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Full Length Research Paper

Effect of water stress and fertilization on yield and quality of sugar beet under drip and sprinkler irrigation systems in sandy soil

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With increasing concern about declining water resources, it has become mandatory to apply appropriate methods to conserve water and reduce chemical inputs in the field of crop production in line with sustainable agricultural practice. Therefore, two field experiments were conducted at Wadi El-Natrun, Egypt (30°23'19.89˝ N latitude and 30°21'41.06˝ E longitude) during 2011/2012 and 2012/2013 seasons to study the effect of water stress (100%, 75% and 50% of irrigation water requirements), two organic fertilization levels (zero and 5 ton compost/fed) and three nitrogen fertilization rates (60, 90 and 120 kg N/fed) on growth, yield and quality of sugar beet plants grown under conditions of drip and sprinkler irrigation systems. Results revealed that drip irrigated sugar beet plants with 75% of irrigation water requirements (IWR) recorded the highest significant leaf area index, sucrose%, purity% and extractable sugar% in both seasons and white sugar yield in the second season only, while application of sprinkler irrigate at 100% of IWR gave the heaviest root weight, root number, purity %, root yield in both seasons. Applying compost (5 ton/fed) with sprinkler irrigation significantly increased root weight, root number and root yield in the both seasons. Also, application of compost (5 ton/fed) with drip irrigation system increased root yield. Increasing N rate up to 120 kg N/fed significantly increased LAI, individual root weight, root number/fed and impurities percentage as well as root yield (ton/fed) in both seasons and white sugar yield (ton/fed) only in the first season. Excessive N application lowered beet quality in terms of sucrose, purity and extractable sugar percentage in both seasons.

Keywords: Sugar beet - Dip irrigation system - Sprinkler irrigation system - Water stress - Compost - Nitrogen fertilization.

INTRODUCTION

In Egypt, sugar industry depends on sugar cane and sugar beet crops. Sugar beet share with about 50% with a total production of 1.255 million tons of sugar (Sugar Crops Council Report, 2014) which indicates the strategic importance of this crop, especially under new soils conditions.
With increasing concern about declining water resources, there is a great intension to improve water management in farming systems to improve water saving (*Buttar et al*, 2007). The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. Irrigated agriculture is the largest water consuming sector and it faces competing demands from other sectors (Sander and Bastianssen, 2004). Arroyo *et al.* (1999) compared the effects of drip (trickle) and sprinkler irrigation systems on yield and quality of sugar beet. Irrigation intensity was 50, 70 and 90% E_{pan} (class A pan evaporation-precipitation). Root yield under drip (77.4 ton/ha) or/and

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undersprinkler (79.2 ton/ha) did not vary significantly at 90% E_{pan}, but drip irrigation resulted in significantly higher yields (80.8 and 73.2 ton/ha) than sprinkler irrigation (72.6 and 69.3 ton/ha) at 70 and 50% E_{pan}, respectively. The highest sugar content was found at 90% $E_{pan}$for drip irrigation and at 70% $E_{pan}$for sprinkler irrigation. Sharmasarkar *et al*. (2001) compared drip and furrow irrigation on sugar beet grown in sandy loam soil. They reported that sugar beet yield and sucrose content were greater under drip irrigation than under furrow irrigation. Kırda (2002) and Ramazzan *et al*. (2014) reported that one of the efficient strategies for efficient irrigation water uses is deficit irrigation program in areas having water shortage. Under well management, deficit irrigation results substantial water savings with little impact on the quality and quantity of the harvested yield. Sugar beet tolerates mid and late-season plant water stress and this characteristic make it a suitable crop for production with limited irrigation. Tognetti *et al.* (2002) applied five irrigation water regimes; 50, 75, 100 and 120% of the estimated evapotranspiration of sugar beet field; adjacent unirrigated beets were taken as control plants. Root yield and sucrose accumulation increased with the amount of irrigation water used. The unirrigated control showed a somewhat worsening of technological characteristics, due to the slight increase of alkali elements and alpha -amino acid N. Increasing the amount of water applied up to 100% of the estimated evapotranspiration, and not beyond, gives benefits in terms of sugar beet root yield and sucrose accumulation. Tognetti *et al*. (2003) compared sugar beet response under drip and low-pressure sprinkler irrigation and reported that yield of drip-irrigated sugar beet with 75% estimated evapotranspiration (ET) matched, in most cases; yield of sugar beet irrigated with 100% estimated ET under low-pressure sprinkler. Hosseinpour *et al.* (2006) studied the effect of variable irrigation in spring on water use efficiency (WUE), yield and quality of two sugar beet cultivars. Five water supply treatments 25, 50, 75, 100 and 125 percent of the plant water requirement (PWR) as drip irrigation was applied. Differences among water supply treatments were significant only for root yield, alpha amino-N, alkalinity, and water use efficiency of root and sugar yield. Increasing of water volume increased root yield and alkalinity and decreased WUE for sugar and root yield. The 100 and 25% PWR treatments had the highest (84 ton/ha) and the lowest (76 ton/ha) root yield, respectively. The 25% PWR treatment had the highest WUE for root and sugar yield which were 18.7 and 2.6 kg/m^3, respectively. Increment of water supply increased leaf area. Based on the results of this experiment, the 25% PWR as drip irrigation in spring can be recommended for autumn sugar beet. Mahmoodi *et al*. (2008) investigate the yield and quality of sugar beet in relation to different irrigation regimes; 30, 50, 70 and 90% of field capacity (F.C). They found that irrigation treatments had a significant effect on sugar beet yield and quality traits. The highest values of root and sugar yields and quality traits was obtained under 70% of field capacity, while the lowest values was recorded under 90% of field capacity. Esmaeili (2011) investigate the effects of water stress and different levels of N fertilizer on yield of sugar beet. Water treatments comprising three levels including control (without water stress), initial water stress and continuous water stress as main plots and different amounts of N fertilizer in 4 levels (0, 50, 100 and 150 kg N/ha) as sub plots were assessed. He reported significant effect of N levels on root yield and sugar percent. Appling 150 kg N/ha without water stress gave the highest root yield, but continuous water stress caused the maximum water use efficiency.

Organic fertilization plays an important role in reducing the use of chemical fertilizers and thus reducing the harmful impact of chemical use on soil and the environment and sustainable agriculture. Over the longer term, the compost is incorporated in the soil, improving its structure and biological activity and increasing the capacity of the soil to capture, store water, therefore the amount of irrigation water could be substantially reduced by the application of compost which helps in increasing water holding capacity. Gaj and Gorski. (2004) reported that application compost at 0, 10, 20 and 40 ton/ha had no significant effect on sugar beet yield and technological characters. Szymczak-Nowak and Tyburski (2006) evaluated the effect of compost application at the time of sowing on sugar beet seed germination, seedling health and yield. Thermophilic compost was applied in two ways: in the first method as a 3-cm layer of compost ("single compost layer"), and in the second method as two split layers of compost of 4 and 3 cm ("double compost layer"). Double row compost application vs. single row application reduced yields of roots, tops and white sugar by 26, 14 and 21%, respectively. Wallace and Carter (2007) studied the effect of compost on yield of sugar beet on various soil types (sandy loam, clay loam, sandy clay loam and sandy silt loam). They showed that the application of compost improves soil fertility. Key benefits were quantified relating to the physical condition of the soil (organic matter, soil structure and water relations); soil chemistry (soil pH and nutrients) and soil biology (increased microbial populations and activity). These benefits contributed an average yield increase of 7% where compost had been used regularly. Mahmoud *et al.* (2012) studied the response of sugar beet to three compost rates (0, 1 and 2 tons/fed). They found that application of 2 tons of compost/fed significantly produced the highest LAI and the heaviest roots, and improved juice quality traits (sucrose, purity and extractable sugar%). Increasing compost rate from zero to 2 tons/fed increased root yield by 16.4 and 14% and sugar yield by 27.8 and 20.2% in the first and second seasons, respectively.

The proper management of nitrogen fertilizer is a major factor in maximizing the production of sugar beet (*Beta vulgaris* L.). Supplies of nitrogen must of readily available during early and mid-season in order to promote root and top growth. However, beets must become deficient in N prior to harvest to attain the maximum sucrose concentration (Lauer, 1995). Widely ranging optimum rates of N have been reported in the literature. Sharif and Eghbal (1994) conducted field trials on loamy clay soil where 7 Germen sugar beet cultivars were given from zero up to 150 kg N/ha. They found that sugar yields increased with up to 150 kg N/ha. Total soluble solids and juice purity% decreased with increasing N rates. El-Hennawy *et al* (1998) reported that increasing N rate up to 120 kg/fed increased individual root weight by 166 and 181 gm in the two growing seasons of study, respectively. Excessive N application lowered beet quality in terms of root sucrose content and recoverable sugar per ton of beet. Recoverable sugar yield followed a production pattern similar to root yield with maximum sugar yield and profits at 90 kg N/fed. Number of plants at harvest was not significantly affected by N rates. Mahmoud and Masri (2009) found that under sprinkler irrigation, increasing N rates from 100 up to 160 kg N/fed significantly increased root weight by 16.51% and 24.77% and No of plants at harvest by 4.05 and 2.89 thousand plants/fed and root yield by 7.22 and 8.34 tons/fed in the first and second seasons, respectively. Excessive N rate lowered beet quality in terms of sucrose content, juice purity and extractable sucrose. Extractable sugar yield increased by increasing N rate from 100 to 120 kg/fed. Such increase amounted to 29.08% in the first season and 31.97% in the second one. More increasing in nitrogen rate had no effect on sugar yield. El-Sarag (2009) determined the effect of 4 nitrogen fertilizer rates (60, 80, 100 and 120 kg N/fed) on the growth, yield and juice quality traits of multigerm sugar beet cv. Farida. A drip irrigation system with an average of 4100 ppm water salinity was used. Increasing N fertilizer rates from 60 to 120 kg N/fed substantially improved most of the studied growth criteria and root yield as well as WUE. Meanwhile, adding 100 kg N/fed gave the optimum sugar yield. The highest sucrose and purity percentage were gained with the lowest nitrogen fertilizer rate (60 kg N/fed).Mahmoud *et al.*(2012 and 2014) found that application N at the rate of 100 kg N/fed significantly increased leaf area index (LAI), individual root weight and root and sugar yields. On the other hand, juice quality traits, sucrose, purity and sugar recovery were decreased.

The objectives of this study were to: (i) evaluate the productivity of sugar beet under drip and sprinkler irrigation systems, (ii) study the effect of water stress in combination with compost and nitrogen fertilization on yield and quality of sugar beet.

MATERIALS AND METHODS

This study was conducted at Wadi El-Natrun, El-Beheira Governorate, Egypt (30°23'19.89˝ N latitude and 30°21'41.06˝ Elongitude) during 2011/2012 and 2012/2013 seasons to study the effect of water stress, organic and nitrogen fertilization on yield and quality of sugar beet grown under conditions of drip and sprinkler irrigation systems in two separates experimental fields. Under each irrigation system, the experimental design was a randomized complete block in a split- split plot arrangement with three replications. Irrigation water levels were allocated to the main plots, while the sub plots were assigned for compost levels. Meantime, nitrogen rates were distributed at random in the sub-sub plots. Each irrigation system included 18 treatments, represented the combination among three water deficit treatments (100%, 75% and 50% of calculated irrigation water requirements), two organic fertilization levels (zero and 5 ton compost/fed) and three rates of nitrogen fertilization (60, 90 and 120 kg N/fed).Sugar beet multi-germ variety Samba was sown on ridges 60 cm apart and 20 cm between hills. Each sub-sub plot included 5 ridges each is 4 m in length. Therefore each subplot size was 12 m^2. Sugar beet seeds were sown on the first week of October of each season. Nitrogen was added in the form of ammonium nitrates (33.5% N) in three equal splits, the first was applied after thinning at 4-leaf stage and other splits were added at one and two months later. Phosphorous in the form of super phosphate (15.5%) at rate of 30 kg P_2O_5 /fed and compost were added before sowing and during land preparation. Potassium in the form of potassium sulfate (48%) was added at the rate of 48 kg K_2O/fed with the first dose of N. Thinning took place to one plant/hill at 4-leaf stage (4 weeks from planting). Other culture practice procedures were done as recommended.

The soil experimental site was sandy soil in texture with (8.10) p^H, (1.55 ds/m) EC, (1.025%) organic matter, (9.1%) available water, (30 ppm) available N, (2 ppm) available P and (250 ppm) available K.

The chemical analysis of the applied compost was contents of (16.6%) moisture, (7.86) p^H, (4.46 ds/m) EC, (1.03%) total nitrogen, (31%) organic matter, (69%) ashes, (1.17) C/N ratio, (1.25%) total phosphorus, (1.34%) total potassium, (141 ppm) ammonium nitrogen, (19.6 ppm) nitrate nitrogen and without weed seeds and nematode.

The amount of irrigation water requirement was determined using Blany and Criddle (1962) method:

$$IRc = \frac{[(ET0 \times Kc) \times Dd]}{Es}$$

Table 1. Average evapotranspiration (ET_o mm/day) at Wadi El-Natrun.

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
ET_0 (mm/day)	5.4	3.45	2.64	2.87	3.76	4.59

Table 2. Crop factor (K_c) through the growing season of sugar beet in the semi-arid region (FAO 33, 1979).

Initial		**Crop development**		**Mid-season**		**Late-season**		**Total (days)**
Time(days)	K_c	Time(days)	K_c	Time(days)	K_c	Time(days)	Kc	
30	0.35	60	0.35>Kc<1.2	60	1.2	30	1.2>Kc<0.7	180

Table 3. mean values of the amounts of the applied water (m^3/feddan*) to the experimental field.

Days from planting	**Growing stage**	**Amount of water (m^3/feddan*)**					
		Sprinkler irrigation			**Drip irrigation**		
		50%	**75%**	**100%**	**50%**	**75%**	**100%**
1 – **30**	Initial	297.7	297.7	297.7	258.9	258.9	258.9
31 – **90**	Development	326.2	483.3	652.4	283.7	425.5	567.3
91 – **150**	Mid-season	624.95	931.43	1249.9	543.5	815.2	1086.9
151 – **180**	Late-season	340.4	510.6	680.8	235.9	443.9	591.9
Total in the season		1589.3	2223.0	2880.8	1322.0	1943.5	2505.0

* feddan = 4200 m^2

Where, IR_c= Total actual irrigation water requirements (mm/intervals), ET_o= Evapotranspiration (mm/day), calculated according to CROPWAT program (Smith, 1991), K_c= Crop coefficient (Doorenbos and Kassam, 1979), D_d = Time intervals and E_s = System efficiency (%).

Sugar beet harvest took place after 180 days from sowing in both seasons. Roots were harvested from each plot. At harvest a random sample of ten plants from each sub-sub plot was taken to determine the following traits;Growth characteristics: Leaf area index[(LAI) = unit leaf area per plant (cm^2)/ plant ground area (cm^2)] was determined after 90 days from planting according to Waston (1958) and leaf area was determined using area meter, ATA60, Model 3100, fresh root weight (kg) and root number/fed. Juice quality characteristics: sucrose percentage was determined by using sacharometer lead acetate extract of fresh moderated roots according to Carruthers and Oldfield (1960). Extractable sugar percentage (ES%)was determined according to the following formula ES% = pol-[0.343(K + Na) + 0.094 α-amino N + 0.29] according to Renfield *et al* (1974), where Pol = sucrose percentage, juice purity percentage (QZ) = (ES%/ pol) x 100, impurities percentage=[0.343(K + Na) + 0.094 α-amino N + 0.29].Yields:root yield (ton/fed) and white sugar yield (ton/fed) = root yield x(extractable sugar percentage/100).

Collected data under each irrigation system were subjected to normal statistical analysis as shown by Snedecor and Cochran (1989). Treatment mean comparisons were made using least significant difference (LSD) at 5% level of probability. After homogeneity test, combined analysis was done to compare between the two irrigation systems.

RESULTS AND DISCUSSION

Effect of water stress:

Results in table (4) cleared that mean root weight, sucrose, impurities and purity percentages as well as root and white sugar yields were significantly affected by

Table 4. Effect of water stress on sugar beet yield and some of its attributes under drip and sprinkler irrigation systems during 2011/2012 and 2012/2013 seasons.

Water stress	Leaf area index (LAI)		Root weight (Kg)		Root number/fed x 10^3		Sucrose%		Purity%		Impurities %		Extractable sugar%		Root yield (ton/fed)		White sugar yield (ton/fed)	
	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler
2011/2012																		
50%	1.54	1.93	0.82	0.78	21.23	21.21	19.70	20.68	82.53	84.86	2.87	2.22	16.27	17.56	17.38	16.52	2.82	2.89
75%	2.30	1.91	1.03	0.96	21.43	21.16	20.17	20.05	85.72	88.56	2.86	2.25	17.30	17.73	21.96	20.39	3.79	3.60
100%	2.00	2.70	1.12	1.00	21.22	22.20	19.87	20.20	85.51	88.80	3.43	3.12	17.00	17.98	23.70	22.18	4.01	3.97
LSD at 5%	**0.42**	**N.S**	**0.02**	**0.037**	**N.S**	**0.62**	**0.18**	**N.S**	**1.49**	**0.76**	**0.29**	**0.29**	**0.25**	**N.S**	**0.30**	**0.30**	**0.08**	**0.15**
2012/2013																		
50%	2.19	2.59	0.94	0.78	21.46	20.63	18.62	19.80	75.98	78.77	3.89	3.24	14.17	15.67	20.08	16.06	3.08	3.15
75%	2.96	2.57	1.10	0.96	21.22	20.93	20.08	19.11	80.57	82.55	3.88	3.27	16.23	15.84	24.09	20.89	3.91	2.52
100%	2.66	3.36	1.18	1.08	21.28	21.31	19.21	18.88	79.67	82.68	4.45	4.14	15.32	15.64	25.19	23.09	3.57	3.61
LSD at 5%	**N.S**	**N.S**	**0.035**	**0.037**	**N.S**	**0.20**	**0.31**	**0.35**	**1.60**	**1.05**	**0.052**	**0.054**	**0.40**	**N.S**	**0.47**	**0.62**	**0.09**	**0.12**

increasing water deficit from 100% up to 50% of the irrigation water requirements (IWR). These results were true under both irrigation systems in the two growing seasons except for sucrose percentage under sprinkler irrigation in the first season. Leaf area index values fluctuated among irrigation levels under drip irrigation systems during the first growing seasons. The highest LAI values under drip irrigation (2.30) were measured in level 75% of IWR. These results are in accordance with those obtained by Hosseinpour *et al*. (2006). Also Waston (1952) and Goodman (1968) reported that the size and longevity of sugar beet leaf canopies strongly influenced by soil moisture and soil fertility. Decreasing the amount of irrigation water from 100% to 75% and 50% of IWR under drip irrigation significantly decreased mean root weight by 8.04 and 26.79% in the 1^{st} season and by 6.78 and 20.34% in the 2^{nd} season, while under sprinkler irrigation the decrease in mean root weight amounted to 4.0 and 22.0% in the 1^{st} season and 7.41 and 27.78% in the 2^{nd} season. Root number was significantly affected by the irrigation water levels only under sprinkler irrigation system during the two growing season. Irrigation sugar beet plants with 2880.8 m^3/fed (100% of IWR) recorded the highest and significant harvested root number in the first season (22.20 thousand root/fed) and in the second season (21.31thousand root/fed).

Drip-irrigated sugar beet plants with 75% of irrigation water requirements (IWR) recorded the highest percentages of sucrose (20.17 and 20.08%), purity (85.72 and 80.57%) and Extractable sugar (17.30 and 16.23%) in the first and second seasons, respectively (Table 4) with significant difference between 50% and 75% of IWR. However, under sprinkler irrigation, juice quality traits values fluctuated among the three irrigation levels during the two growing seasons. Also, data averaged over seasons revealed that application of 75% of IWR gave the highest values of extractable sucrose percentage under both irrigation systems (Figure 1). These results are in agreement with those reported by Roberts *et al*., (1980) who reported that deficit irrigation usually increases percent of sucrose in root. Hang and Miller (1986) found that sugar concentration in well watered crops rises steadily through the growing season, often leveling off before the harvest between 15 and 18% (g sugar per 100 g fresh roots). In water stressed crops it rises more quickly, and under severe stress conditions it can be 5% higher than in unstressed crops.

Increasing water deficit from 100% to 50% of IWR significantly decreased

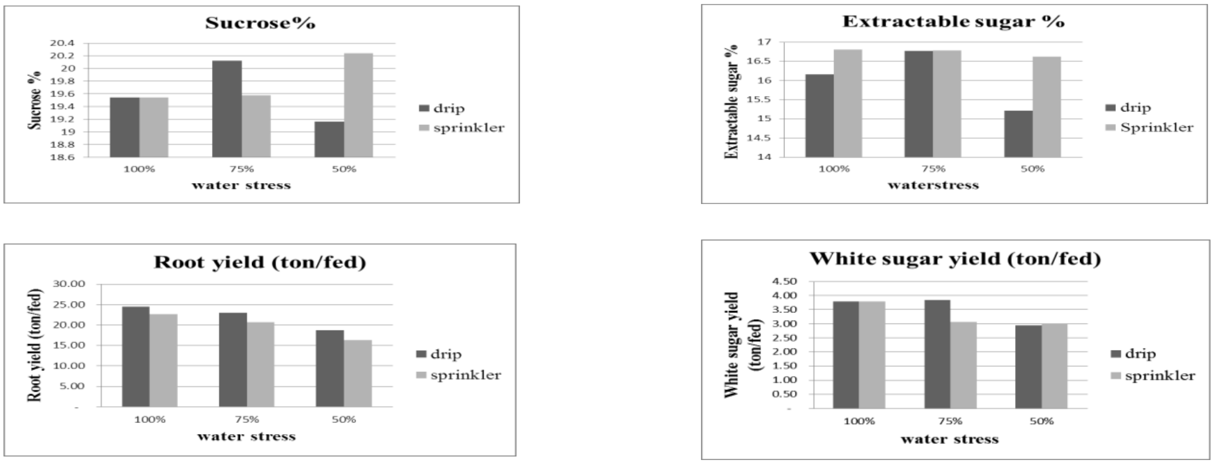

Figure 1. Sucrose%, extractable sugar%, root yield (ton/fed) and white sugar yield (ton/fed) under the effect of water stress under drip and sprinkler irrigation systems companied over seasons.

root and sugar yields under both irrigation systems during the two growing seasons (Table 4). Root yield decrease amounted to 26.67 and 25.52% in the first season and 20.29 and 30.45% in the second one under drip and sprinkler irrigation systems, respectively. Sugar yield decrease amounted to 29.68% in the first season and 26.30% in the second one under drip irrigation system, corresponding to 27.20 and 30.47% under sprinkler irrigation system. However, the decrease in sugar yield accompanying high water deficit might have been due to the decrease in root yield as well as extractable sucrose percentage as mentioned before. Results on root and white sugar beet yields indicated that yield of drip-irrigated sugar beet with 75% of IWR nearly matched yield of sprinkler- irrigated sugar beet with 100% of IWR during the two growing seasons and this might be due to the high efficient of drip irrigation system compared to sprinkler irrigation system (Tognetti *et al*., 2003). Also, data averaged over seasons revealed application of 100% of IWR gave the highest value of root and sugar yield/fed under drip and sprinkler irrigation systems (Figure 1). Such results are in accordance with those reported byTognetti *et al.*(2002), Tognetti *et al*. (2003) and Hosseinpour *et al.* (2006).

Effect of compost:

Adding compost had no clear trend with respect to its effect on sugar beet yield and its attributes (table 5). In the first season, some traits showed significant response either under both irrigation systems (root number and root yield) or under sprinkler irrigation (root weight, impurities and white sugar yield). In the second season, most evaluated traits significantly responded to compost under both irrigation system except for root weight, root number and impurities under drip irrigation system. Applying compost with sprinkler irrigation significantly increased root weight (3.33 and 5.38%), root number (1.50 and 3.56%), impurities (1.59 and 22.26%) and root yield (4.62 and 3.61%) in the 1^{st} and 2^{nd} seasons, respectively. Also, adding compost with drip irrigation increased root yield by about 4.13 and 6.48% in the first and second season, respectively. Data averaged over seasons (Figure 2) indicated that, without used compost recorded the highest sucrose%, extractable sugar% and white sugar yield (ton/fed), on the contrary application of 5 ton/fed of compost gave the highest value of root yield/fed under both irrigation systems. Similar results were reported by Wallace and Carter (2007)and Mahmoud *et al*. (2012).

Effect of nitrogen rate:

The effect of N rates on sugar beet yield, yield components and juice quality traits in 2011/2012 and 2012/2013 seasons are presented in table (6).

Leaf area index (LAI) tended to increased significantly due to increasing nitrogen fertilizer levels from 60 to 90 and 120 kg N/fed under drip irrigation system during the two growing seasons. Application of 120 kg N/fed to drip irrigated plants significantly increased LAI by about 112.20 and 73.02% in the 1^{st} and the 2^{nd} seasons, respectively as compared to application of 60kg N/fed. Such increase in this trait may be returned to the role of nitrogen fertilizers certainly stimulating growth and

Table 5. Effect of compost on sugar beet yield and some of its attributes under drip and sprinkler irrigation systems during 2011/2012 and 2012/2013 seasons.

Compost levels (ton/fed)	Leaf area index (LAI)		Root weight (kg)		Root number/fed x 10^3		Sucrose%		Purity%		Impurities%		Extractable sugar%		Root yield (ton/fed)		White sugar yield (ton/fed)	
	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler
2011/2012																		
0	2.29	2.48	0.99	0.90	20.89	21.36	20.06	20.32	84.77	87.60	3.04	2.51	17.02	17.80	20.59	19.25	3.58	3.41
5	1.59	1.88	0.99	0.93	21.69	21.68	19.76	20.30	84.40	87.20	3.07	2.55	16.69	17.70	21.44	20.14	3.50	3.56
significance	*	N.S	N.S	**	**	*	N.S	N.S	N.S	N.S	N.S	*	N.S	N.S	**	**	N.S	**
2012/2013																		
0	2.71	2.89	1.06	0.93	21.24	21.08	19.68	19.54	81.04	83.42	3.71	3.19	15.99	16.35	22.39	19.66	3.58	3.21
5	2.49	2.78	1.09	0.98	21.40	21.83	18.92	18.99	76.44	79.24	4.43	3.90	14.48	15.08	23.84	20.37	3.45	3.07
significance	N.S	N.S	N.S	**	N.S	*	**	*	**	**	N.S	**	**	**	**	**	**	**

increasing leaf area per plant. The aforementioned results generally are in good agreement with those stated by Mahmoud *et al* (2012).

Results revealed that N rates exhibited significant effect on root fresh weight in both seasons under both irrigation systems. A gradual increase in root weight as N rate increased up to 120 kg N/fed was recorded. The increase amounted to (9.89%, 16.48%) and (11.22%, 17.35%)in the first and second season under drip irrigation system and (9.64%, 20.48%) and (9.09%, 15.90%) in the first and second season under sprinkler irrigation system as N rate increased from 60 and90 to 120 kg N/fed, respectively. This increasing in root weight is mainly due to the role of N in stimulating the meristematic growth activity which contributes to the increase in number of calls in additions to cell enlargement. Similar findings were reported by El-Hennawy *et al.* (1998)and Mahmoud *et al* (2014).

Number of root at harvest was significantly affected by N rates in both seasons. Increasing N rate up to 120 kg N/fed increased No of root at harvest by (1.47 and 0.57 thousand root/fed under drip) and (1.39 and 0.45 thousand root/fed under sprinkler) as compared to application of 60 kg N/fed in the first and second seasons, respectively. This result is in agreement with that obtained by Mahmoud and Masri (2009).

Root quality traits, in terms of sucrose%, purity% and extractable sucrose%as well as impurities % were significantly affected by varying N rates in both seasons under two irrigation systems (table 6). Decreasing N rates from 120 to 60 kg N/fed with the drip irrigated plants significantly increased sucrose% by 6.75 and 7.49%, purity by 5.02 and 6.24% and extractable sugar % by 11.35 and 13.18% in the first and second seasons, respectively; while with sprinkler irrigated plants these increases amounted to 6.92 and 6.87% for sucrose%, 2.53 and 3.30% for purity% and 9.42 and 10.04% for extractable sugar% in the first and second seasons, respectively. On the contrary, impurities% decreased by about 18.78 and14.45% under drip and by 11.57 and8.38% under sprinkler in the first and second seasons, respectively. Also, data averaged over seasons revealed that Application of 60 kg N/fed gave the highest values of sucrose percentage and extractable sucrose percentage under both irrigation systems (Figure3). The

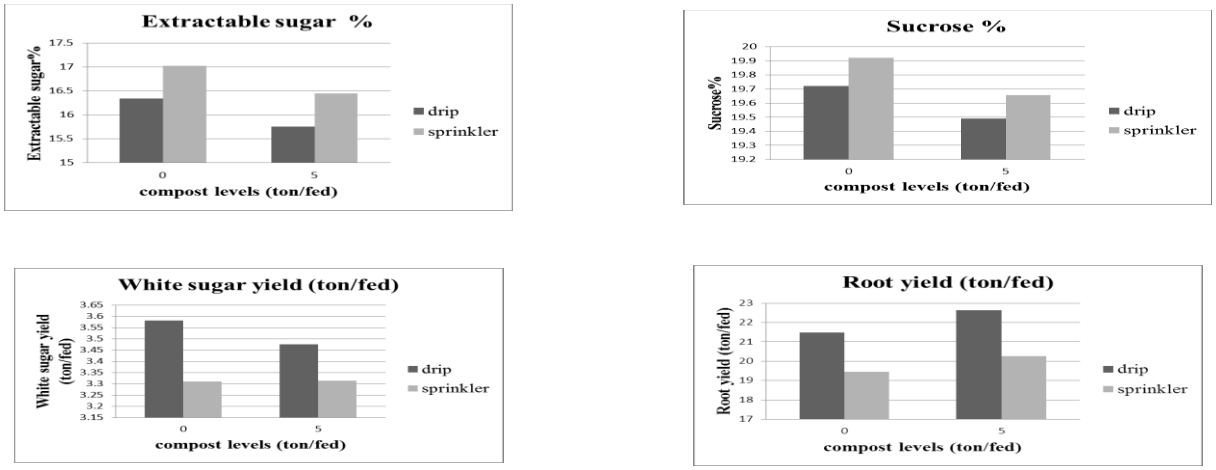

Figure 2. Sucrose%, extractable sugar%, root yield (ton/fed) and white sugar yield (ton/fed) under the effect of compost under drip and sprinkler irrigation systems companied over seasons.

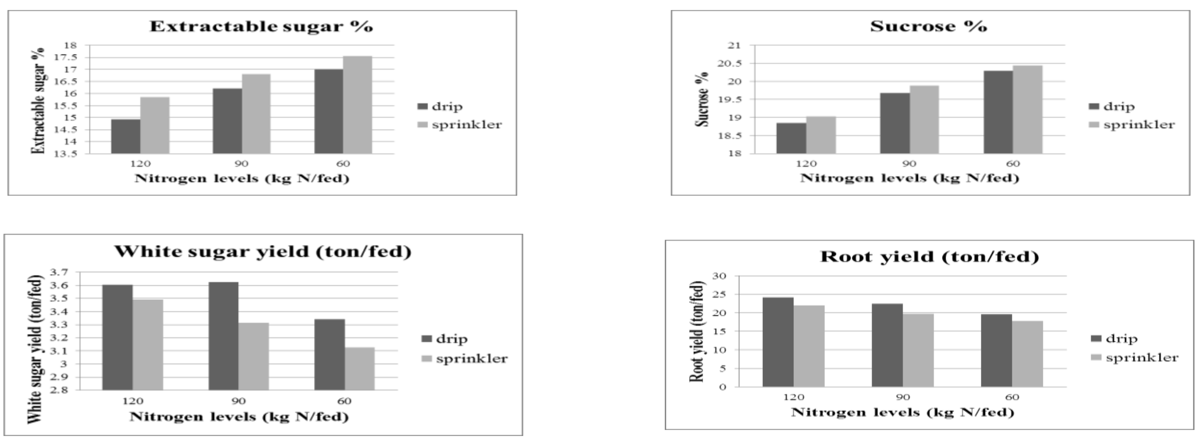

Figure 3. Sucrose%, extractable sugar%, root yield (ton/fed) and white sugar yield (ton/fed) under the effect of nitrogen levels under drip and sprinkler irrigation systems companied over seasons.

depressive effect of N on beet quality coincides whit those reported by Sharif and Eghbal (1994), El-Hennawy *et al* (1998), Mahmoud and Masri (2009) and Mahmoud *et al* (2012).Significant differences among N rates in root yield were recorded under two irrigation systems in both seasons (table 6). Increasing N rate from 60 to 90 kg/fed and from 90 to 120 kg/fed increased root yield under drip irrigation system by about 10.77% and 13.10%in the 1st season, corresponding to 5.17% and 15.50% in the 2nd season, respectively, also, under sprinkler irrigation system by about 13.59% and 13.19% in the first season, corresponding to 9.38% and 8.84% in the second season, respectively. The increase in root yield accompanying high N rate might have been due to the increase in number of harvested root as well as individual root weight as mentioned before. Also, data averagedover seasons revealed that application of 120 kg N/fed gave the highest values of root yield/fed under both irrigation systems (Figure 3). Such results are in accordance with these reported by El-Hennawy *et al* (1998), Mahmoud and Masri (2009), Mahmoud *et al* (2012), El-Sarag (2009) and Mahmoud *et al* (2014).

Results in table (6) cleared that sugar yield was significantly increased by increasing N rate from 60 to 120kg/fed. These results were true in the two growing seasons under both irrigation systems except the second season under sprinkler irrigation system. Such increase amounted to 10.48% in the first season and 5.39% in the second one under drip irrigation system and 16.15% in the first season under sprinkler irrigation system.

Table 6. Effect of nitrogen levels on sugar beet yield and some of its attributes under drip and sprinkler irrigation systems during 2011/2012 and 2012/2013 seasons.

Nitrogen levels (kg N/fed)	Leaf area index (LAI)		Root weight (kg)		Root number/fed x 10^3		Sucrose%		Purity%		Impurities %		Extractable sugar%		Root yield (ton/fed)		White sugar yield (ton/fed)	
	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler
2011/2012																		
60	1.23	1.89	0.91	0.83	20.67	20.84	20.57	20.95	86.51	88.46	2.77	2.37	17.79	18.58	18.63	17.29	3.34	3.22
90	1.99	2.26	1.00	0.91	21.08	21.50	19.99	20.48	85.07	87.53	2.98	2.54	17.01	17.86	21.07	19.57	3.59	3.50
120	2.61	2.39	1.06	1.00	22.14	22.23	19.18	19.50	82.17	86.22	3.41	2.68	15.77	16.83	23.34	22.23	3.69	3.74
LSD at 5%	**0.58**	**N.S**	**0.02**	**0.025**	**0.26**	**0.20**	**0.36**	**0.32**	**0.71**	**0.61**	**0.12**	**0.052**	**0.39**	**0.37**	**0.30**	**0.48**	**0.10**	**0.12**
2012/2013																		
60	1.89	2.55	0.98	0.88	21.15	20.79	20.02	19.94	81.00	82.72	3.79	3.39	16.23	16.54	20.58	18.31	3.34	3.03
90	2.65	2.92	1.09	0.96	21.09	20.83	19.36	19.29	79.27	81.29	4.00	3.55	15.40	15.73	23.77	19.93	3.66	3.13
120	3.27	3.05	1.15	1.02	21.72	21.24	18.52	18.57	75.95	79.99	4.43	3.70	14.09	14.88	25.00	21.80	3.52	3.24
LSD at 5%	**0.58**	**N.S**	**0.19**	**0.027**	**0.28**	**0.22**	**0.23**	**0.44**	**0.75**	**0.81**	**0.12**	**0.083**	**0.29**	**0.08**	**0.25**	**0.47**	**0.07**	**N.S**

Table7. Effect of interaction between water stress and compost levels on significant sugar beet yield and some of its attributes under drip and sprinkler irrigation systems during 2011/2012 and 2012/2013 seasons.

Water stress	compost levels	Root weight (kg)	Root number/fed x 10^3			Sucrose%	Purity%	Impurities%		Extractable sugar%	Root yield (ton/fed)		White sugar yield (ton/fed)
		Drip	Drip		Sprinkler	Sprinkler	Sprinkler	Sprinkler		Sprinkler	Drip		Sprinkler
		2011/12	2011/12	2012/13	2012/13	2011/12	2012/13	2011/12	2012/13	2011/12	2011/12	2012/13	2011/12
50%	**0**	0.81	21.25	21.64	20.42	21.04	80.18	2.18	3.04	17.94	17.23	19.99	2.84
	5	0.82	21.21	21.29	20.83	20.31	77.37	3.13	3.44	17.18	17.54	20.16	2.93
75%	**0**	1.02	21.17	21.18	21.43	19.87	85.92	2.25	2.62	17.62	21.54	22.93	3.55
	5	1.03	21.69	21.25	20.43	20.24	79.17	2.24	3.91	17.83	22.37	25.24	3.65
100%	**0**	1.14	20.26	20.90	21.38	20.03	84.18	3.10	4.36	17.86	22.99	24.26	3.84
	5	1.10	22.18	21.65	21.23	20.36	81.18	2.55	3.91	18.11	24.41	26.12	4.10
LSD at 5%		**0.02**	**0.39**	**0.30**	**0.25**	**0.43**	**0.91**	**0.30**	**0.12**	**0.41**	**0.26**	**0.35**	**0.06**

However, fertilized plants with 120 kg N/fed had lower effect on sugar yield than 90 kg N/fed in the 2nd season under drip irrigation system because of the depressive effect of high N rates on extractable sugar%. It is worth to mention that the reduction in quality traits (sucrose, purity and extractable sucrose percentages) accompanying higher N rates was compensated by higher root yield. Also, data averaged over seasons revealed that application of 120 kg N/fed gave the highest values of sugar yield/fed under both irrigation systems (Figure 3). Similar results were reported by Sharifand Eghbal (1994), El-Hennawy *et al* (1998), Mahmoud and Masri (2009) and Mahmoud *et al* (2012).

Effect of interaction between water stress and compost levels:

Data of traits that affected significantly by the interaction between water regimes and compost levels are listed in table (7) for irrigation systems during the two growing seasons.
Root fresh weight was significantly affected by the interaction between water regimes and compost application under drip irrigation system in first season. The heaviest roots 1.14 kg resulted from 100% water regimes and 0 ton/fed compost.
Water regimes x compost interaction exhibited significant effect on number of root/fed at harvest during the two seasons under drip irrigation system and the second season for sprinkler irrigation system **.**Applying 100% of IWR with 5 ton/fed compost produced the highest number of root at harvest being 22.18 and 21.65 thousand root under drip irrigation system in the first and second seasons, respectively. While, under sprinkler irrigation system was 21.43 thousand root/fed with 75% of IWR without compost in the second season.
Interaction between water stresses and compost under sprinkler irrigation system was significant for sucrose% and extractable sugar% in the first season, while it was significant for purity% in the second season and impurities in both seasons. The highest sucrose content (21.04%) resulted from 50% water regimes without compost (table 7). The highest percentages of purity% (85.92%) were resulted from 75% water regimes without compost. On the other hand, the highest impurities% (3.10 and 4.36%) was obtained with 100% water regimes without compost in the first and second season, respectively. while, the highest extractable sugar percentage (18.11%) resulted under 100% water regimes + 5 ton/fed compost
The highest and significant root yield (24.41 and 26.12 ton/fed) resulted from applying 100% of IWR and5 ton/fed compost under drip irrigation in the 1st and in the 2nd seasons, respectively. The same trend was for white sugar yield (4.10 ton/fed) under sprinkler irrigation system in the first season.

Effect of interaction between water stress and nitrogen rates:

Data of traits that affected significantly by the interaction between water regimes and nitrogen rates are listed in table (8) for irrigation systems during the two growing seasons.
Applying 100% of IWR and 120 kg N/fed to sprinkler irrigated plants gave the highest and significant value of root weight (1.05 kg) in the first season and root number (23.49 and 21.81thousand root/fed) in the two growing seasons as well as root number (22.23 thousand/fed) under drip in the second season.
Results also revealed that application of 50% of IWR and 90 kg N/fed produced the highest purity% being 90.33 and 84.59%under sprinkler irrigation system in the first and second seasons, respectively. On the other hand, impurities% was significantly high with application of 100% of IWR with 120 kg N/fed under drip (4.72%) or 90 kg N/fed under sprinkler (4.23%) in the second season only compared to other interactions.
Data during 2011/12 season revealed that application of 100% water regimes and 120 kg N/fed gave the highest values of root yield (ton/fed) being 26.70 and 24.48 ton/fed under drip and sprinkler irrigation systems, respectively. Also, application the same rate of IWR and N rate gave the highest value of white sugar yield (4.14 ton/fed) with sprinkler irrigation system in 1stseason, vice versa application of 75% of IWR and 90 kg N/fed resulted the highest value of white sugar yield (4.27 ton/fed) with drip irrigation system in 2nd season.

Effect of interaction between compost levels and nitrogen rates:

Among the studied traits only root number/fed affected significantly by the interaction between compost levels and nitrogen rates under both irrigation systems in 2012/13 growing seasons. The highest value of root number (22.12 thousand/fed) was produced from application of 5 ton/fed compost and 120 kg N/fed under drip irrigation system and being (21.47 thousand/fed) from 5 ton/fed compost and 120 kg N/fed under sprinkler irrigation system.

Effect of interaction among water regimes, compost levels and nitrogen rates:

Among the studied traits only root number/fed affected significantly by the interaction between water stress, compost levels and nitrogen rates under drip irrigation

Table 8. Effect of interaction between water stress and nitrogen rates on significant sugar beet yield and some of its attributes under drip and sprinkler irrigation systems during 2011/2012 and 2012/2013 seasons.

Water stress	Nitrogen levels	Root weight (kg)	Root number/fed x 10^3			Purity%		Impurities%		Root yield (ton/fed)		White sugar yield (ton/fed)	
		Sprinkler	Drip	Sprinkler		Sprinkler		Drip	Sprinkler	Drip	Sprinkler	Drip	Sprinkler
		2011/12	2012/13	2011/12	2012/13	2011/12	2012/13	2012/13	2012/13	2011/12	2011/12	2012/13	2011/12
50%	**60**	0.65	21.69	21.05	20.66	85.25	79.57	3.46	3.07	15.68	13.70	3.02	2.48
	90	0.76	21.31	21.05	20.51	90.33	84.59	3.82	3.12	19.53	18.25	3.02	3.43
	120	0.93	21.39	21.54	20.71	89.81	84.01	4.38	3.43	20.68	19.92	3.15	3.76
75%	**60**	0.89	21.19	20.51	20.98	84.40	77.88	3.62	2.97	17.55	15.87	3.68	2.77
	90	0.98	20.92	21.32	20.60	89.01	83.01	3.83	3.21	21.93	20.71	4.27	3.70
	120	1.03	21.54	21.66	21.21	89.19	82.98	4.19	3.61	23.73	22.13	3.75	4.03
100%	**60**	0.95	20.57	20.96	20.72	84.92	78.88	4.29	4.13	18.92	19.98	3.32	3.41
	90	1.00	21.04	22.15	21.39	86.34	80.04	4.35	4.23	24.41	22.22	3.69	3.68
	120	1.05	22.23	23.49	21.81	87.40	81.05	4.72	4.05	26.70	24.48	3.63	4.14
LSD at 5%		**0.043**	**0.49**	**0.35**	**0.38**	**1.05**	**1.40**	**0.14**	**0.14**	**0.51**	**0.82**	**0.12**	**0.20**

Table 9. Effect of irrigation systems on sugar beet yield and some of its attributes during 2011/2012 and 2012/2013 seasons.

Measurements	2011/2012			2012/2013		
	Drip	Sprinkler	Significance	Drip	Sprinkler	Significance
Leaf area index (LAI)	1.94	2.18	*	2.60	2.84	*
Root weight (kg)	0.99	0.91	*	1.07	0.95	*
Root number/fed x 10^3	21.29	21.52	*	21.32	20.95	*
%Sucrose	19.91	20.28	*	19.31	19.26	*
%Juice purity	84.58	87.41	*	78.74	81.33	*
%Impurities	3.05	2.53	*	4.07	3.55	*
%Extractable sugar	16.86	17.75	*	15.24	15.72	*
Root yield (ton/fed)	21.03	19.70	*	22.84	20.01	*
White sugar yield (ton/fed)	3.54	3.49	*	3.52	3.15	*

systems in two growing seasons. The highest values of root number were produced from application of 5 ton/fed compost and 120 kg N/fed with 75% water stress in the first season (22.98 thousand/fed) and 100% water stress in the second season (22.63 thousand/fed).

Effect of irrigation systems

Data in table (9) revealed that drip irrigation system in the first season was significantly more efficient than sprinkler irrigation system due to root weight (kg), root yield (ton/fed) and white sugar yield (ton/fed), while in the second season it was significantly more efficient than sprinkler system due to leaf area index, root weight (kg), root number, sucrose%, root yield (ton/fed), white sugar yield (ton/fed).These results are in agreement with that of Arroyo *et al.* (1999).

CONCLUSIONS

Testing sugar beet crop under water stress, compost application and nitrogen levels under drip and sprinkler irrigation systems in Wadi El Natrun which represent the dry climate with sandy soil recommended to use drip irrigated by 1943.5 m^3/fed with used compost by 5 ton/fed and 120 kg N/fed, also led to the following:

- Results on root and white sugar beet yields indicated that yield of drip-irrigated sugar beet with 75% of IWR nearly matched yield of sprinkler- irrigated sugar beet with 100% of IWR during the two growing seasons and this might be due to the high efficient of drip irrigation system compared to sprinkler irrigation system
- The results showed significant increase in root yield and white sugar yield by increasing irrigation water requirement from 50% up to 75 and 100%
- Results illustrated that root yield and white sugar yield increase by increasing nitrogen fertilizer levels from 60 up to 90 and 120 kg N/fed.
- Technological characters of sugar beet (sucrose, purity and extractable sugar%) rose with increasing water stress and decreasing with increasing N fertilization rate.

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