean coastal zone of Turkey in 2016. The experiment was set up in randomized blocks experimental design as 4 replicates. The parcels in the experiment were set up 5 m length, 4 rows, row spacing was 70 cm and intrarow was 10 cm. The planting was done in Adana location in 14.06.2016, in Antalya location in 10.06.2016. The stem juice yield (L ha^{-1}), brix (%), total sugar content (kg ha^{-1}), ethanol yield (L ha^{-1}), sucrose (%), glycose (%) and fructose (%) were investigated in the experiment. The datas obtained from the analyses were subjected to the variance analysis with using JUMP statistical programme, the averages were compared according to the LSD test.

III. RESULTS AND DISCUSSION

Stem Juice yield

Location x variety interaction was found as significant in terms of the stem juice yield. Therefore, each location was evaluated in itself (Table 3). The stem juice yields were varied between 8728 and 35143 L ha^{-1} in Adana location. The minimum stem juice yield was obtained from Gozde 80 variety, the highest stem juice yield was obtained from genotype number 3 in this location. The stem juice yields were varied between 5353 and 37018 L ha^{-1} in Antalya location. The minimum stem juice yield was obtained from Gozde 80 variety, the highest stem juice yield was obtained from genotype number 9.

As a result of the other studies about sweet sorghum stem juice; Rao et.al. (2013) conducted a study in India and they determined the stem juice yield as between 1554 and 2084 L da^{-1}, Davilla-gomez et.al. (2011) conducted a study in Texas/USA and they determined the stem juice yield as between 1500 and 2830 L da^{-1}, Teetor et.al. (2011) conducted a study in Arizona/USA and they determined the stem juice yield as between 3044.94 and 5360.07 L da^{-1}. The stem juice yield is an important selection criteria for breeding studies oriented bioethanol. The brix values of the genotypes are no matter how high it is, ethanol yields are low in case of the juice amount is low.

In our study, higher results were obtained according to the Rao et.al. (2013) study, similar results were obtaine with the Davilla-gomez et.al. (2011) study. Besides, in our study, lower results were obtained according to the Teetor et.al. (2011) study. It can be said that the differences could be derived from the environment and the difference of the varieties.

Brix

In the study, location x variety interaction was found as significant in terms of brix values (Table 3). Brix values were varied between 13.25 and 17.38% in Adana location. The lowest brix value was determined in Early sumac variety, the highest brix value was determined in genotype number 6. The brix values were determined between 11.08 and 17.73% in Antalya location. The lowest brix value was determined in Gozde 80 variety, the highest brix value was determined in genotype number 1. Genotype number 1 was in the first group in each location and it showed that it has high brix value.

Reddy et.al. (2005) made a study about sorghum varieties and they determined the brix values between 14.2 and 17.7 °Bx, Almodores and Hadi (2009) made a study about 36 sweet sorghum varieties and lines and they determined the brix values between 11.16 and 23.01 °Bx. Atokple et.al. (2014) made a study about sweet sorghum genotypes in Ghana, they found the brix values between 11.1 and 17.3% at flowering period, 12.5 and 19.6% at early dough period, 11.9 and 21.4% at late dough period.

The brix values of the varieties increased with the ripening. Also, the genotype and the environment have a significant effect. Therefore, temperature, after flowering period, ripening, variety, cultural practices cause the differences at brix values (Prasad et.al., 2007; Davilla-Gomez et.al., 2011).

The genotype number 1 was in the first group in each location. It had a brix value over 17% in each location.

Totalsugar

The location x variety interaction was found as significant in terms of total sugar, therefore each location was evaluated in itself (Table 3). The total sugar content was detected between 1245 and 5909 kg ha^{-1} in Adana location. The lowest content was determined at Gozde 80 variety with 1245 kg ha^{-1} value, the highest content was determined at genotype number 3 with 5909 kg ha^{-1} value. In Antalya location, total sugar content varied between 612 and 6381 kg ha^{-1}. The lowest sugar content was determined in Gozde 80 variety (612 kg ha^{-1}), the highest content was determined in genotype number 1. The highest values were determined at genotype number 3 in Adana location, genotype number 1 and 9 in Antalya location in terms of total sugar content and it is came to a conclusion that these results must be evaluated for the studies which will be made in the future.

It was reported that there is a linear correlation with total sugar content and brix in sorghum and these values are pretty close with eachother (Audilakshmi et.al., 2010). Much as the sugar content changes with cultural practices, the genetical structure is effective firstly in the sugar content of sorghum (Calviño and Messing, 2012; Zegada-Lizarazu and Monti, 2012).

Ethanol yield

Location x variety interaction was found as significant in terms of ethanol yield. Therefore, each location was evaluated in itself (Table 3). The ethanol yields varied between 738 and 3146 L ha^{-1}. In this location, the lowest ethanol yield was obtained from Gozde 80 variety, the highest ethanol yield was obtained from genotype number 3. In Antalya location, ethanol yields varied between 439 and 3397 L ha^{-1}. The lowest ethanol yield was obtained from Gozde 80 variety, the highest ethanol yield was obtained from genotype number 1.Rutto et.al., (2013) determined the 5 sweet sorghum yields between 53.2 and 141.9 L da^{-1} , Teetor et.al., (2011) determined the ethanol yields between 81.1 and 425.2 L da^{-1} , Smith et.al., (1987) determined the ethanol yields between 2182 and 3664 L da^{-1} . Our studys results was higher than the Rutto et.al., was similar with Teetor et.al., and Smith et.al. It was reported that besides the sugar amount and juice yield, yeast, yeast concentration, pH, temperature, starting sugar concentration of sorghum juice, chemical composition, distribution in the sugar concentration effected the ethanol yield directly (Zhao et.al., 2009; Guigou et.al., 2011; Shen et.al., 2011; Matsakas and Christakopoulos, 2013).

Genotype	Stem Juice yield (Lha^{-1})		Brix (%)		Totalsugar (kg ha^{-1})		Ethanol Yield (Lha^{-1})	
	Adana	Antalya	Adana	Antalya	Adana	Antalya	Adana	Antalya
1	26680 ab	35948 a	17.25 ab	17.73 a	4627 ab	6381 a	2463 ab	3397 a
2	25400 ab	22713 cd	17.00 ac	16.17 b	4327 ac	3675 bd	2304 ad	1957 b
3	35143 a	28585 b	16.75 ac	13.72 df	5909 a	3899 bc	3146 a	2076 b
4	24893 ab	22153 cd	15.50 ad	14.40 ce	3827 bd	3191 cd	2038 be	1699 bc
5	21938 ab	26343 bc	15.75 ad	15.82 bc	3464 bd	4167 b	1845 be	2218 b
6	23715 ab	24883 bd	17.38 a	15.90 b	4113 ac	3954 bc	2190 ad	1605 bc
7	26798 ab	25263 bd	17.00 ac	14.85 bd	4573 ab	3746 bc	2435 ac	1994 b
8	23358 ab	29088 b	13.88 d	12.71 fg	3215 bd	3697 bc	1712 bf	1969 b
9	25158 ab	37018 a	14.75 cd	16.13 b	3724 bd	5983 a	1983 be	3210 a
E.Sumac	14157 bc	21528 cd	13.25 d	12.98 eg	1843 de	2793 d	979 ef	1487 bc
Rox	17520 bc	15038 e	14.13 d	11.58 fg	2469 ce	1664 e	1315 df	886 cd
Gozde 80	8728 c	5353 f	14.88 bd	11.08 h	1245 e	612 f	738 f	439 d
Gulseker	21938 b	20515 de	15.00 bd	14.88 bd	2807 be	3057 cd	1495 cf	1628 bc
Significance	**	**	**	**	**	**	**	**

Table 3. Juice yield, brix, total sugar content and ethanol yield values

Sucrose, Glycoseand Fructosevalues

Location x variety interaction was found as significant in terms of sucrose and fructose values, therefore each location was evaluated in itself. Adana location was found as insignificant in terms of glycose values (Table 4).

In Adana location, sucrose values were varied between 8.02 and 13.89%, glycose values were varied between 1.73 and 2.69%, fructose values were varied between 1.12 and 2.78%. The lowest sucrose value was determined in E.Sumac variety, the highest sucrose value was determined in genotype number 6. The lowest glycose value was determined in Rox variety with 1.73%, the highest glycose value was determined in genotype number 1 with 2.69%. The lowest fructose value was determined in genotype number 1 with 1.22%, the highest fructose value was determined in E.sumac with 2.78%.

In Antalya location, sucrose values were varied between 7.08 and 14.02%, glycose values were varied between 0.96 and 2.72%, fructose values were varied between 0.87 and 3.04%. The lowest sucrose value was determined in Gozde 80 variety, the highest sucrose value was determined in genotype number 1. The lowest glycose value was determined in Rox variety with 0.96%, the highest glycose value was determined in genotype number 1 with 2.72%. The lowest fructose value was determined in genotype number 8 with 0.87%, the highest fructose value was determined in genotype number 3 with 3.04%.

Genotype	Sucrose (%)		Glycose (%)		Fructose (%)	
	Adana	Antalya	Adana	Antalya	Adana	Antalya
1	13.35 ab	14.02 a	2.69	2.72 a	1.22 d	0.99 d
2	12.95 ac	11.26 bc	2.05	2.14 ab	2.00 ad	2.78 ab
3	12.00 ad	8.69 de	2.16	1.99 b	2.55 ac	3.04 a
4	11.56 ad	10.91 c	1.96	1.81 bc	1.99 ad	1.69 cd
5	10.84 cd	12.62 ab	2.16	1.71 bd	2.76 ab	1.49 cd
6	13.89 a	12.76 ab	1.86	1.06 de	1.67 cd	2.09 ac
7	12.96 ac	10.31 cd	2.51	2.14 ab	1.54 cd	2.40 ac
8	10.26 de	10.18 cd	1.95	1.66 bd	1.67 bd	0.87 d
9	11.22 bd	13.03 a	1.78	1.28 ce	1.75 ad	1.82 bd
E.Sumac	8.02 e	8.33 e	2.45	1.88 bc	2.78 a	2.77 ab
Rox	9.82 de	7.99 e	1.73	0.96 e	2.58 ac	2.13 ac
Gozde 80	10.63 ce	7.08 e	2.19	2.28 ab	2.06 ad	2.22 ac
Gulseker	1150 bd	10.86 c	1.87	1.97 b	1.62 cd	2.05 ac
Signifiance	**	**	ns	**	**	**

Table 4. Sucrose, glycose and fructose values

In our study, sucrose was determined as dominant component, glycose and fructose were found as similar values with eachother. Nan and Best (1994) were reported that sugar composition of the sorghum is composed of sucrose, glycose and fructose. Yang et.al., (2013) were investigated the variance in the sugar composition along with the ripening period of the sorghums and they determined that sucrose is the dominant component. In the same study, they determined that glycose was varied between 0.14% and 1.46%, fructose was varied between 0.17 and 1.24%. Audilakshmi et.al., (2010) were determined the sucrose as dominant component and it was varied between 7.7 and 18.1%. Our study showed similarity with the other studies in terms of sucrose component.

Nan and Best (1994) were reported that the glycose content was varied between 1 and 4% at 5 different sorghum varieties 3 and 3 different harvesting time. In other study, glycose content was varied between 2.25 and 2.88% in 3 different sorghum hybride varieties (Andrzejewvski et.al., 2013). In our studies results supported the other researchers studies.

In different studies, researchers were detected the fructose content as 0.18 between 1.24% (Yang et.al., 2013), 1.5 and 1.66% (Andrzejewski et.al., 2013), 0 and 2.41 % (Kawahigashi et.al., 2013) and 1.43 and 3.73% (Almodares and Hadi, 2009). The values which were obtained in these studies and our results showed total harmony.

IV. CONCLUSION

Turkey is a foreign dependent country in terms of fossil sourced energy. As a result of the increase of energy requirement in the world and decrease in the oil reserve, the countries gravitated to the alternative renewable energy resources. Turkey has potential in terms of water power, geothermal, wind and biomass energy. Sweet sorghum plant is one of the important plant species which can be used for biomass energy. This study was conducted at Adana and Antalya locations in 2016 with using 9 sweet sorghum genotypes and 4 sorghum varieties and juice yield, brix, total sugar content, ethanol yield, sucrose, fructose and glycose contents were detected. As a result of the study, sweet sorgum genotypes gave higher yields and it can be a renewable energy source alternative to the fossil fuels. Genotype number 3 in Adana location and genotypes number 1 and 9 in Antalya location were determined as hopeful with higher yields.

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