Performance of Sugar Beet (*Beta vulgaris* L.) Cultivars under the Intercropping with Clover in Arid Land Conditions

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Abstract. This investigation was carried out at Hada AL-Sham Agricultural Research Station, KAU to study the behavior of three sugar beet cultivars (Farida, Dita and Heros) under three intercropping systems (sugar beet sole, 1sugar beet: 2 clover and 1sugar beet:3 clover rows) during 2016-208 seasons. Intercropping systems produced higher root and sucrose yield/ha more than sole plantation. In addition, Farida cv was the highest in root and sucrose yield compared with the other cultivars. Farida cv under the 1sugar beet: 3clover intercropping system produced the highest sucrose yield/ha (4.45t and 7.04 t/ha in the 1st and 2nd seasons, respectively).

Keywords. Chlorophyll, Cultivar, Intercropping, Sucrose, Sugar beet.

1. Introduction

Sugar beet is the second sugar crop in the world. It is with sugar cane produce almost all world consumption from sugar used in different sugar utilization. In arid land under the stress conditions and low available water and land use efficiency, intercropping system between field crops is very successful system to utilize the available resources to produce the highest benefit from the soil. In agriculture, several studies on intercropping have been carried out to evaluate potential agronomic and economic benefits (Hauggaard *et al.*, 2001). Sugar beet root yields and sucrose yield were maximum in lentil intercropping compared to cereals and oilseeds intercroppings. It is recommended that intercropping of sugar beet variety Kaweterma with lentil should be practiced for higher qualitative, quantitative and monetary benefits (Usmanikhail *et al.*, 2012). In the arid land conditions, the interest

in intercropping has increased in recent years (Connolly *et al.*, 2001; Anil *et al.*, 1998). The intercropping of legumes with sugar crops may also be a feasible alternative system to increase the crop productivity (Carruthers *et al.*, 1998; Ofori and Stern, 1987). Values of land return ratio were greater than 1.00 in any intercropping system of sugar beet with wheat, barley, and faba bean, indicating an advantage of the intercropping patterns for land usage and yield gain (Salama *et al.*, 2016). Intercropping sugar beet with 25 cm – onion maximized the growers income and reduced insect pest infestations (Badawy and Shalaby, 2015). Farghaly *et al.*, (2003) reported that yield of sugar beet has been reduced by intercropping with onion or faba bean compared to sole sugar beet. However, sugar beet intercropped with coriander gave a better performance to get interim benefit from the same area (Azad and Alam, 2004).

Intercropping can improve soil quality and ecological microclimate and enhances crop productivity (Li *et al.*, 1999). Intercropping sugar beet with lentil gave the highest monetary benefits compared to the sole sugar beet, or other intercropping systems. In addition, the highest values of land equivalent ratio were observed when sugar beet was intercropped with onion, while the least were found when sugar beet was intercropped with faba bean (Farghaly *et al.*, 2003). Intercropping faba bean with sugar beet on different ridge width significantly affected sugar beet yield and yield components. (Hamdany and Aassar, 2017). Sugar beet genotypes differed significantly in root length, root fresh weight, root yield, and sucrose content (Enan *et al.*, 2009, Mohamed *et al.*, 2012, Mohamed and Yasin, 2013 and Mekdad and El-Sherif, 2016). Significance differences in crown tissue production and development rate may cause quality differences between sugar beet genotypes (Halvorson *et al.*, 1978, Halvorson and Hartman, 1980 and Al-Sayed *et al.*, 2012).

This study was conducted to investigate behavior of three sugar beet diverse genotypes including one monogerm cultivar from Belgium, one polygerm cultivar from Egypt and the third is polygerm cultivar from Syria under different intercropping systems with Saudi local clover cultivar under the arid land conditions.

2. Materials and Methods

This research was conducted during 2016/2017 and 2017/2018 seasons in the Agricultural Research Station, King Abdulaziz University at Hada Al-Sham region, Saudi Arabia. Three sugar beet cultivars from different regions were tested under 3 intercropping systems between sugar beet and Al-Hassawi local clover cultivar. Split plot design with 4 replicates was used in the two

seasons. The main plot treatments were the 3 intercropping systems: 1 row sugar beet: 2 rows clover (1S: 2C), 1 sugar beet: 3 rows clover (1S: 3C), besides the sugar beet sole (So). Sub plots were occupied by 3 sugar beet cultivars: Farida polygerm cultivar from Egypt, Dita monogerm cultivar from Belgium and Heros polygerm cultivar from Syria. The sub plot consisted of 10 rows with 40 cm between each 2 rows and 30 cm between hills with one plant in each hill. Surface drip irrigation system was used and the dripper lines was installed with 40 cm between two adjacent dripper lines while the distance between drippers is 30 cm. The type of the dripper line is RAIN BIRD LD- 06- 12-1000 Landscape drip 0.6 G/h @12". Inlet pressure on each tape was about 1.5 bars. The system uses 125-micron disk filter. Planting dates were 12 November and 20 October in the first and second season, respectively the common cultural practices were done according to El-Nakhlawy and Ghandorah, 2009. At harvesting root length (mm), root diameter (mm), fresh root yield /ha (t), dry root yield /ha (t) and sucrose yield/ha (t). Sucrose yield/ha was calculated by multiply sucrose content (%) by dry root yield/ha. Sucrose (%) was measured using the Polarimetry method (A.O.A.C., 2006). Total chlorophyll content of leaves was measured at 55 days sugar beet age. Representative sugar beet leaves samples/sub plot were collected to determine total chlorophyll content. The total chlorophyll of sugar beet leaves were extracted from the fresh leaves of each sample by acetone (80%). The spectrophotometer readings of the samples were measured using Spectrophotometer (Spectrophotometer Model 6120, perkin-Elmer) at wave length 663 nm. The equations of Jayarman (1988) were used to calculate the total chlorophyll concentrations (mg/g) in the leaves.

3. Statistical Analysis

The obtained data of the experiment in the two seasons was statistically analyzed through analysis of variance procedures (ANOVA) then revised least significance difference (RLSD) test was used to compare between the treatment means after applying the statistical analysis assumptions according to El-Nakhlawy (2010) using SAS (2006).

4. Results

4.1 Effect of Intercropping Systems

4.1.1 Root length

The obtained results of root length under the effect of the three intercropping systems in the 2 seasons (Table 1) showed insignificant differences between the systems of 1sugar beet: 2clover and 1sugar beet : 3clover , but they significantly different from the sugar beet root length under the sole plantation. Root length ranged from 210.21 mm to 202.91 mm in the first season and from 216.43mm to 207.01mm in the second season.

4.1.2 Root diameter

The response of root diameter to the treatments of intercropping was opposite to the root length. The highest root diameter values were detected from the sugar beet sole and significantly different from the (1S: 2C) or (1S: 3C) intercropping systems without significant differences between these last 2 intercropping systems in the 2 seasons. Root diameter of sugar beet as sole plantation in the 1st and 2nd seasons were 91.23 mm and 122.86 mm, respectively while under the 2 intercropping systems (1S: 2C) and (1S: 3C) were around 83 mm and 119 mm as average of the 2 seasons, respectively (Table 1).

4.1.3 Fresh root yield /ha

The statistical comparisons between the means of fresh root yield /ha in each seasons (Table1) showed that the (1S: 2C) and (1S: 3C) intercropping systems produced the highest fresh root yield /ha without significant difference and they dominated over the sole plantation. Fresh root yield /ha ranged from 61.50 t to 60.50 t in the first season and from 106.39 t to 104.13 t/ha in the second season.

4.1.4 Dry root yield/ha

The presented data of dry root yield /ha under the intercropping systems (Table 2) showed similar trend as the fresh root yield/ha. No significant differences were found between the (1S: 2C) and (1S: 3C) intercropping systems but they significantly dominated over the sugar beet sole in both seasons. Dry root yield /ha ranged from 19.55 t/ha to 16.89 t/ha in 1st season and from 37.13t/ha to 35.11t/ha in the 2nd season.

4.1.5 Total chlorophyll content of leaves

The intercropping system (1S: 2C) was the highest in the total chlorophyll content of sugar beet leaves (2.55 mg/g and 3.01 mg/g in both seasons, respectively) and significantly different from (1S: 3C) system and sugar beet sole in both seasons. No significant differences were showed between the (1S: 3C) and sugar beet sole in both seasons.

4.1.6 Sucrose yield/ha

As shown in Table 2, the 2 intercropping systems (1S: 2C) and (1S: 3C) significantly similar in sucrose yield and significantly more than the sugar beet sole in the 2 seasons. Sucrose yield ranged from 3.3 t/ha - 2.57 t/ha in the first season and 6.43 t/ha to 5.91 t/ha in the second season.

Table 1. Means of root length (mm), root diameter (mm) and fresh root yield /ha (t) of sugar beet under the effect of intercropping systems during 2016/2017 and 2017/2018 seasons.

Intercropping System	Means					
	Root length (mm)		Root diameter (mm)		Fresh root yield/ha (t)	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
1 sugar : 3 clover	210.21 a*	216.43 a	82.14 b	118.61 b	62.52 a	108.77 a
1 sugar : 2 clover	207.06 a	212.04 a	83.62 b	119.16 b	61.49 a	106.39 a
Sugar beet sole	202.91 b	207.01b	91.23 a	122.86 a	60.50 b	104.13 b
RLSD (0.05)	3.37	6.40	2.11	1.78	1.42	2.45

*Means of each trait under the main factor treatments followed by the same letter are not significantly different according to RLSD at $p \leq 0.05$.

Table 2. Means of dry root yield (t/ha), total chlorophyll (mg/g) and sucrose yield/ha (t) of sugar beet under the effect of intercropping systems during 2016/2017 and 2017/2018 seasons.

Intercropping Systems	Means					
	Dry root yield/ha (t)		Total chlorophyll (mg/g)		Sucrose yield/ha (t)	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
1 sugar : 2 clover	18.43 a*	36.65 a	2.53 a	3.01 a	3.12 a	6.21 a
1 sugar : 3 clover	19.55 a	37.13 a	2.46 b	2.84 b	3.31 a	6.43 a
Sugar beet sole	16.89 b	35.11 b	2.44 b	2.87 b	2.57 b	5.91 b
RLSD (0.05)	1.18	0.91	0.03	0.05	0.21	0.26

*Means of each trait under the main factor treatments followed by the same letter are not significantly different according to RLSD at $p \leq 0.05$.

4.2 Effect of Sugar Beet Cultivars

According to the sugar beet cultivars genetic makeup and their interaction with the environment conditions, the data of the 3 studied sugar beet cultivars were expressed on these genetic, environment and genetic $\times$ environment interaction.

4.2.1 Root length/ha

Farida cv. had the longest roots and significantly more than the other 2 cultivars in both seasons. No significant differences were showed between Dita and Heros cv in both seasons. Root length means of Frida, Heros and Dita cultivars were 228.69, 204.8 and 208.69 mm, respectively in the first season and 215.09, 210, and 209.32 mm, respectively in the second season as shown in Table 3.

4.2.2 Root diameter

As shown in Table 3, Farida cv was the highest in root diameter (92.83 mm in the 1st

season and 118.55 mm in the 2nd season) followed by Dita cv then Heros cv was the lowest in root diameter (70.72 mm and 113.42 mm in both seasons, respectively).

4.2.3 Fresh root yield/ha

The highest fresh root yield/ha was produced from Frida and significantly was over the two cultivars in both seasons. Farida fresh root yield /ha in the 1st and 2nd season were 60.62 t/ha and 97.02 t/ha, respectively. Heros produced 57.26 t/ha and 64.55 t/ha and Dita cv produced 58.62 t/ha and 90.72 t/ha in both seasons, respectively (Table 3).

4.2.4 Dry root yield /ha

As for fresh root yield /ha, dry root yield /ha responded to the genotype, where Farida cv was the highest in both season (22.69t/ha in the 1st season and 37.94t/ha in the 2nd season) followed by Dita cv (18.24t/ha and 34.69 t/ha in the 1st and 2nd seasons, respectively). Heros

produced the lowest dry root yield /ha in both seasons (Table 4).

4.2.5 Total chlorophyll content

The obtained results of total chlorophyll content of the leaves in the three cultivars (Table 4) showed that Farida cv was the highest followed by Dita cv while Heros was the lowest. No significant differences were found between Farida cv and Dita cv but they significantly dominated over Heros cv in both seasons. Total chlorophyll in Farida, Dita, and Heros cultivars were 2.67, 2.59 and 2.17mg/g, respectively in the first season, and in the second season were 3.14, 3.15 and 2.43 mg/g, respectively (Table 4).

4.2.6 Sucrose yield/ha

Significant differences were found between the 3 cultivars for sucrose yield/ha in the 2 seasons. Farida cv produced the highest sucrose yield /ha in the 1st season (4.06 t/ha) and 2nd season (6.97 t/ha) followed by Dita cv (3.43 t/ha and 6.72 t/ha) then Heros cv (2.12 t/ha, 3.35 t/ha) in the 1st and 2nd season, respectively as shown in Table 4.

4.3 Effect of the Interaction between Intercropping Systems and Sugar Beet Cultivars

4.3.1 Root length

Significant differences were showed for the root length under the 9 interaction treatments in both studied seasons. The tallest root were found in Farida cv under the (1S:2C) intercropping system with values of 228.43 mm and Dita cv under (1S:3C) intercropping system (225.72 mm) in the first season. The shortest root length means were detected from the sugar beet Dita and Heros cv sole plantations (195.48 mm and 195.83 mm, respectively). In the second season the highest root length means were showed from Farida cv under 1:3system (217.68mm), Heros cv under (1S:3C) system (217.76 mm) without significant differences from Farida cv and Dita

cv under (1S:2C) intercropping system with values of 215.91 mm and 214.86 mm, respectively. The shortest roots were found in Heros cv and Dita cv as sole plantations (205.26 mm and 204.08 mm, respectively) as shown in Table 5.

4.3.2 Root diameter

The presented data in Table 5 showed that Farida cv was the highest in root diameter under any intercropping systems and no significant differences were found between root diameter means of Farida under the 3 intercropping systems in each season. Root diameter ranged from 89.25 mm to 67.96 mm in the first season and from 119.03 mm to 100.36 mm in the second season. Heros cv under the system of (1S : 3C) in the first season (67.96 mm) and (100.36 mm) under (1S: 3C) also in the second season.

4.3.3 Fresh root yield/ha

The statistical comparisons of fresh root yield /ha under the intercropping between 3 sugar beet cultivars and 3 intercropping systems, showed that Farida cv was the highest in fresh root yield/ha under any intercropping system and significantly different from the other interaction treatments. Dita cv under the intercropping system of (1S:2C) in the first season, the system of (1S:2C), and sugar beet sole occupied the 2nd rank in fresh root yield/ha. The lowest fresh root yield/ha produced from Heros cv under the systems of (1S: 2 C) and (1S:3C) in the 1st and 2nd seasons, respectively (Table 5).

4.3.4 Dry root yield/ha

Similar response as the fresh root yield/ha, dry root yield/ha responded to the interaction between intercropping system and cultivar. Farida cv under sole plantation produced the highest dry yield in the first and second seasons (24.27 t/ha and 39.14 t/ha) respectively followed by Farida cv under

(1S:2C) intercropping system. Significant differences were found between Heros cv under (1S:2C) and (1S: 3C) intercropping systems and the other 2 cvs under intercropping systems in both seasons. Generally, Heros cv was the lowest cultivar under all intercropping systems compared with the other interactions treatments (Table 6).

4.3.5 Total chlorophyll content

The obtained results (Table 6) showed that Farida cv under the (1S:3C) system had the highest chlorophyll content in both seasons (2.68 and 3.3 mg/g, respectively). Heros cv as a sole plantation was the lowest in total chlorophyll content (2.15 and 2.92 mg/g in both seasons, respectively). Dita cv under the intercropping systems of (1S:2C) or (1S:3C) followed Farida

cv under the different intercropping systems in total chlorophyll in the 2 seasons.

4.3.6 Sucrose yield/ha

As shown in Table 6, Farida cv under the (1S:3C) intercropping system produced the highest sucrose yield/ha in the 1st and 2nd seasons (4.45 t/ha and 7.04 t/ha, respectively) followed by Farida cv under (1S:2C) system (4.32 t/ha and 7.02 t/ha in both seasons, respectively). Dita cv under (1S:3C) system and Dita cv under (1S:2C) system occupied the 2nd rank with significant difference from Farida cv under (1S:3C) system. Heros cv under the 3 intercropping systems were significantly the lowest in sucrose yield /ha compared with the other interaction treatments.

Table 5. Means of root length (mm), root diameter (mm) and Fresh root yield (t) under the effect of the interaction between intercropping systems and sugar beet cultivars during 2016/2017 and 2017/2018 seasons.

Intercropping system	Cultivar	Means					
		Root Length (mm)		Root diameter (mm)		Fresh root yield (t/ha)	
		2016/17	2017/18	2016/17	2016/17	2017/18	2016/17
1sugar:2clover	Dita	207.87	214.86	83.62	119.13	58.65	91.56
	Heros	203.88	208.35	70.73	115.57	54.45	65.72
	Farida	228.43	215.91	86.07	119.03	68.29	97.42
1sugar:3clover	Dita	225.72	207.85	79.16	104.72	60.93	88.26
	Heros	214.77	217.76	67.96	100.36	59.13	59.65
	Farida	212.17	217.68	89.25	118.39	67.5	94.4
Sugar beet sole	Dita	195.48	205.26	85.17	114.58	58.07	92.34
	Heros	195.83	204.08	73.88	112.66	56.28	67.2
	Farida	215.43	211.68	88.18	118.25	70.08	99.25
RLSD (0.05)		5.03	8.75	4.40	2.78	2.20	3.60

Table 6. Means of Dry root yield(ha), Total chlorophyll (mg/g), and Sucrose yield ha(t) and under the effect of the interaction between intercropping systems and sugar beet cultivars during 2016/2017 and 2017/2018 seasons.

Intercropping system	Cultivar	Means					
		Dry root yield (t/ha)		Total chlorophyll (mg/g)		Sucrose yield/ ha (t)	
		2016/17	2017/18	2016/17	2016/17	2017/18	2016/17
1sugar:2clover	Dita	17.92	34.78	2.67	3.16	3.35	6.68
	Heros	17.66	25.57	2.19	2.43	2.26	3.39
	Farida	22.72	38.36	2.72	3.04	4.32	7.02
1sugar:3clover	Dita	20.12	34.66	2.54	3.27	3.88	6.77
	Heros	18.44	23.59	2.16	2.47	2.44	3.22
	Farida	21.09	36.31	2.68	3.3	4.45	7.04
Sugar beet sole	Dita	17.75	34.62	2.54	3.02	3.06	6.56
	Heros	16.67	26.19	2.15	2.42	1.68	3.37
	Farida	24.27	39.14	2.62	3.08	4.05	6.80
RLSD (0.05)		1.20	0.86	0.15	0.08	0.30	0.26

5. Discussions

At first the big differences between the results of the two seasons, may be due to the effects of the environmental conditions during the 2 seasons, which resulted from the different planting dates in the 2 seasons. The second season was earlier in planting date with 22 days than the first season. In the second season, plants grow in long season under the not long photoperiod than the first season. The long growing season enhanced the photosynthesis and nutrients accumulation, which reflected into high yield and yield components in the second season more than the first season (Mohamed and Yasin, 2013, Enan *et al.*, 2009). The superiority of Farida cultivar over Dita and Heros cultivars in root yield, yield components, sucrose yield and total chlorophyll might be due to the genetic makeup of the 3 cultivars. Farida polygerm cultivar had genes of high yield potential and yield components more than the other 2 cultivars. In addition, Farida cv was Egyptian cultivar and adopted to the environmental conditions nearly like the conditions of the winter season of Jeddah, while and although Dita cv is a monogerm cv but its Belgium cv and produced under the cold conditions, accordingly it affected by the interaction between genetic makeup and Jeddah environment. Also, Heros cv was a Syrian cv and was cultivated under low temperature in Syria less than the Jeddah temperature besides the genetic makeup of this cultivar which reflected on its performance under the Jeddah conditions. (Enan *et al.*, 2009, Mohamed *et al.*, 2012, Mohammed and Yasin, 2013 and Mekdad and EL-Sherif, 2016). In addition, the significance differences between the genotypes in chlorophyll content and development rate may cause sucrose content differences (Halvorson and Hartman, 1980 and AL-Sayed *et al.*, 2012). The good sugar beet performance and dominating under the intercropping with

clover with (1S: 2C) or (1S: 3C) systems more than the sugar beet sole plantation may be due to the positive effects of the intercropping with the legume crop in improving of soil nutrients profile, soil texture, soil water holding capacity, ecological micro climate and enhancing crop productivity (Li *et al.*, 1999). Intercropping sugar beet with clover increase the nutrients in the soil through the analysis of clover roots and plant residuals after cutting of clover plants (Salama *et al.*, 2016 and Carruthers *et al.*, 1998).

6. Conclusions

The obtained results of this study showed that sugar beet crop intercropped with clover in 1sugar beet: 3clover and 1 sugar beet: 2 clover significantly increased sugar beet root yield/ha and sucrose yield/ha compared with sugar beet sole. Farida cultivar was the highest cultivar in root yield/ha, sucrose yield/ha and total chlorophyll content. The best sugar beet root yield and sucrose yield/ha were produced from Farida cultivar under the 1 sugar beet: 3 clover intercropping system.

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أداء أصناف بنجر السكر تحت التحميل مع البرسيم في ظروف المناطق الجافة

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المستخلص. أجريت هذه الدراسة بمحطة الأبحاث الزراعية بهذا الشام التابعة لجامعة الملك عبدالعزيز لتقييم أداء ثلاثة أصناف بنجر سكر، هي: أصناف فريدة (متعدد الأجنة-مصري)، وديتا (وحيد الجنين-بلجيكي) وهيروس (متعدد الأجنة-سوري) تحت ثلاثة نظم من التحميل، هي: زراعة بنجر السكر منفردا، وتحميل ١ خط بنجر سكر: ٢ سطربرسيم، وتحميل خط ١ بنجر سكر: ٣ سطر برسيم، خلال ٢٠١٦-٢٠١٨م. وأظهرت النتائج تفوق نظامي التحميل على الزراعة المنفردة، وكذلك تفوق الصنف فريدة على الصنفين الآخرين في محصول الجذور ومحصول السكر والمحتوى الكلي للكلوروفيل في الأوراق، وكان محصول السكر للصنف فريدة تحت نظام تحميل (١: ٣) الأعلى، حيث كان ٤,٤٥ طن/هكتار، ٧,٠٤ طن/هكتار في الموسمين الأول والثاني علي الترتيب.

الكلمات المفتاحية: الكلوروفيل، الأصناف، التحميل، السكر، بنجر السكر.