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Yield and quality of two sugar beet (*Beta vulgaris* L. ssp. *vulgaris* var. *altissima* Döll) cultivars are influenced by foliar application of salicylic acid, irrigation timing, and planting density

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Yield and quality of two sugar beet (*Beta vulgaris* L. ssp. *vulgaris* var. *altissima* Döll) cultivars are influenced by foliar application of salicylic acid, irrigation timing, and planting density

Abstract: Two field experiments were conducted to evaluate the time of foliar application of 100 ppm salicylic acid (SA), two irrigation (IR) timings, three levels of spacing (SP) hill^{-1} with different plant density on growth, yield and quality characters of two sugar beet cultivars ('Samba' and 'Farida'). The results revealed that the foliar application of 100 ppm SA at 30 days after planting (DAP) and 14 days after the first application significantly influenced top fresh mass and root biomass of sugar beet plants. Conversely, the increasing period between planting and first irrigation scheduling led to significant differences in fresh mass, sugar yield, and sucrose % as well as purity % of sugar beet. Plants density with 60 × 20 cm spacing hill^{-1} was found to be better than the other two spacings for major characters, particularly root fresh mass, and Total soluble solids and purity %. Inversely, spacing at 60 × 15 cm, between hills gave the maximum levels of top fresh mass, root yield and sugar yield in the first season. The interaction effect between spacing hill^{-1} at 60 × 20 cm and 100 ppm SA applied at 30 DAP gave the maximum levels of increment for most of the studied characters, particularly for cultivar 'Farida'.

Key words: planting density; sugar quality; salicylic acid; sugar beet; irrigation timing; yield

Vpliv foliarnega dodajanja salicilne kisline, časa namakanja in gostote setve na pridelek in kakovost dveh sort sladkorne pese (*Beta vulgaris* L. ssp. *vulgaris* var. *altissima* Döll)

Izvleček: Izvedena sta bila dva poljska poskusa za ovrednotenje vpliva časa foliarnega dodajanja 100 ppm salicilne kisline (SA), dveh terminov namakanja (IR), treh gostot setve (SP), na pridelek in kakovostne parametre dveh sort sladkorne pese ('Samba' in 'Farida'). Rezultati so pokazali, da je foliarno dodajanje 100 ppm SA 30 dni po setvi (DAP) in 14 dni po prvi uporabi DAFA značilno vplivalo na svežo maso nadzemnih delov in biomaso korenov sladkorne pese. Naraščanje časa med setvijo in prvim zalivanjem je privedlo do značilnih razlik v sveži masi, pridelku sladkorja, v odstotku saharoze in v čistosti posevka sladkorne pese. Gostota z razmakom rastlin 60 × 20 cm se je izkazala boljša od ostalih dveh za večino merjenih lastnosti, še posebej v sveži masi korenov, v odstotku TSS in odstotku čistosti. Obratno je dal razmak 60 × 15 cm največjo svežo maso nadzemnih delov, pridelka korenov in sladkorja v prvi sezoni. Interakcija gostote setve 60 × 20 cm in dodatek 100 ppm SA 30 dni po setvi je dala največje vrednosti vseh preučevanih znakov, še posebej pri sorti 'Farida'.

Ključne besede: gostota setve; kakovost sladkorja; salicilna kislina; sladkorna pesa; režim namakanja; pridelek

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1 INTRODUCTION

Sugar beet (*Beta vulgaris* L. ssp. *vulgaris* var. *altissima* Döll) is a temperate crop also cultivated in subtropical countries. It is generally considered as a crop of temperate region, however, it is largely cultivated also in sub-tropical countries, where it can be grown successfully during the winter season (Brar et al., 2015). It is a biennial plant and one of the most essential sugar crops. The global cultivated area of sugar beet in 2014 was 4.47 million ha with a total root yield of 266.8 million tons (FAOSTAT, 2016). In Egypt, the cultivated area in the year 2016 was 254, 991 ha with the root yield of 13.3 million tons (FAOSTAT, 2016). Sugar beet is a widely adaptive crop and grows in multiple agro-ecological conditions. It takes a shorter period to maturity than the sugar cane plant and also productivity per unit time is higher and requires less water than sugarcane (Brar et al., 2015). Many environmental and agronomic factors such as biofertilization, irrigation, planting spacing sowing methods had influenced the production and quality of sugar beet (Abdelaal, 2015a; Abdelaal and Tawfik, 2015; Omar et al., 2019a,b). The main target for growers and sugar companies is to improve their quality and increase the extracted sugar (Awad et al., 2013). Therefore to get maximum benefits from sugar beet, there is a need to select the most appropriate varieties, to reduce planting time, to optimize planting methods, planting density, sowing depth as well as to provide adequate crop nutrition and irrigation schedule (Seadh et al., 2013; Brar et al., 2015).

However, among the abiotic stresses, water deficit is one of the most environmental factors threatening the agricultural production and the main reason of crop loss worldwide, reducing morphological characters and yield components of plants (Abdelaal, 2015b; EL Sabagh et al., 2019a). Due to drought stress the growth duration, growth, and development, as well as yield, are decreased (EL Sabagh et al., 2019e). Furthermore, under drought stress, the accumulation of osmoprotectants like proline is noticed (EL Sabagh et al., 2019d).

Reduced photosynthetic rates of plants have a direct effect on growth characters such as decrease dry mass and leaf area (Gong et al., 2005). Under drought stress, nitrogen metabolism, enzyme activities and protein synthesis can be impaired (Saneoka et al., 2004). However, plants have many mechanisms to adjust abiotic stress by changing the morpho-physiological characters (Todaka et al., 2012; Molla et al., 2019; Yassin et al., 2019). Neseim et al. (2014) found that under drought stress, morphological characters such as root yield and white sugar/fedden (0.42 ha) were significantly reduced, whereas, total soluble phenols and free amino acid concentrations in leaves and roots were significantly increased that ultimately led to surviving under stress condition.

It was previously reported, that root diameter, percentage of sucrose, and root yield, as well as sugar yield (t/fedden (0.42 ha)) of sugar beet, increased significantly with larger plant spacing from 20 to 30 cm (Nafei et al., 2010; Shalaby et al., 2011). While, Ramazan (2002) observed that root yield and sugar content were the highest at closer planting density of 103600 plants/ha (i.e 45 × 20 cm spacing), as compared to 555000 (45 × 40 cm), 73000 (43 × 30 cm) and 88900 (45 × 25 cm) plants ha^{-1}. Similarly, Bhullar et al. (2010) reported that the highest root and sugar yield of sugar beet were produced from the planting density at 1,00,000 plants ha^{-1} (50 x 20 cm) as compared with planting densities 83,333 plants ha^{-1} (60 x 20 cm) and 1,11,111 plants ha^{-1} (60 x 15 cm).

The previous studies have reported that the application of osmoprotectants under stressful environment (biotic and abiotic) help to maintain plant growth and yield. Moreover, osmoprotectants led to alleviate the injurious effect of stress conditions and enhance the growth characters and yield parameters of different crops moreover, it helps to survive under different biotic and abiotic stress. (El?? Sabagh et al., 2019 b,c).

Salicylic acid (SA) is recognized as a phytohormone produced after a chain of chemical reactions as benzoic acid derivative and plays a vital role in many physiological process such as photosynthesis, nutrient uptake, membrane permeability and also help to survive under different biotic and abiotic stress playing a key role in systemic acquired resistance (Noreen et al., 2009; Abdelaal, 2015b). Moosavi (2012) and Abido et al. (2015) observed that foliar spray of SA led to improve plant growth characters and enhanced the tolerance capacity of plants under abiotic stress as well as it protects the plant from oxidative stress by increasing antioxidant enzymes activity, finally increasing the fresh root and shoot mass of sugar beet and sunflower plants (Merwad, 2015; Noreen et al., 2017a,b). Furthermore, However, the foliar application of 100 mg l^{-1} SA gave the highest values for growth characters of stevia plants (reported by El-Housini et al., 2014); soybean plants (Mishra and Prakash, 2013).

There is an insufficient amount of information about the effect of SA on sugar beet growth and productivity that are linked to water deficit and density population under field conditions. The main target for the cultivation of sugar beet is to extract sugar of high yield and quality. Therefore, to get maximum benefits from sugar beet there is a need to select the most appropriate varieties, planting methods, planting density, providing adequate crop nutrition and irrigation schedule. Considering the important issues, two field experiments were conducted to evaluate the foliar application of 100 ppm, irrigation

(IR) and spacing (SP) on growth, yield and quality characters of two sugar beet cultivars (‘Samba’ and ‘Farida’).

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITES

Two field experiments were conducted at Kalabsho, El-Dakahlia Governorate, Egypt (30° 35´41.9” N latitude and 32° 16´ 45.8” E longitude) in consecutive two winter seasons 2016-17 and 2017-18. The area is characterized by a short warm-winter and long-hot summer. The annual average rainfall and relative humidity are about 40.4 mm and 65.4 %. The area of study exhibits certain desertification features because the surface Nile water does not adequately reach to the ends of canals. Groundwater is the major source of irrigation.

2.2 EXPERIMENTAL TREATMENTS, DESIGN AND PLANT MATERIALS

Two sugar beet cultivars namely ‘Farida’ and ‘Samba’ were used in the experiment. Treatments included:

three levels of plant density such as 44465 plants/fedden (0.42 ha), 33335 plants/fedden (0.42 ha), and 26665 plants/fedden (0.42 ha);

three types of plant spacing (SP) hill^{-1} such as at 60 x 15 cm , 60 x 20 cm and 60 x 25 cm;

foliar application of 100 ppm SA, applied at 30 DAP and 14 days after the first application,

and two irrigations (IR) times, one applied at 20 DAP and another one applied at 30 DAP.

All treatments were arranged in a split-split plot design and repeated four in four blocks to minimize the biasness.

To minimize the experimental errors, two irrigations’ times (IR) were arranged in main plots, while hill spaces (spacing (SP) hill^{-1} with three levels of plant density were arranged in sub-plots and two sugar beet cultivars were located in sub-sub-sub plots.

2.3 EXPERIMENTAL PROCEDURE

Four seeds were sown in hills on 4th and 3rd October in 2016-17 and 2017-18 seasons. Each sub-plot contained 6 rows, which were 60 cm apart. Potassium at 24 kg K_2O/fedden (0.42 ha) and phosphorus at 30 kg P_2O_5/fedden (0.42 ha) were applied in the soils during final land preparation. Ammonium nitrate (33.5 % N) at 100 kg N/fedden (0.42 ha) was added at two equal doses after thinning and one month later after the first application. Foliar application of 100 ppm SA was applied 30 DAP and 14 days after the first application (DAFA). Harvest date was after 210 days from sowing.

2.4 DATA COLLECTION

2.4.1 Morphological characters

At harvesting time ten plants were randomly taken from each sub-sub-sub plot to determine morpho-physiological and yield characters. Morphological characters such as root diameter (cm), root fresh mass (kg plant^{-1}) and top fresh mass (kg plant^{-1}) were recorded.

2.4.2 Yield and quality evaluation

Total soluble solids (TSS %) were estimated in the juice of fresh roots by using Hand Refractometer. Sucrose percentage (%) was determined polarimetrically on lead acetate extract of fresh macerated roots according to the method of (Le Docte, 1927; Dutton et al., 1961). Apparent purity percentage (%) was determined as a ratio between sucrose % and TSS % of roots. Sugar beet plants from each plot were harvested topped to calculate root yield and top yield (t/fedden (0.42 ha)). Sugar yield (t/fedden (0.42 ha)) was calculated as follows: Sugar yield (t/fedden (0.42 ha)) = Root yield (t/fedden (0.42 ha)) x sucrose %.

2.5 STATISTICAL ANALYSES

Data represent the mean ± SD. The student’s t-test was used to determine whether significant difference ($p < 0.05$) existed between mean values according to O’Mahony (1986).

3 RESULTS AND DISCUSSION

3.1 YIELD AND QUALITY PARAMETERS OF SUGAR BEET ARE INFLUENCED BY SA, IRRIGATION TIMES, DIFFERENT SPACINGS AND CULTIVARS

After two years of observation, the results of the study revealed that foliar application of 100 ppm SA at 30 DAP and 14 DAFA significantly influenced the top fresh mass and root biomass of sugar beet plants under both the two growing seasons. Conversely, the increasing

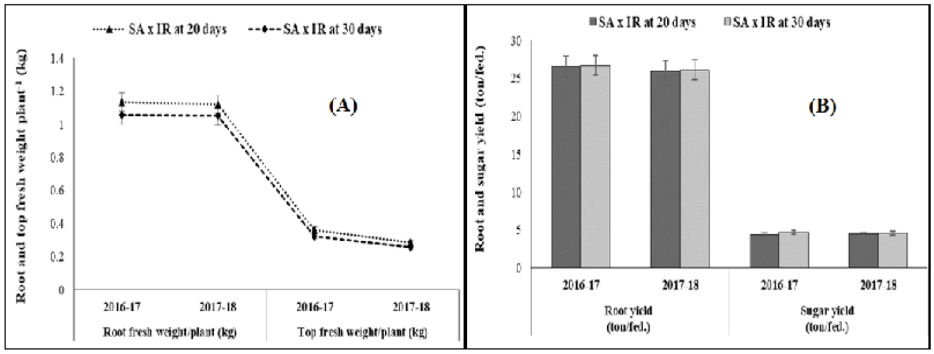

Figure 1: (A): Root and top fresh mass plant^{-1} of sugar beet are influenced by SA (applied at 30 DAP and 14 days after first application), and irrigation (IR) at 20 and 30 DAP. (B): Root and sugar yield (t/fedden (0.42 ha) of sugar beet are influenced by the application of SA (applied at 30 DAP and 14 days after first application), and irrigation (IR) at 20 and 30 DAP.

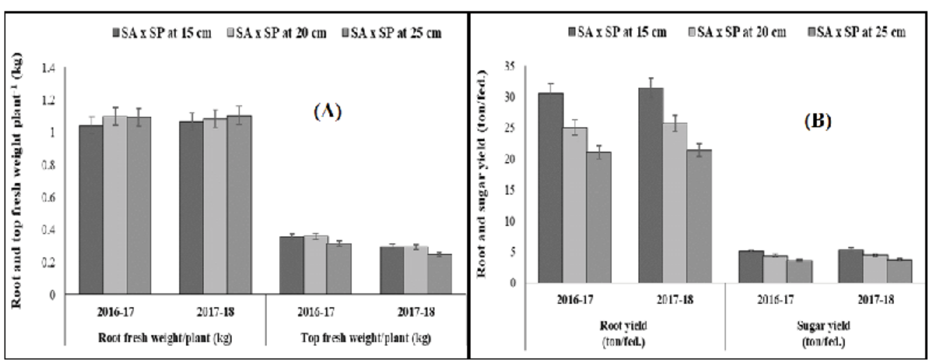

Figure 2: **(A):** Root and top fresh mass plant^{-1} of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and spacing (SP) hill^{-1} at 60 x15, 60 x 20 and 60 x 25 cm. (**B**)**:** Root and sugar yield (t/fedden (0.42 ha) of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm.

period of irrigation led to significant differences in fresh mass, sugar yield, and sucrose % as well as purity % in both the seasons (Figure 1 (A & B), 2 (A & B) and 3 (A & B)). Prolongation of irrigation to 30 days gave the highest values of sugar yield in the two seasons, whereas the increment of root and sugar yield was not significant in the first season (2016-17). The influence of prolonged period between last irrigation on morphological characters such as root fresh mass and top fresh mass are similar to the results which have been reported by Jain et al. (2010) and Abdelaal et al. (2017).

In the present study, planting at space 20 cm between hills with the application of SA was more promising than other spaces and gave the highest levels of root fresh mass and top fresh mass in both seasons. However, the increment of root and sugar yield was significant and obtained with SA and 15 cm space between hills. Regarding the effect of cultivars, the maximum levels of root fresh mass, top fresh mass, and root yield, as well as sugar yield, were obtained with the cultivar 'Farida' compared to 'Samba'. The results of the present study concerning cultivars are similar to the findings of Ramadan, (1999) and Awad et al (2012), who also observed significant variations between different cultivars, due to the application of SA, IR and also for SP.

Results presented in Figure 4 (A & B) & 5 (A) on the interaction effects between 100 ppm SA, water regimes before harvest and hills' spacing were signifi-

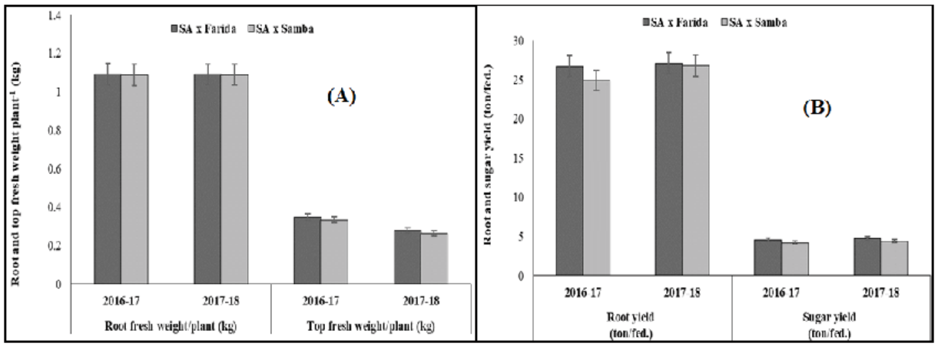

Figure 3: (A): Root and top fresh mass plant^{-1} of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and cultivars ('Farida' and 'Samba'). (**B**): Root and sugar yield (t/fedden (0.42 ha)) of sugar beet is influenced by SA (applied at 30 DAP and 14 DAFA), and cultivars ('Farida' and 'Samba').

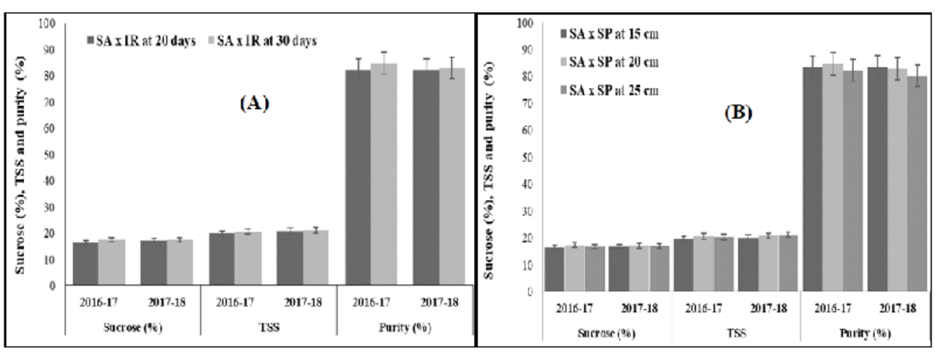

Figure 4: (A): Sucrose (%), total soluble solids (TSS %) and purity (%) of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and irrigation (IR) at 20 and 30 days. (**B**): Sucrose (%), TSS and purity (%) of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm.

cant on the most of the characters of sugar beet in both seasons under the study. Nevertheless, the interaction effects between SA, regime water and spacing hills were not significant on TSS % in the second season only. The valuable effect of SA on root fresh mass, top fresh mass, and root yield may be due to its role in increasing chlorophyll concentration and enhancement photosynthetic process as well as decreasing the injurious effect of water deficit on plants Abdelaal (2015b). These effects are in agreement with those recorded by Azooz et al. (2011) and Kang et al. (2013). The authors found the relationship between SA, IR, and SP for root fresh mass, top fresh mass, root yield and also for sucrose (%), TSS and purity (%).

3.2. YIELD AND QUALITY PARAMETERS OF SUGAR BEET ARE INFLUENCED BY INTERACTION EFFECT OF SA, IRRIGATION, SPACING, AND CULTIVARS

The results of the current study presented in Figure 5 (B), and 6 (A & B) revealed that the interaction effects between SA, last irrigation and hill spacing were significant on root fresh mass, top fresh mass, root and sugar yield, sucrose %, TSS % as well as purity % in both seasons. The maximum values of root fresh mass, top fresh mass, root yield, and sugar yield were obtained with SA, 15cm between plants and period between last irrigation and harvest date at 20 days in both seasons (Figure 5(B), 6(A)). Like-

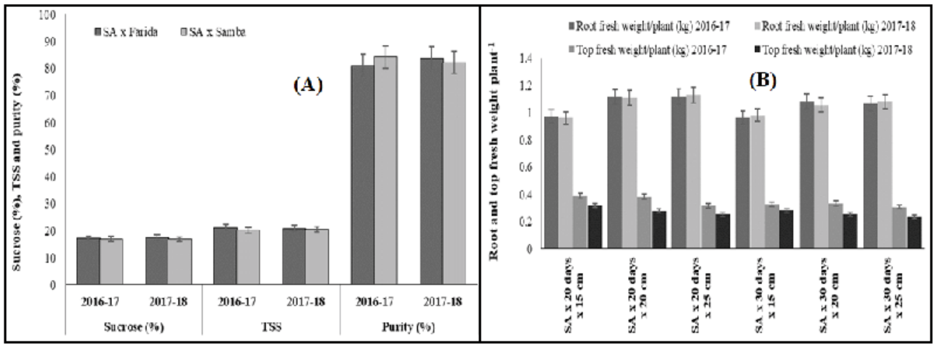

Figure 5: (**A**)**:** Sucrose (%), TSS and purity (%) of sugar beet are influenced by SA (applied at 30 DAP and 14 DAFA), and cultivars ('Farida' and 'Samba'). **(B):** Root and top fresh mass plant^{-1} of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, and spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm.

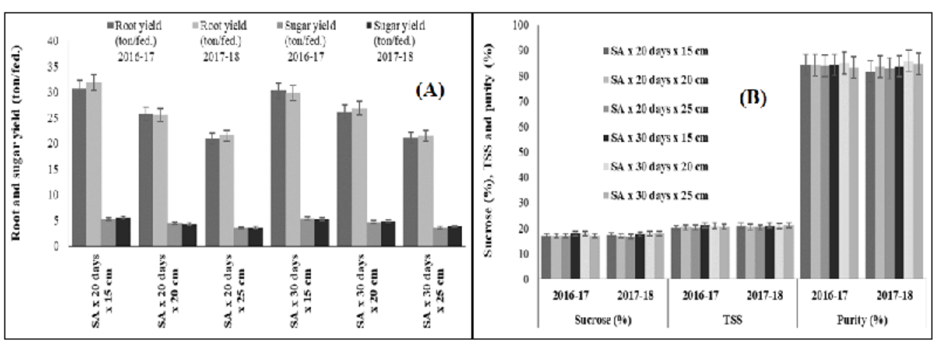

Figure 6: (**A**)**:** Root and sugar yield (t/fedden (0.42 ha) of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, and spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm. (**B**)**:** Sucrose (%), TSS and purity (%) of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, and spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm.

wise, the highest levels of sucrose %, TSS %, and purity % were obtained with the interaction between SA, the period between last irrigation and harvest date at 30 days and 20 cm between plants (Figure 6 (B)). It might be due to the reduction of competition between plants for light and nutrients, consequently improving plant growth and production (Nafei et al., 2010).

Referring to the effect of interaction between SA, the period between last irrigation and harvest date as well as cultivars on root fresh mass, root yield, sugar yield, and quality characteristics, presented data in Figures 7 (A & B) displayed a significant effect on most characteristics in the two growing seasons. The maximum values of root yield, sugar yield, sucrose %, and purity % were recorded with the interaction between SA, the period between last irrigation and harvest date at 30 days and 'Farida' cultivar compared with other treatments. Increasing the prevention period of water supply before harvesting led to increasing the concentrations of sucrose and purity %. These results are in harmony with the achieved results by Sohrabi and Heidari (2008), who also found the maximum values of plant biomass such as root, top biomass , sugar yield due to the combined effect of SA, application times of irrigation and different crop cultivars.

Regarding to interaction effects between SA, hill spacing and cultivars on fresh mass of root, root yield, sugar yield, sucrose %, TSS %, and purity % obtained

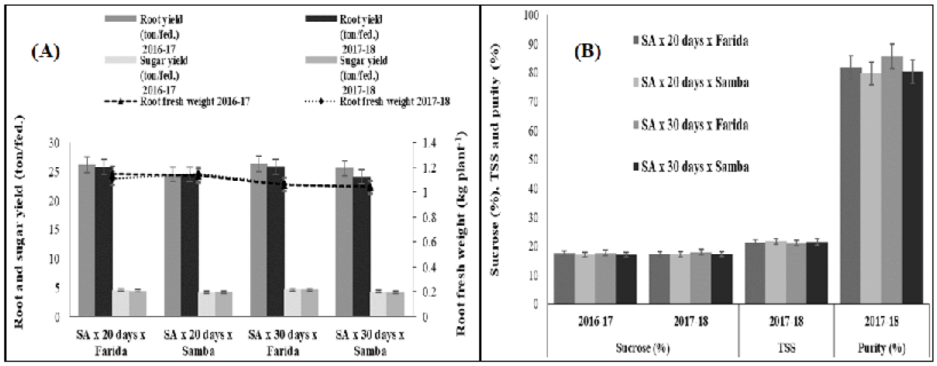

Figure 7: (A): Root fresh mass plant^{-1} (kg), root yield (t/fedden (0.42 ha) and sugar yield (t/fedden (0.42 ha)) of sugar beet is influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, and cultivars ('Farida' and 'Samba'). (**B):** Sucrose (%), TSS and purity (%) of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, and cultivars ('Farida' and 'Samba').

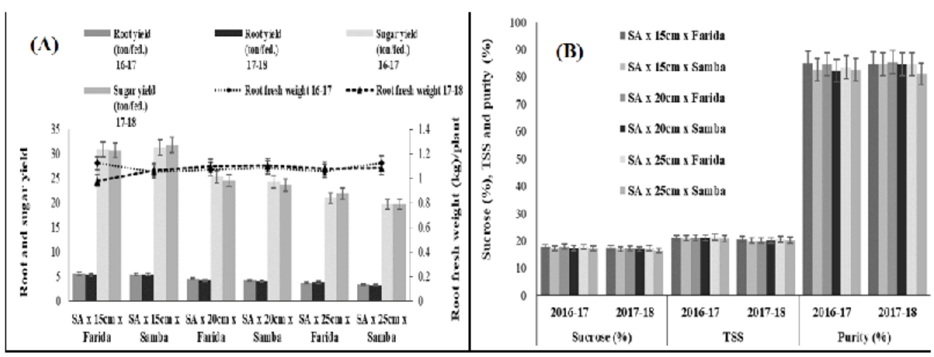

Figure 8: (A): Root fresh mass plant^{-1} (kg), root yield (t/fedden (0.42 ha)) and sugar yield (t/fedden (0.42 ha)) of sugar beet is influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm, and cultivars ('Farida' and 'Samba'). (**B):** Sucrose (%), TSS and purity (%) of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), spacing (SP) hill^{-1} at 60 x15, 60 x 20 and 60 x 25 cm, and cultivars ('Farida' and 'Samba').

results in Figure 8 (A) showed that the maximum levels of fresh mass of root, root yield, and sugar yield were recorded at treatment interaction between SA, 15 cm hill spacing and 'Farida' cultivar as well as interaction between SA, 15cm hill spacing and 'Farida' cultivar respectively in both season comparing with other treatments. The same trend was observed with the combined effect of SA, IR, plants' spacing and cultivars'(Ramadan, 1999; Shalaby et al., 2011). Furthermore, the maximum levels of sucrose % and purity % were obtained with the interaction between SA, 15 cm hill spacing and 'Farida' cultivar Figure 8 (B). The assumption is confirmed by several earlier findings but for different crops, who also revealed that application of SA influenced the growth, photosynthesis and carbohydrate metabolism of maize (Zhou et al., 1999; Khodary, 2004), sugar beet (Ghoulam et al., 2001) and sugarcane (Du et al., 1998) under stressed condition.

Results presented in Figure 9, clearly show that the highest levels of sucrose, root and sugar yield were recorded with the interaction between SA, the period between last irrigation and harvest date at 30 days, 15cm spacing hills and 'Farida' cultivar. These findings are in agreement with the observation of Awad et al. (2014). The results may be due to the essential role of SA in the enhancement of cellular osmolytes and improve photosynthetic pigments as well as plant production under water deficit conditions (Abdelaal, 2015b).

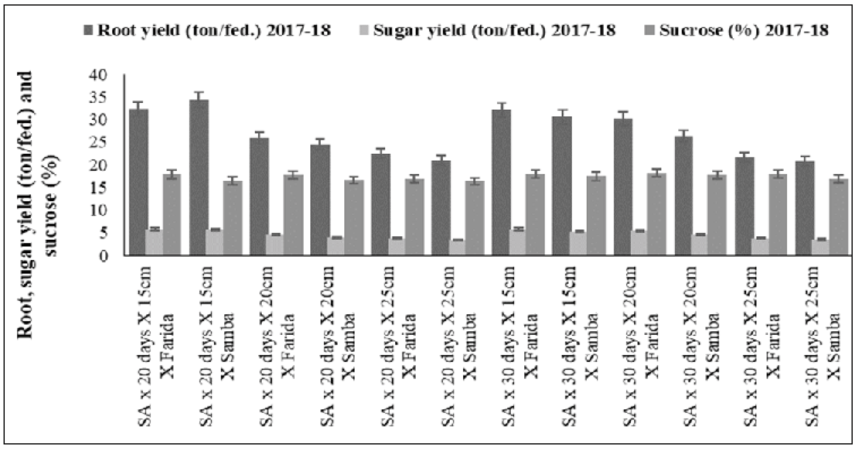

Figure 9: Root, sugar yield and sucrose (%) of sugar beet are influenced by interaction effect of SA (applied at 30 DAP and 14 DAFA), irrigation (IR) at 20 and 30 days, spacing (SP) hill^{-1} at 60 x 15, 60 x 20 and 60 x 25 cm, and cultivars ('Farida' and 'Samba').

4 CONCLUSION

Our results of the study suggest that the foliar application of 100 ppm SA at 30 DAP and 14 DAFA significantly influenced the top fresh mass and root biomass of sugar beet plants under both the two growing seasons. Conversely, the increasing period between planting and first irrigation led to significant differences in fresh mass, sugar yield, and sucrose % as well as purity % of sugar beet in both the seasons. Plants spacing hill^{-1} of 60 × 20 cm with 33335 plants/fedden (0.42 ha)) were found to be better than the other two spacings for most of the characters, particularly root fresh mass, and sucrose total soluble solids (TSS %) and purity %. Inversely, spacing at 60 × 15 cm (with 44465 plants/fedden (0.42 ha)), between hills gave the maximum levels of top fresh mass, root yield and sugar yield in the first season. The interaction effect between spacing hill^{-1} at 60 × 20 cm (33335 plants/fedden (0.42 ha)) and 100 ppm SA applied at 30 DAP gave the maximum levels of increment for most of the studied characters, mainly for the cultivar 'Farida' than 'Samba'.

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