American-Eurasian Journal of Scientific Research 18 (1): 11-17, 2023
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2023.11.17

Effect of Varietal Differences on Sugar Beet Yield, Quality and Bioethanol Production Under Sandy Soil Conditions

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Abstract: Two Field experiments were conducted in the Experimental Farm of the National Research Centre, El-Behaira Governorate. The experiments were conducted in 2021/22 and 2022/23winter seasons and included the evaluation of 6 sugar beet varieties for yield, quality and bioethanol production. The results showed significant differences among the tested varieties in mean root length and diameter, root and top weight per plant as well as root and top weight per feddan. The data show that Ravel variety significantly surpassed the other varieties in root and top yields per plant while Rizobel produced the highest root yield per feddan and possessed reasonable criteria for root length and diameter. However, the varieties SV 1841 and Amina gave the lowest studied parameters in root length and diameter as well as root and top yields per plant and per feddan. The tested varieties could be arranged according to sugar yield per feddan in the following order Gross sugar yield per feddan ranged between 3.14 and5.86 with an average of 4.498 ton fed^{-1}. It is worthy to note that the lowest sugar beet varieties in yield contained the extractable and gross sugar yields per feddan whereas the variety SV 1841 could not compensate the lower production ability as occurred by containing the higher sugar %. Moreover, it can be noticed that the high purity percentage expressed as (Qz %) shared in the partial compensation of the extractable for some tested varieties. Bio ethanol production significantly differed according to the variety used. It ranged between 1.66and 2.95 tons fd^{-1}for the varieties Amina and Rizobel, respectively. It could be concluded from this study that sugar beet variety may affect yield and quality of sugar beet in sandy soil conditions. Due to the instability of sugar beet varieties performance in yield and quality, it is recommended to continue varietal evaluation under such conditions. The sugar beet can be also considered an important renewable energy crop under Egyptian conditions.

Key words: Sugar beet · Varieties · Yield · Quality · Bioethanol production

INTRODUCTION

Sugar beet (*Beta vulgaris var. saccharifera* L.) ranks as the second important sugar crops after sugar cane, producing annually about 40 % of sugar production all over the world. In Egypt, it has been a large importance where there are wide newly reclaimed sandy soils at the northern and southern parts of Egypt, that could be cultivated with sugar beet without competition with other winter crops due to its tolerance to salinity and ability to produce high sugar yield under saline conditions and limited water requirements in comparison to the other traditional winter crops.

The total sugar beet cultivated area reached about 559744 feddan with an average of 20 ton fed^{-1} [1]. Recently, sugar beet has an important position in winter crops not only in the fertile soils, but also in poor, saline, alkaline and calcareous soils. Sugar beet varieties in Egypt are imported and regular evaluation for these imported varieties is essential in order to get stability of root and sugar yields as well as farmer confidence in these varieties.

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Osman *et al.* [2] found significant differences among the sugar beet varieties Gloria, Toro and Pamela in root length, diameter, fresh weight, root and sugar yield (ton fed^{-1}), as well as sucrose and purity %. Azzazy [3] and Abd El-Aal and Amal [4] showed that sugar beet varieties varied significantly for root fresh weight plant^{-1}, root and sugar yields fed^{-1}, while root length and diameter as well as sucrose and purity% did not differ significantly and sugar beet variety KWS-9422 gave the highest root and sugar yields fed^{-1}. El-Bakary [5] and Ismail *et al*. [6] found that sugar beet genotypes differed significantly in growth parameters, i.e. root length, diameter and root fresh weight as well as top, root and sugar yields fed^{-1}. Also, impurities %, Na, K and N % in sugar beet roots and quality sucrose and purity % in both seasons increased except impurities Na and K% in both seasons. Farida and Gazella genotypes gave the highest values, while, Samba and LPII contained the highest impurities.

Hozayn *et al*. [7] cleared that individual variability of different varieties might be attributed to their genetic constituents and their capacity to benefit from the environmental factors, which enable them to acclimatize and attain better yield and quality parameters. Ntwanai and Tuwana [8] stated that planting date x varieties and location x varieties interactions had a significant effect on sugar and root yields and sugar content as well as impurities of sugar beet cultivars. Ghareeb *et al.* [9] found that Pleno, Samba, Sultan and Farida sugar beet genotypes had the highest root and sugar yields at early sowing dates in October than that in November

Recently, due to the shortage of energy products using energy crops attracted the attention. Energy crops, also called "bioenergy crops", are grown for the specific purpose of producing energy (electricity or liquid fuels). As these crops are not grown for the purpose of producing food, there are no health risks implicated for the consumers. The possibility of using biomass as a source of energy in reducing green-house gas emissions is a matter of great interest. In particular, biomass from agriculture represent one of the largest and most diversified sources to be exploited and more specifically, ethanol and diesel deriving from biomass have the potential to be a sustainable means of replacing fossil fuels for transportation [10-11]. Nowadays, it is evident that sugarcane, sugar beet, sweet sorghum and some fruits are the good sources of sugar-rich juices used as feed stocks in ethanol production Bryan [12]. Direct fermentable juices obtained from these crops contain free sugars, especially, sucrose, glucose and fructose [13] make them more cost-effective feed stocks in fuel ethanol industry than starchy or lignocellulosic materials [12, 13].

The sugar beet crop can be also considered an important renewable energy factor [14], mentioned that it makes an annual contribution of 1.6 million tonnes of sugar syrup for the bioethanol (also known as ethyl or grain alcohol) production, according to the International Confederation of European Beet Growers. The bioethanol is mainly obtained due to fermentation of agricultural crops, such as corn grain, sugar beet, sugar cane and vegetable residues [15] and can be a suitable alternative to replace fossil fuels [16]. Furthermore, in order to reduce both gasoline and pollution consumption levels, bioethanol might be a key for a cheap and ecological manner. World ethanol production has reached 51.4 million m^3 in 2006 increasing 10% annually from 28 million m^3 in 2000 [17]. Bioethanol production from renewable sources to be used in transportation is now an increasing demand worldwide due to continuous depletion of fossil fuels, economic and political crises and growing concern on environmental safety. Bioethanol production is related to sugar beet quality and it was found that the highest ethanol production and theoreticalyield for ethanol production in a packed-bed bioreactor was obtained with 10.90% initial sugar concentration [18].

Therefore, the aim of this work is to evaluate sugar beet production as sugar or energy crop in newly reclaimed sandy soil.

MATERIALS AND METHODS

Two field experiments were conducted in the experimental Farm of the National Research Centre (latitude of 30.87°N and longitude of 31.17°E and mean altitude 21 m above sea level), El-Behaira Governorate. The experiments were conducted in 2021/22 and 2022/23winter seasons and included the evaluation of 6 sugar beet varieties which were AS 0082, Ravel, Rizobel, MK 4016, SV 1841 and Amina. The mechanical and chemical analysis of the soil are presented in Table 1.

Seeds of sugar beet were sown in 21th and 29th November in 2021/22 and 2022/23seasons, respectively. The experimental design was Complete Randomized Block Design (CRBD). During soil preparation, the recommended dose of phosphorus fertilizer was applied at a level of 200 kg calcium super phosphate fed^{-1} (15.5% P_2O_5). Nitrogen fertilizer (as ammonium nitrate 33.5% N) at the rate of 100 kgfed^{-1} was applied in four equal portions, the first was applied after thinning and

Table 1: Mechanical and chemical analysis of experimental soil.

Sand %	Silt %	Clay %	pH	Organic matter, %	$CaCo_3$ %	E.C. dS/m	Soluble N, ppm	Available P, ppm	Exchangeable K, ppm
91.2	3.7	5.1	7.3	0.3	1.4	0.3	8.1	3.2	20

15 days between the others. Potassium fertilizer (as potassium sulfate 48% K_2O) at the rate of 36 kgfed^{-1} was applied with nitrogen fertilizer after thinning. Then the experimental area was ridged and divided into plots (3.5 m width x 7m length). Sugar beet cultivars were sown in hills 25 cm apart at rate of 2 kg fed^{-1} by hand in rows. After 35 days from sowing, plants were thinned twice and later one was left to ensure one planthill^{-1}. Other agricultural practices were kept the same as normally practiced in growing sugar beet fields.

Data Recorded: At harvest, plants in the four inner ridges of each plot were collected and cleaned, therefore harvest was done at early April. Root and shoot yields fed^{-1} were determined from a central area of 10.5 m^2.

Studied Characters: Plant samples were taken from 3 replicates and 10 plants were taken from each variety to estimate root characters:root length (cm), root diameter (cm), root weight (g) and top weight per plant (g).

Yield per Feddan: Number of plants in the experimental unit was counted and top and root weights of 3 x 3.5m were determined, then total yield was calculated fed^{-1} (ton).

Chemical Determinations

Chemical Composition of the Roots: A sample of 5 kg of each variety was taken from the roots for analysis done by the sugar factory in El-Nubaria to determine:

Gross sugar %: Juice sugar content, which was determined by means of an Automatic Sugar Polarimetric according to [19].

Extractable white sugar%: Corrected sugar content (white sugar) of beets was calculated by linking the beet non-sugar K, Na and α-amino (expressed as a meq/100 g of beet) according to Harvey and Dutton [20] as follows:

$$ZB = pol - [0.343(K + Na) + 0.094\ AmN + 0.29]$$

where:
ZB = Corrected sugar content (% per beet) or extractable white sugar
Pol = Gross sugar %
AmN = α-amino-N determined by the "blue number method".
Loss sugar % = Gross sugar % - white sugar %
Juice purity percentage: Juice purity % (Qz) = ZB/ Pol x100

Soluble Non-sugar Content: The soluble non-sugars (potassium, sodium and α-amino nitrogen in meq/100 g of beet) in roots were determined by means of an Automatic Sugar Polari metric system. The results of these quality parameters were automatically calculated through the analyzer and the final results were tabulated and sugar yield fed^{-1} was calculated.

Bio Ethanol Determination: A composite sample of 50 kg of each treatment was taken and milled to obtain juice. Thereafter, bioethanol was determined using fermentation by yeast according to Hyun-Beom Seo *et al*., 2009. [21]

Statistical Analysis: The analysis of variance of the complete Randomized Block Design was carried out using MSTAT-C Computer Software [22]. Means of the different treatments were compared using the least significant difference (LSD) test at $P < 0.05$.

Effect of Varietal Difference on Sugar Beet Yield Characteristics: Data presented in Table (2) and Fig. (1, 2) show significant differences among the tested sugar beet varieties. The combined analysis of the data showed significant differences among the tested varieties in mean root length and diameter, root and top weight per plant (Table 3 and Fig. 2) as well as root and top weight per feddan (Table 2 and Fig. 2). The data show that Rizobel variety significantly surpassed the other varieties in root and top yields per plant and per feddan and possessed reasonable criteria for root length and diameter. The most superior variety in root and top yields per feddan was reported by Rizobel followed by MK 4016. However, the varieties SV 1841 and Amina gave the lowest studied parameters in root length and diameter as well as root and top yields per plant and per feddan. The tested varieties could be arranged according to root yield fed^{-1} in the following order Rizobel>MK 4016>Ravel>AS 0082>SV 1841>Amina. These results indicate that there were not clear tendency for the performance of sugar beet varieties even under the same soil type or the same district indicating the need for concentrating evaluation

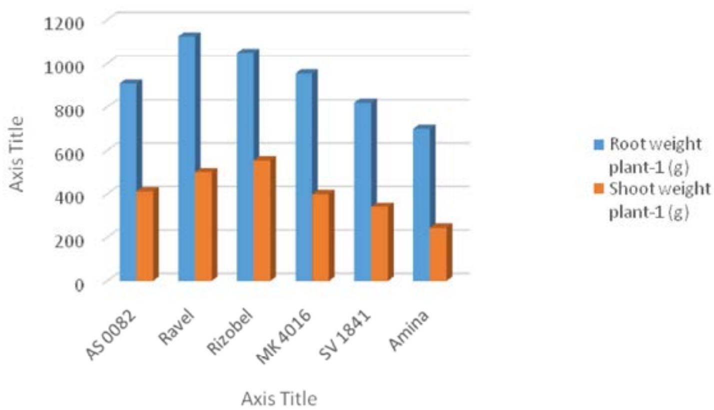

Fig. 1: Effect of varietal differences on root and shoot yields per plant combined data of 2016/17 and 2018/19.

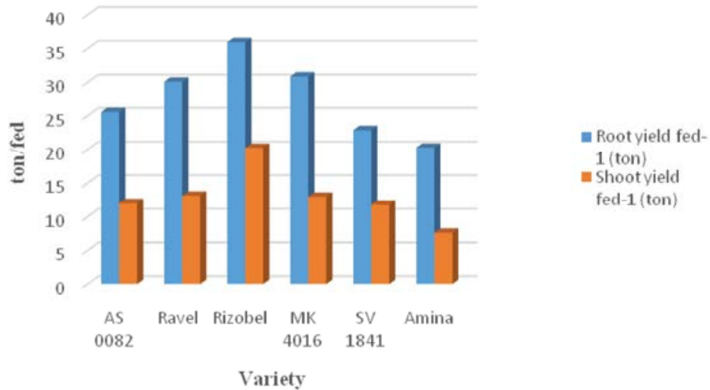

Fig. 2: Effect of Sugar beet varietal differences on root and shoot yields per fed.

Table 2: Effect of Sugar beet varietal differences on root characters and yield.

Varieties	Root length (cm)	Root diameter (cm)	Root weight plant-1 (g)	Shoot weight plant-1 (g)	Root yield fed-1 (ton)	Shoot yield fed-1 (ton)
AS 0082	33.5	11.75	908.75	412.7	25.57	11.97
Ravel	34.5	10.55	1124.3	498.8	30.1	13.095
Rizobel	35.2	9.6	1049	553.6	35.95	20.225
MK 4016	37.35	9.5	954.4	398.9	30.87	12.96
SV 1841	35.5	9.5	820.9	339.7	22.86	11.76
Amina	33.35	8.5	699.15	245.75	20.27	7.61
LSD 0.05	8.78	3.125	53.205	51.015	4.65	3.495

Table 3: Effect of sugar beet varietal differences in chemical composition of roots.

Variety	Sugar %	Na %	K %	α-Amino-N %	Juice purity (Qz) %	Sugar yield fed^{-1} (ton)	Extractable %
AS 0082	14.2	2.5	6.5	2.3	75.07	3.989	16.23
Ravel	15.65	3	4.35	1.45	82.385	4.61	15.29
Rizobel	15.7	2.6	4.65	1.9	83.375	5.86	15.30
MK 4016	15.9	2.35	5.05	2.35	80.6	5.06	15.45
SV 1841	16.85	2	4.8	2.35	81.205	3.82	16.41
Amina	15.55	2.95	5.85	1.7	81.615	3.14	15.16
Mean	15.93	2.58	4.94	1.95	81.836	4.498	15.736
Min.	16.85	1.7	3.25	1.2	78.325	3.14	15.75
Max.	17.4	3.15	5.85	2.45	87.025	6.63	14.78
CV%	5.505	23.65	18.31	24	3.85	28.17	16.90

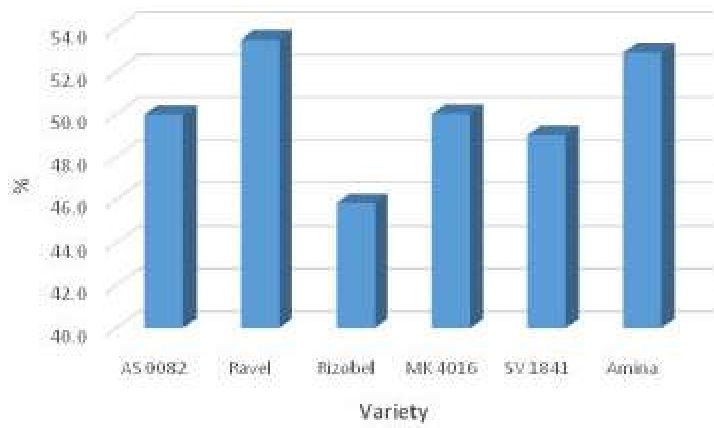

Fig. 3: Extractable sugar percent % of the gross sugar percentage

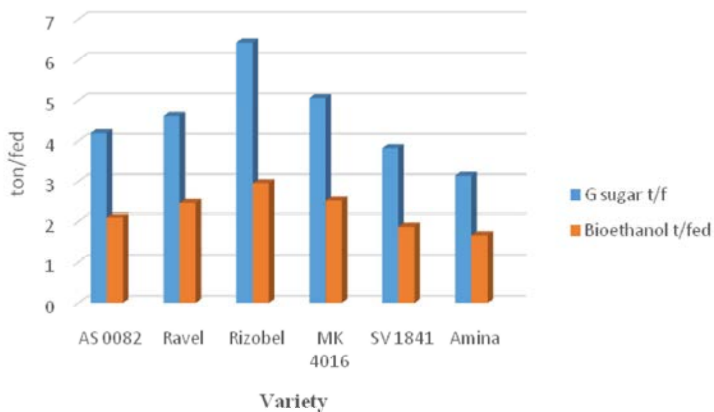

Fig. 4: Effect of sugar beet varietal differences on gross and extractable sugar yield. Bioethanol production

Table 4: Effect of sugar beet varietal differences on gross sugar yield and Bioethanol production

	G sugar t/f	Bioethanol t/fed
AS 0082	4.194	2.09674
Ravel	4.6115	2.4682
Rizobel	6.4325	2.9479
MK 4016	5.059	2.53134
SV 1841	3.822	1.87452
Amina	3.1415	1.66214

over repeated seasons to give the confidence to sugar beet growers and producers for specific region. These results were similar to those obtained by Aly [23] and El-Sheikh *et al.* [24] they found that the examined sugar beet varieties varied significantly for root fresh weight plant^{-1}, as well as, root and sugar yields fed^{-1}, while, root length and diameter, as well as, sucrose % and purity % were insignificant differences. Enan *et al*. [25] in Egypt, showed that sugar beet varieties differed significantly in root length, diameter, fresh weight plant^{-1}. Shalaby *et al*. [26] reported that sugar beet varieties showed insignificant differences in root length in two seasons. While, root diameter was affected significantly in the 2nd season and gave the highest value (15 cm). Also, root fresh weight was significantly superior to the other varieties in both seasons were it produced (1300 and 1250 g plant^{-1}) obtained from Lola variety. Hozayn *et al*. [27] cleared the individual variability of different varieties might be attributed to their genetic constituents and their capacity to benefit from the environmental factors, which enable them to acclimatize and attain better yield Also, Aly *et al* [28] tested the sugar beet varieties and found that Oscar Poly variety significantly surpassed of root fresh weigh/plant and root yield fed^{-1}.

Effect of Varietal Differences on Sugar Beet Quality: Data presented in Table (3) and Fig (3) show that sugar beet varieties exhibited clear differences in quality parameters which affected sugar extraction parameters. Data in Table (3) show that the minimum sugar % in beet roots expressed as polarity % ranged between 15.65and

16.15% with an average of 15.93. Sugar yield ranged between 3.14 and5.86ton fed^{-1} with an average of 4.50 ton fed^{-1}.It is worthy to note that the lowest sugar beet varieties in in sugar yield contained the the highest sugar percentage. The data of the extractable sugar indicated similar tendency for the gross sugar yield per feddan it seems that α-Amino-N the component is related to sugar detracting where as it is lower the juice purity (Qz %) parameter increase. The tested varieties could be arranged according to sugar yield fed^{-1} in the following order Rizobel>MK 4016>Ravel>SV 1841>AS 0082>Amina. It is worthy to note that the lowest sugar beet varieties *in yield contained the lowest extractable and gross sugar yields per feddan* and could not compensate the lower production ability as occurred by the variety SV 1841 which possessed higher sugar %. Such effect was more pronounced for the variety Amina which possessed lower root yield and gross and extractable sugar yield indicating that root yield is a limiting factor in producing sugar. The obtained results are in accordance with those obtained by Jassem [29]. Also, Khan *et al*. [30] reported that varieties differed significantly for yield and sugar contents in districts of southern KPK, Pakistan. The average beet yield remained 36.0 to 72.8 t ha^{-1}. It has been reported from three years of sugar beet varietal trials that in different parts of Punjab sugar beet varieties performed differently with respect to germination, yield and sugar recovery. El-Kammash *et al*. [31] pointed out that sugar beet cultivars had no significant effect on sugar recovery per feddan.

Bioethanol Production: Data presented in Table (4) and Fig4show the production of ethanol from sugar beet after harvest. The results indicate that the production of bio-ethanol from sugar after harvest. Bio ethanol production significantly differed according to the variety used. It ranged between 1.66and 2.95 tons fd^{-1} for the varieties Amina and Rizobel, respectively.

It is estimated that from the context that each gram of sucrose that is recovered from sugar beets can be converted into approximately half a gram of ethanol. Sugar beets are generally about 17% sucrose by mass, although genetic modifications, selective breeding and irrigation increase this number substantially, up to 21% [32]. In 2009 25.8 tons or about 23,400 kg of sugar beets were harvested per acre of land cultivated [33] which represents approximately 1930 kg of ethanol could be produced. Ogbonna *et al*. [34] reported that sugar beet yield of ethanol reached 72-86% of the sugar beet juice fermented.

CONCLUSION

It could be concluded from this study that sugar beet variety may affect yield and quality of sugar beet in sandy soil conditions. Due tothe instability of sugar beet varieties performance in yield and quality, it is recommended to continue varietal evaluation under such conditions. The sugar beet can be also considered an important renewable energycrop under Egyptian conditions.

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