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THE COMBINED EFFECT OF SUPERABSORBENT CONDITIONERS AND WATER DEFICIT STRESS ON PRODUCTIVITY TRAITS OF SOME SUGAR BEET VARIETIES

Wafaa E. Grad[1], M.S. El-Kady[2], E. Kenawy[3]
and Mona I. Massoud[2*]

1. Department of breed. and genetics, Sugar Crops Res. Inst., ARC, Alexandria, Egypt.
2. Department of Physiology and Chemistry, Sugar Crops Res. Inst., ARC, Giza, Egypt.
3. Department of Chemistry, Faculty of Science, Tanta University, Egypt.

ABSTRACT

Superabsorbent polymers based on rice husk (RHP) and loaded with urea (RHPU) can be used as soil conditioners to sustain sugar beet production in desert regions. Two field experiments were conducted in the Wadi El-Natron region, Egypt (longitude 30° 13' 0 E°, latitude 30° 25' 0 N) during the 2020/2021 and 2021/2022 seasons. A split-split plot design in a randomized complete block arrangement with three replicates was employed to study the combined effects of RHP and RHPU (0, 1g, and 3g), with three irrigation levels (IR100, IR80, and IR 60%) under a drip irrigation system on the physiological, yield and quality traits of five sugar beet varieties. The results indicated that the RHPU doses recorded higher values of leaf area index, net assimilation rate, relative growth rate, and root weight after 120 days of planting as compared to the RHP and controls (rice husk or untreated). RHPU application had a positive influence on the increase in root yield, under IR80% and IR60%. The interaction between RHPU (3 g) and IR60% showed a significant increase in the physiological traits, and root yield, compared to the IR100% control. No significant differences were observed in the interactions between RHPU doses + IR60% + Dina variety and RHPU3g + IR100% + Panther variety. Furthermore, a significant positive correlation was demonstrated between plant growth and yield, but not between quality attributes. In conclusion, the application of RHPU (0.5:0.5) improved the growth characteristics and productivity with the economic return of the sugar beet crop under the newly reclaimed lands.

Key words: ***Sugar beet, Sustainability, Superabsorbent polymers, Drip irrigation, Economic returns.***

INTRODUCTION

The sugar beet (*Beta vulgaris*) is the second-most important source of sugar production, after sugar cane, which supplies about 25% of the world's sugar requirements. It contributes to the production of 12% of the world's sugar and 57% of sugar production in Egypt (FAOSTAT 2022). China and Egypt were the main contributors to the increase in sugar beet root production worldwide over the past ten years. Egypt ranks eighth globally and produced 1.3 million tonnes (~59%) of sugar from 518.3 thousand feddan of sugar beet cultivation in 2020 (Abdelwahab *et al* 2022).

Egypt is currently dealing with a number of problems due to its population's rapid growth and the urgent need to supply Egypt's food needs. Therefore, the Egyptian government is to find out sustainable ways to enhance sugar beet crop productivity in the desert and New Delta under severe drought conditions, as well as the allocation of 35 thousand feddans for sugar beet production to sustain food security (USDA 2022). Furthermore, there is a considerable interest in enhancing the efficiency of water management because of insufficient water resources, which is one of the main axes of stable agriculture in various regions under global climate change and its effects on economic and environmental status.

Numerous technologies can be applied as soil conditioners to lessen the negative effects of drought stress, increase nutrient uptake efficiency, and create favorable conditions for plant growth in desert soil (Malik *et al* 2023). Much attention has been given to superabsorbent composites (SACs) containing natural biodegradable polymers such as rice husk, sugarcane bagasse, or alginate (Kenawy *et al* 2019). SAC-based rice husk was used as an environmentally friendly soil conditioner to improve soil nutrient status, increase crop nutrition, decrease water loss through evapotranspiration, and thus conserve the environment (Bressan *et al* 2022). Rice husk is the major by-product of rice milling and accounts for two-thirds of the total rice milling product. Theoretically, rice husk residues represent 22% of Egypt's annual average rice production, which is equivalent to 0.44 million tonnes. According to Nnadiukwu *et al* (2023), rice husk increased the nutrients in the soil, which contain carbohydrate (37.04%), fiber (25.74%), and ash content (23.39%). Rice husk contains a good amount of potassium, calcium, magnesium, iron, and manganese, while other minerals such as copper, zinc, phosphorus, sodium, and selenium exist in lower concentrations (Iniaghe *et al* 2009 and Laftah and Abdul Rahman 2021). This increased soil bioactivity also increased plant yield, in addition to maximizing the recycling and utilization of organic agricultural wastes and minimizing environmental pollution (Mantanis *et al* 2000). Additionally, superabsorbent polymers have also been investigated as an eco-friendly soil conditioner because of their ability to effectively absorb water (Malik *et al* 2023). SAPs can increase soil porosity and water holding capacity, which increases water efficiency and extends irrigation periods. Furthermore, it enhances the O_2

accessibility in the plant root zone (Wang *et al* 1990), increases the different enzymatic activities (Cannazza *et al* 2014), and improves the physiological characteristics of crops because of their unique biochemical and structural properties (Malik *et al* 2023). Furthermore, the combination of absorbent materials with sandy soil improved the structure of the soil, germination, plant growth, absorbance of nutrients by plants, and water utilization efficiency. (El-Hady and Abo-Sedera 2006). Rice husk-reinforced polymer composites can be used as a friendly, sustainable soil conditioner (Kenawy *et al* 2018). Adding a superabsorbent made from rice husks to soil significantly improves soil capacity to retain water and urea release control. Rashad *et al* (2020) also demonstrated that the soil amended with a 1% superabsorbent polymer increased plant productivity under deficit irrigation conditions by enhancing soil water retention and urea use efficiency by decreasing urea loss. Grad *et al* (2021a) found that adding rice husk-reinforced polymer composites prepared with urea to the soil significantly increased sugar yield from sugarcane as compared to untreated plants under irrigation every 3 weeks. Loading of urea onto the superabsorbent composites may be an operational strategy to improve fertilizer retention, increase water efficiency, improve crop nutrition, and hence protect the environment. It contributes to slowing urea diffusion and release in soil, which may improve urea use efficiency conditions, improve crop yield and quality, protect the plant from severe water deficiency, and lower plantation costs (Kenawy *et al* 2021). Application of the super absorbent polymer (hydroxyethylcekkulose) at the rate of 6 g/kg soil provided 20% of the water requirements of the durum wheat crop (Meleha *et al* 2022).

Novel biodegradable superabsorbent composites made of rice husk (RHPs) and loaded urea onto the produced superabsorbent polymers (RHPU) synthesized by a scientific team at the Science Faculty, Tanta University, Egypt. The RHP was prepared using copolymerization of acrylic acid, acrylamide, gelatin, and rice husk in aqueous media containing N, N0-methylenebisacrylamide and potassium per sulfate. The RHP displayed good resistance in saline solutions at pH of 6–10. The RHPU was made by loading a weighed amount of urea (N fertilizer) onto a weighed amount of RHP dissolved in distilled water to enhance water retention, urea release, and crop growth parameters while reducing irrigation water use. The RHPU showed a regulated biodegradability in soil that ensures their presence in the soil for a sufficiently long time, more than five months. In addition, soil with 1% RHP can retain water for more than a month (Kenawy *et al* 2021). Therefore, the goal of this study was to evaluate the combined effects of RHP and RHPU rates and water stress levels under a drip irrigation system on the physiological, yield, and quality traits of five sugar beet varieties, as well as the economic returns as a result of the addition of soil superabsorbent conditioners.

MATERIALS AND METHODS

- Rice husk (RH) derived from rice was supplied from the Agricultural Research Center, Ministry of Agriculture, Egypt. It was milled, sieved through thirty mesh sieves, and kept at room temperature.
- Rice husk-reinforced superabsorbent conditioner (RHP) and loading of urea onto the produced superabsorbent conditioner (RHPU) were donated to our laboratory by Professor El-Refaie Kenawy of the Department of Chemistry, Faculty of Science, Tanta University, Egypt (this work was done through research project ID: 5842 entitled "Superabsorbent Polymer Composite for Agricultural Applications").
- Five different sugar beet varieties are evaluated in the tested area: Kn-627 (V1) and Mammut (V2) as two monogerms, and Fernand (V3), Panther (V4), and Dina (V5) as polygerms.

Characteristics of location and soil properties

Two field experiment were conducted during the seasons of 2020/2021 and 2021/2022, at Wadi El-Natron Research Station, Water Management Research Institute, National Water Research Center, Egypt (longitude 30° 13' 0 E°, latitude 30° 25' 0 N). The soil was sandy as a result of its composition, which included 95% sand, 3.2% silt, and 1.8% clay. The soil reaction was slightly alkaline (pH 7.9), containing 2.23 meq/l of sodium, 1.35 meq/l of calcium, 0.5 meq/l of magnesium, and 0.18 meq/l of potassium. Chloride was the main anion in soil, followed by sulphate (0.83 meq/l) and HCO_3 (0.83 meq/l). The conductivity was

3.76 dSm^{-1}. The bulk density is 1.56 g/m^3, with a field capacity of 9.1% and a wilting point of 5.9%. The artesian well was the source of irrigation water with a pH of 7.14. The average temperature is 17.5°C in the coldest month (Jan.) and 39.7°C in the hottest month (July). The annual mean relative humidity is 65%.

Treatments

The following soil conditioner treatments were applied to the soil during sowing: T1 = without, T2 = rice husk, T3 = RHP at 1 g/plant, T4 = RHPU at 1g (0.5g RHP loaded with 0.5 g urea)/plant, T5 =RHP at 2 g/plant, T6 =RHPU (1 g RHC loaded with 1 g urea) in three replicates and three irrigation water levels (IR): 100% (normal), 80% (moderate stress), and 60% (severe stress), of their specified field capacity, Figure (1).

Experimental Design

The field experiment was set up in a split-split plot design in a randomized complete block arrangement. The main factor was different soil conditioner treatments, while irrigation water levels were allocated in the sub- plots and sugar beet varieties were distributed at random in the sub-sub plots. Each plot consisted of five rows with a length of 25 m, a distance of 70 cm between rows, and a 25 cm distance between plants. The dimension of each plot was 25 x 3.5 m, and the distance between the two plots was 1m. The sugar beet seeds were sown manually on 3rd of October and harvested on 15th of April in both seasons. Seeds were sown at a rate of 4 kg/fed, with two seeds per hill. The seedlings were thinned to one plant per hill after 35 days. Prior to sowing, normal agricultural practices and fertilizer rates for growing sugar beet were followed as recommended by the Sugar Crops Research Institute, Agricultural Research Center.

Irrigation system

The experimental drip irrigation system was used. The irrigation system (Fig. 1) consists of a 50-HP centrifugal pump, screen filter, control unit, 110 mm main line, 90 and 75 mm sup main line, 40 mm manifold, and 180 laterals with a 25 m length on an area of around 1.07 fed.

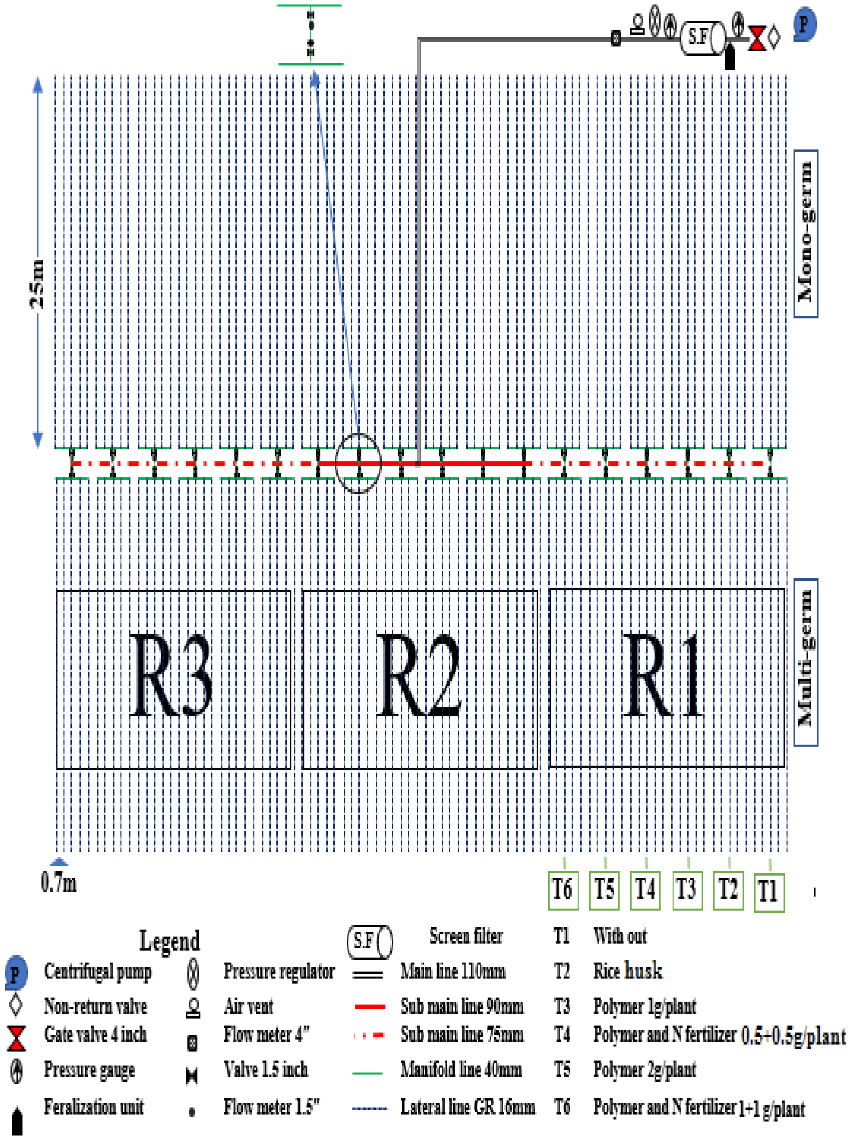

Fig. 1. Schematic sketch of treatments and drip irrigation system components.

Dripper's lines consist of polyethylene with a diameter of 16 mm, GR drippers with 4 lit/hr discharge, and 25cm between drippers. A dielectric sensor Delta Devices model Profile Prob-PR2 (England) (soil moisture meter) was used for measuring the moisture content of plots. Each plot is irrigated regularly when 50 and 60% of the initial stage and other stages of moisture deplete the soil, respectively, and the Israelsen and Hansen (1962) equation was used to determine the amount of water applied.

Soil moisture studies

Water productivity was calculated as described in the Ali and Talukder (2008) equation. The water-holding capacity of the soil was measured by a tensiometer according to the procedure of Kramer (1983).

Crop growth characteristics

Five plants per treatment were randomly selected every week from the middle row of each plot to evaluate the sugar beet growth. Growth analyses were determined after 90, 105, and 120 days from planting, according to Watson (1958). The mean leaf area index (LAI) and some of the growth rates for net assimilation rate (NAR), crop growth rate (CGR), and relative growth rate (RGR) were calculated using the equations proposed by Gardner *et al* (1985).

Yield and quality characteristics

The sugar beet crop was harvested for each plot of 3.5 x 3 meters. The root yield of each plot was collected, cleaned, weighed and recorded. The harvested yield was performed for each experimental plot 3.5 x 3 meters. The root yield of each experimental plot was collected, cleaned, and weighed and then sent for quality analysis of the sugar beet to the Sugar Beet Laboratory at Nubaria Sugar Factory in El-Beheira Governorate, Egypt. The sugar content was determined using a saccharometer analyzer according to official ICUMSA methods. Alpha-amino-nitrogen was determined by a spectrophotometer (Sheikh 1997), while sodium, and potassium were measured using Autoanalyzer (Brown and Lilland 1964). The sugar yield (ton/fed) was calculated by multiplying the root yield by the percentage of white sugar (Reinefeld *et al* 1974).

Cost analysis

The dependent and independent variables for the sugar beet root crop under study were calculated for different treatments over the experiment period. The irrigation costs were based on the rental amount of water during the season. The net return (LE /fed), total return, and total cost of production were determined according to Moursy (2018). Return on investment (LE/fed) = total return minus total expense.

Statistical analysis

The generalized linear model (GLM) procedure of SAS version 9.4 was used for all statistical analyses of the obtained data. The Duncan multiple range test ($P \leq 0.05$) was used to compare significant differences of means.

RESULTS AND DISCUSSION

During the two growing seasons, the application of superabsorbent conditioner rates under both irrigation levels had a significant impact on the sugar beet crop characteristics and productivity.

Effect of RHP/RHPU treatments on water holding capacity

The RHP gave a maximum water absorbency value in distilled water of 795 g/g. The absorption capacity was enhanced by 17.95% and 22.82% when 1 and 3 g of RHP respectively, were applied to the soil compared to the untreated control. In addition, the RHPUs showed controlled biodegradability in soil, which guarantees their presence in the soil for >3 months. This result agreed with Abrisham *et al* (2018) who mentioned that soil polymer swelling increases the capacity for cation exchange, lowers the rate of soil infiltration, increases air capacity, and improves soil porosity, all of which help crops withstand dry spells and lessen the harm that comes from water deficit stress. According to Kenawy *et al* (2021), certain hydrogel matrices with some polysaccharide-based controlled-release formulations have the advantages of being environmentally friendly, inexpensive, readily available, and biodegradable; as a result, their presence in soil improved water retention capacity and allowed for the soil solution to release water sustainably.

Impact of superabsorbent conditioner based on rice husk (RHP) and loaded with urea (RHPU) under water stress levels on crop growth characteristics

Analysis of variance showed that the growth rates of the sugar beet varieties were significantly affected by RHP and RHPU rates under different irrigation treatments at 90 to 105 and 105 to 120 days (Table 1). RHPU and RHP at dose of 3g application led to an increase of 18.50 and 12.88%, respectively, in leaf weight compared with the non-treated control (937.28g) at 120 days. The highest mean value of leaves weight (1546.63g) was recorded for variety Dina at 120 days. On the other hand, leaf area was significantly affected by the RHP and RHPU doses and growth season. Moreover, the irrigation treatment (IR) and sugar beet variety did not significantly affect the leaf area or leaf area index (Table 1).

At all growth stages, RHPU treatments produced the highest mean value of leaf area compared with the RHP treatment and control. The application of rice husk as a positive control improved the growth parameters of the studied varieties in comparison to the control (untreated) Leaf area index (LAI) increased in the early growth stages and then gradually decreased until harvest. As can be seen in Figure (2), the highest LAI was observed in the control (1.27 m^2m^{-2}) and positive control (1.22 m^2m^{-2}) at 90-105 days. While the highest LAI was given in RHP at dose 3 g (0.781 m^2m^{-2}) which was statistically similar to that in RHPU at dose 1g (0.716 m^2m^{-2}) at 105-120 days. These results are in accordance with those obtained by Pačuta *et al* (2021), who reported that the superabsorbent had a positive impact on mitigating the drought consequences at the initial growth of vegetation. Moreover, silicon elements found in rice increase resistance to stresses in sorghum and sunflower (Yan *et al* 2018), improve wheat's photosynthesis rate, and fortify its antioxidant defenses (Ali *et al* 2019). Also, data in Table (1) showed that the superabsorbent composite doses, sugar beet varieties, and seasons showed significant effects on root weight during all studied growth stages. The root weight was not significantly affected by the urea rate in composites, but it increased depending on the doses of composites in both growth seasons.

Table 1. Means and analysis of variance for effects of superabsorbent conditioners, water deficit stress treatment, variety and seasons on sugar beet growth characteristics.

Source of variation Measurement	Mean	Standard deviation	Superabsorbent conditioners			Water stress treatments			Varieties			Season		
			Mean Squares	F Value	p-value	Mean Squares	F Value	*p*- value	Mean Squares	F Value	p-value	Mean Squares	F Value	*p*-value
Leaves weight (g) at 90day	886.15	230.18	27550.48	0.25	0.9313	27463.05	0.4	0.687	255720.58	2.23	0.1386	96105.95	1.16	0.3543
Leaves weight (g) at 105 day	994.90	283.12	32535.59	0.23	0.9425	32632.43	0.32	0.7379	358350.46	1.8	0.2057	102009.51	0.91	0.5020
Leaves weight (g) at 120 day	1070.37	286.13	44712.48	0.31	0.8971	38170.07	0.38	0.6991	409783.75	2.17	0.1458	118384.95	1.04	0.4227
Leaf area (cm^2) at90day	3946.5	335.64	5670246.73	45.12	<.0001	77044.46	0.71	0.5281	43566.81	0.34	0.8452	9654759.93	84.96	<.0001
Leaf area (cm^2) at 105day	5345	281.11	5154323.56	57.58	<.0001	89715.42	1.32	0.3359	36158.26	0.4	0.8048	8787625.24	108.79	<.0001
Leaf area (cm^2) at 120day	6140.5	178.17	5551171.31	190.97	<.0001	77157.18	6.95	0.07741	42374.68	1.28	0.3401	9880449.39	292.72	<.0001
LAI1 (90 to 105day)	1.165	0.451	0.625	3.16	0.0081	0.067	0.34	0.7118	0.045	0.23	0.9236	1.88	9.53	0.0021
LAI2 (105 to 120day)	0.663	0.286	0.709	9.41	<.0001	0.08	1.06	0.3468	0.017	0.23	0.9193	0.534	7.09	0.008
Root weight (g) at90day	788.11	461.04	1436127.81	8.72	<.0001	164206.82	1	0.3695	5031695.28	30.57	<.0001	180804	1.1	0.2951
Root weight (g) at 105day	1163.63	635.49	2596422.36	8.84	<.0001	56258.54	0.19	0.8258	11746970.7	39.99	<.0001	2792452.27	9.51	0.0022
Root weight (g) at 120day	1494.45	895.13	2765269.7	4.7	0.0003	332737.4	0.57	0.5685	25487069.1	43.31	<.0001	5271770.4	8.96	0.0029
CGR1 (90 to 105day)	242.29	202.97	74090.64	2.22	0.0506	5339.67	0.16	0.8519	794003.38	23.84	<.0001	1099809.07	33.03	<.0001
CGR2 (105 to 120day)	203.23	213.74	93805.58	2.41	0.0908	62922.31	1.62	0.1538	879823.91	22.6	<.0001	88294.491	2.27	0.1326
RGR1 (90 to 105day)	3.89	0.273	0.159754	2.87	0.0144	0.155	2.79	0.0621	1.86	33.41	<.0001	2.37	42.6	<.0001
RGR2 (105 to 120day)	3.94	0.276	0.087	1.52	0.1804	0.1163	2.03	0.1327	2.28	39.78	<.0001	1.103	19.22	<.0001
NAR1 (90 to 105day)	0.057	0.052	0.0184	8.16	<.0001	0.001	0.45	0.6391	0.041	18.21	<.0001	0.027	12.29	0.0005
NAR2(105 to 120day)	0.037	0.038	0.009	7.06	<.0001	0.0015	1.2	0.3007	0.024	19.31	<.0001	0.0004	0.3	0.585

LAI: leaf area index; CGR: crop growth rate; RGR: relative growth rate; NAR: net assimilation rate (Analysis was obtained at a level of significance $P \geq 0.05$ (not significant), $P \leq 0.05$ (significant), $P \leq 0.01$ (very significant), $P \leq 0.001$ (highly significant).

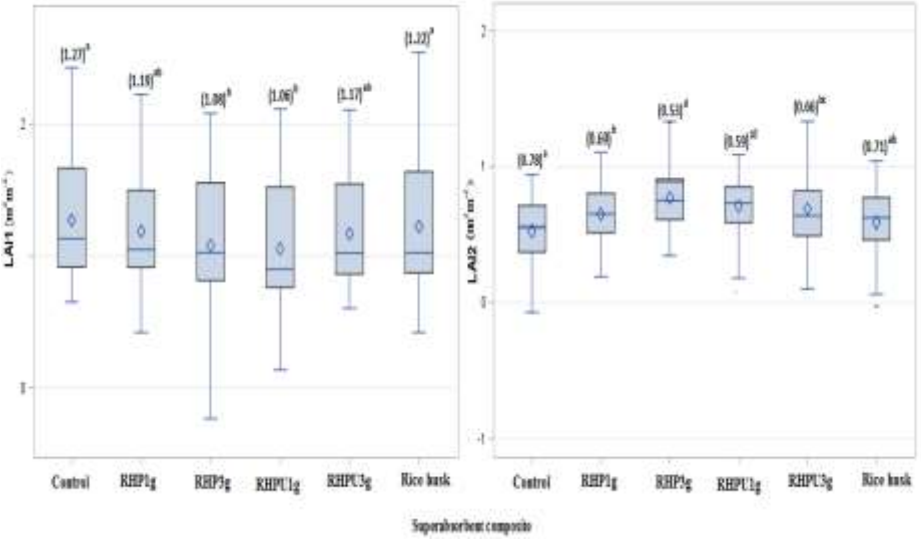

Fig. 2. **Effect of rice husk superabsorbent conditioner (RHP) and loading with urea (RHPU) treatments on leaf area index (LAI) of sugar beet (*p* ≤ 0.05).**

As illustrated in Figure 3, the highest roots weight at 120 days was recorded in the 3g RHPU (1695g) and 3 g RHP (1609 g) treatments, and this result was significantly ($p \leq 0.05$) higher than that of the negative control (1129.2g). Treatment with rich husk as a positive control increased roots weight by 10.95% compared to the negative control (not treated) at 120 days. Decreasing the RHPU rate from 3g to 1 g decreased root weight by 7.93%. This may be due to the role of nitrogen in meristematic growth activity stimulation, which increases in the number and size of cells. This could be because the hydrogel particles also surround the substrate near the root zone, which encourages the controlled release of water from the hydrogel composite by the osmotic pressure difference to the plant roots (Cerasola *et al* 2022).

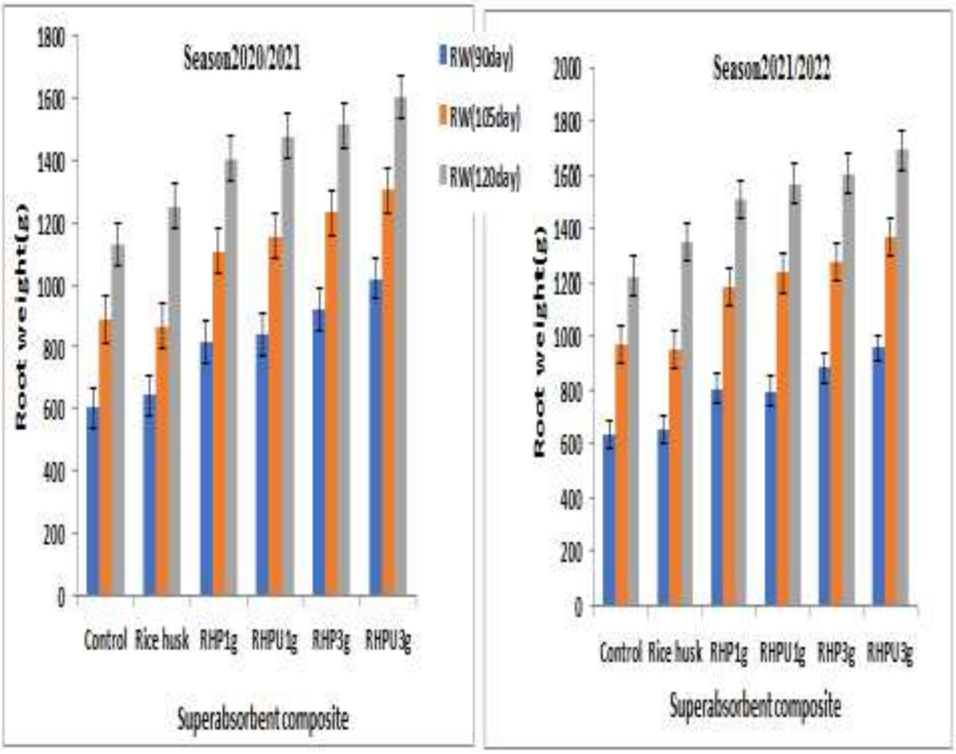

Fig. 3. Sugar beet roots weight (RW) at different growth stages as influenced by rice husk superabsorbent conditioner (RHP) and loading with urea (RHPU) treatments during 2020-21 and 2021-22 season.

These findings are in agreement with Pattanaaik *et al* (2015), who found that the volume of the hydrogel particles decreased, causing spaces that increased the amount of space available for root growth, water and air infiltration. Vasconcelos *et al* (2020) found a superabsorbent hydrogel composite based on starch and rice husk ash significantly impacted melon root size in sandy soil. The highest value of roots weight (2204.7 g) was recorded in the variety Dina, while, the variety Kn-627 had the lowest value of root weight. The results of the root weight examinations in this study showed that different varieties had different responses to the related conditions (Hoffmann 2019).

The results of CGR, RGR, and NAR indicated that sugar beet varieties and growth seasons were highly significantly ($P \leq 0.05$) affected by these rates (Table 1). It was observed that the Dina variety had the greatest CGR, RCR, and NAR, followed by Panther, Fernand, and Mammut, while Kn-627 recorded the lowest value of these rates. It is probable that the different genetic bases of the used varieties led to these significant differences (Hoffmann, 2019). The highest CGR (219.28 g/m^2/day) and RGR (3.93 g/g/ day) values were recorded in RHPU (at 3 g) treatment at 90–105 days in the 1st season. Also, RHPU (3 g) gave the highest means of CGR (280.96 g/m^2/day) and RGR (3.91 g/g/day) in the 2nd season compared to other composites (Figure 4). Concerning NAR, there were significant differences between the all-superabsorbent composites, or rice husk, and the negative control. The NAR in rice husk positive control (0.054 g/cm^2/day) was non-significant as compared to the negative control (0.045 g/cm^2 /day) at 105 to 120 days (Figure 4).

The application of RHP and RHPU can positively influence photosynthesis intensity using two near-reflectance bandwidths that are related to the carotenoid pigment cycle (Wu *et al* 2008). The growth rate and leaf area of sorghum plants were increased by 40 and 80 kg ha^{-1} of super absorption polymer-containing soil (Kazempor and Zakernejad 2019). According to Mikhael *et al* (2018), the silicone of the rice crop increases photosynthetic activity and water use efficiency. This can also be attributed to RHP, which collected soil moisture and transferred it to the seeds and roots. As a result, these plants managed to endure the drought stress significantly better than the plants in the control (Pačuta *et al* 2021).

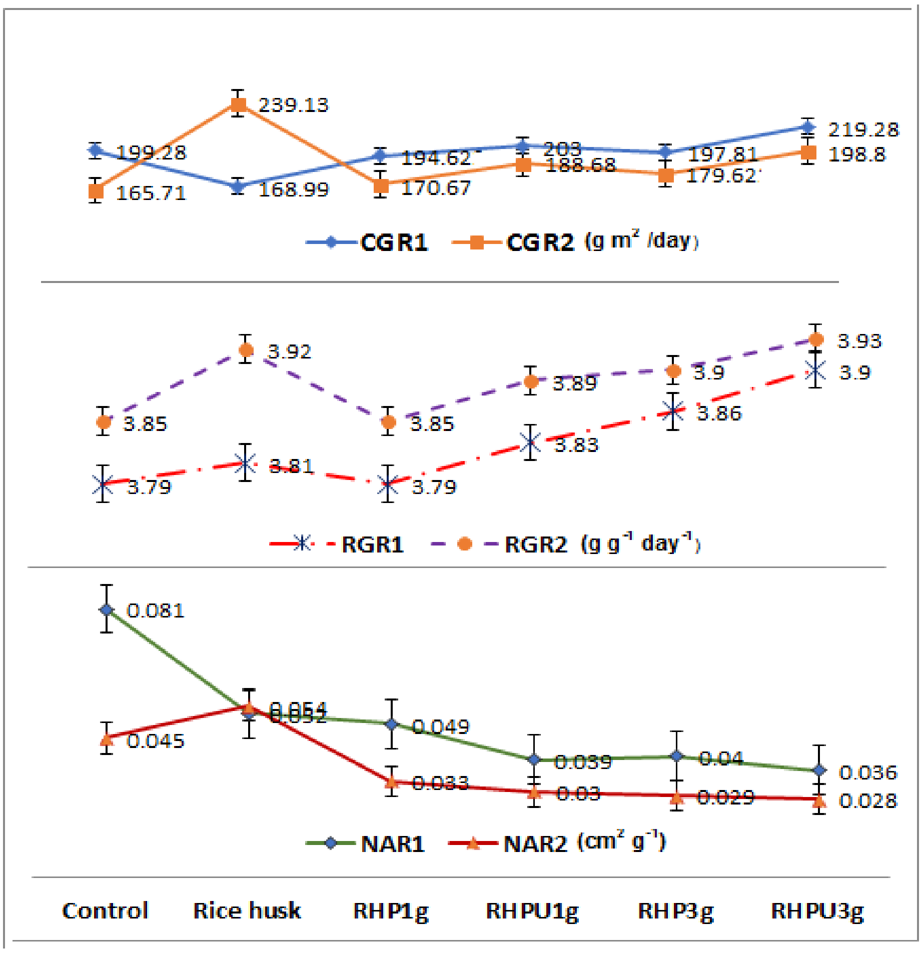

Fig. 4. Impact of rice husk superabsorbent conditioner (RHP) and loading with urea (RHPU) treatments on crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) of sugar beet ($\alpha \leq 0.05$). 1: at 90-105 days, 2: at 105-120 days.

Interactions between the experimental treatments on sugar beet growth parameters

As shown in Table (1) and Figure (5), the interaction between RHP or RHPU and the three IR levels demonstrated the effectiveness of RHP and RHPU in reducing water consumption and enhance the conditions for root growth. The RHP or RHPU application and IR treatments interaction did not have a significant effect on LAI and CGR, nevertheless, they showed significant effects on RW, RGR and NAR compared with the control. At 105-120 days, the RHPU(3g) + IR60% interaction showed a significant increase of the roots weight, RGR and NAR by 87.12g, 6.87 g/g/day and 62.38 g/cm^2/day, respectively compared to control IR100% (Figure 5 B, C & D).

The highest value of root weight (1799.6 g) and RGR (4.02 g/g/day) recorded in RHPU (3 g) + IR60% while rice husk and IR60% interaction recorded the highest value of NAR (0.059 g/cm^2/day). The data indicated that superabsorbent based on rice husk loaded with urea can be applied for controlled urea release (Ni *et al* 2011),where the components presented a synergistic effect, as soil conditioner and/or nutrient carriers led to improve the growth parameters under drought stress (Abobatta 2018).

The interaction between RHP or RHPU and the sugar beet varieties revealed that the RHPU (3g) +Dina variety interaction had the highest value of root weight (3193.1g), CGR (550.2 g/m^2/day), and RGR (4.33 g/g/day). The treatment RHPU (3g) + the Fernand variety had the lowest NAR value, whereas the Dina variety + rice husk produced higher NAR values. During both growing seasons, RHPU and IR interaction demonstrated significant effects on root weight and growth rates due to different weather conditions and genetic bases.

The obtained results are in line with the results found by Grad *et al* (2021b) when applying a superabsorbent sugarcane bagasse polymer composite as a soil conditioner to a grown stevia plant under deficit irrigation systems. Pačuta *et al* (2021) found the Brian sugar beet variety showed higher values of LAI and photochemical reflectance index (PRI) in the SAPs treatment than the Kosmas variety in the interaction of the experiment conditions with variety.

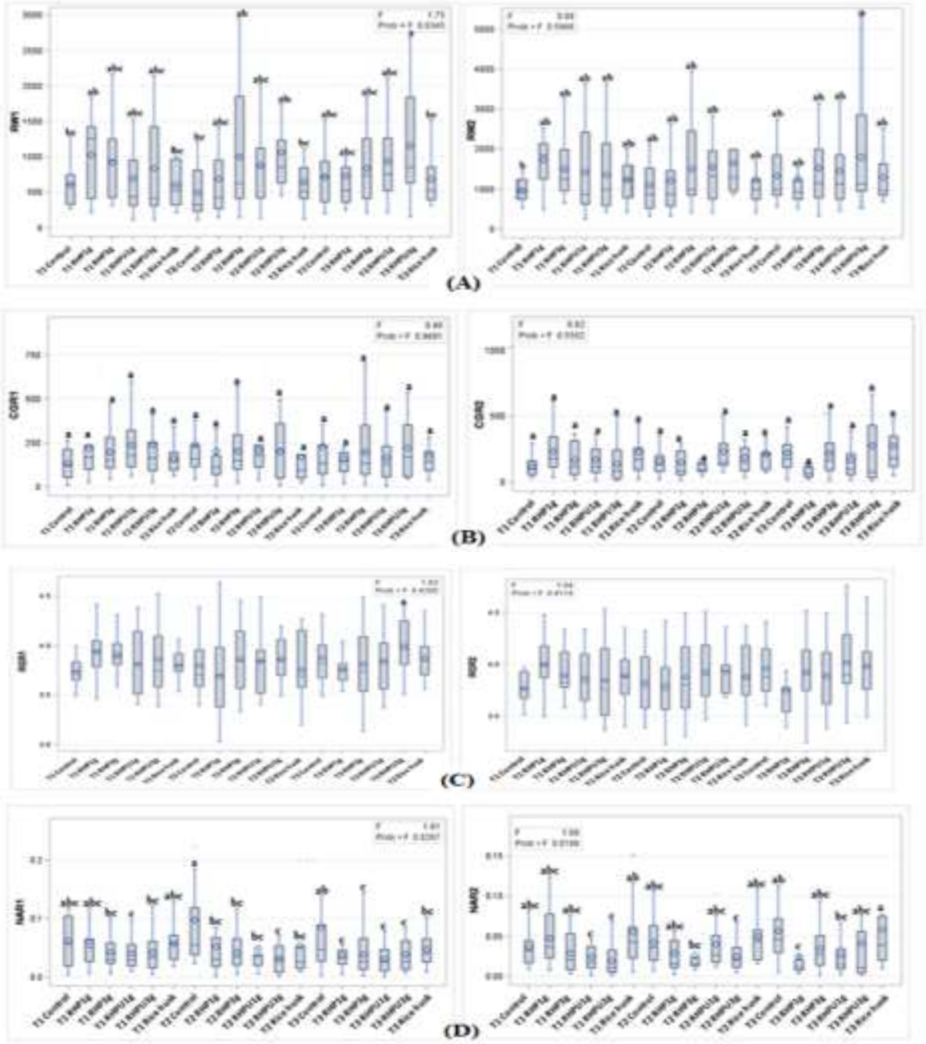

Fig. 5. The interaction between rice husk (RHP) and rice husk loaded urea (RHPU) superabsorbent polymer and the three water stress treatments on root weight: RW(A), crop growth rate: CGR (B), relative growth rate: RGR (C) and net assimilation rate: NAR (D) of sugar beet (*P* ≤ 0.05).

Impact of RHP and RHPU under water stress levels on productivity and technological quality characteristics

The results indicated that productivity and technological quality characteristics were highly significantly ($P \leq 0.05$) affected by superabsorbent composite, irrigation treatment, variety and season (Table 2). It was observed that superabsorbent composite structure had a positive effect on sugar beet root yield, especially under water stress of both growth seasons. RHPU gave the highest mean values of root yield than RHP treatment.

The increase of root yield was 27.67, 22.85, 18.12 and 11.32% in RHPU (3 g), RHPU (1 g), RHP (3g), RHP (1 g) treatments respectively, compared to control. This can be due to biodegraded composites increasing plant productivity and protecting the plant from severe water deficiency (Rashad *et al* 2020). Nitrogen rates could activate photosynthesis more and increase root yield at harvest (Malnou *et al* 2008). The sugar beet root yield values were higher in 2nd season than 1st season (Table 3). In addition, the sugar beet root yield did not significantly increased when applying superabsorbent compost in IR 60% as stress treatments by 2.31% as compared to application of IR100% in the 1st growth seasons (Table 3). This could be the result of hydrogels based on modified rice husks that were used in controlled-release urea and enhancement of the water-holding capacity of the soil and productivity crop (Guilherme *et al* 2015). Also, Zheng *et al* (2023) stated that super absorbent polymers absorb and release nutrients, decreasing nutrients losses and improving nitrogen use efficiency that lead to higher root yield.

Regarding the sugar beet varieties, the variety Dina had higher values of sugar beet root yield and statistically similar to that Fernand and Panther varieties while the variety Kn-627 had the lowest values of root yield in the two growth seasons. Results of root quality revealed that the RHPs treatments ($p < 0.05$) had highly significant effect on technological quality characteristics of sugar beet (Table 2).

Table 2. Means and analysis of variance for effects of superabsorbent conditioners, water deficit stress treatment, variety and seasons on sugar beet productivity and quality characteristics.

Measurement	Mean	Standard deviation	Mean standard error	Superabsorbent conditioners			Water stress treatments			Varieties			Season		
				Mean squares	F value	p-value	Mean squares	F value	*p*-value	Mean squares	F value	p-value	Mean squares	F value	p-value
Root yield (ton/fed)	23.79	2.92	2.04	332.97	80	<.0001	15.320	3.68	0.026	26.81	6.44	<.0001	220.37	53	<.0001
Sucrose (%)	17.98	1.86	1.13	207.28	75.78	<.0001	18.61	14.45	<.0001	15.14	11.7	<.0001	37.13	28.8	<.0001
Purity (%)	84.55	3.46	2.20	741.09	153	<.0001	83.32	17.2	<.0001	80.81	16.7	<.0001	942.63	195	<.0001
Potassium (%)	5.02	0.87	0.77	14.27	23.91	<.0001	2.768	4.64	0.01	11.02	18.5	<.0001	112.02	188	<.0001
Sodium (%)	1.58	0.59	0.41	17.96	108.1	<.0001	1.81	10.88	<.0001	0.229	1.38	0.238	62.07	373	<.0001
Alpha-amino-nitrogen (%)	1.87	0.73	0.48	33.80	148.8	<.0001	0.89	3.95	0.02	0.922	4.06	0.003	2.42	10.7	0.0012
Impurity (%)	2.73	0.43	0.31	9.59	98.18	<.0001	1.104	11.29	<.0001	1.13	11.6	<.0001	41.97	429	<.0001
Extracted sugar (%)	15.17	2.51	1.56	298.19	123.1	<.0001	17.13	7.07	0.0004	12.57	5.19	0.0004	2.00	0.83	0.36
Sugar yield (ton/fed)	3.60	0.48	3.59	3.88	21.4	<.0001	0.54	2.99	0.051	0.84	0.21	1.16	0.327	28.3	<.0001

Analysis was obtained at a level of significance *P* ≥ 0.05 (not significant), P ≤ 0.05 (significant), P ≤ 0.01 (very significant), P ≤ 0.001 (highly significant).

Data in Table (3) showed that the sugar beet varieties in soil amendment with RHPU (at does 3g) had the lowest content of sucrose (16.40 and 16.71%), purity (81.54 and 80.28%), and extractable sugar (13.42 and 13.47%) in two seasons, respectively.

This reduction in quality characteristics was due to an increase in the levels of potassium, sodium and α-amino-nitrogen, consequently, increased impurities in the sugar beet root. These impurities have a negative impact on quality sugar beet as well as the extractable sugar. This may be an adverse influence of these matrices on cell size which increased the uptake of potassium over sodium in roots and decreased the possibility of sucrose accumulation in roots (Tsialtas and Maslaris 2009). Nonetheless, the application of 1g of RHPU did not significantly decrease the sugar yield (3.67ton/fed) compared to the untreated control (3.71 ton /fed). However, increasing the RHPU level to 3g resulted in a significant decrease in sugar yield by 6.46% compared to control. The quality characteristics of sugar beets, such as sucrose, purity, and extractable sugar, increased with a decreasing nitrogen fertilization rate. An increase in the impurity percentage leads to a reduction in extractable sugar content and white sugar yield due to the loss of sugar in molasses (Prysiazhniuk *et al* 2021). Also, Pačuta *et al* (2024) reported that the accumulation of compatible solutes during sugar beet growth in low water availability causes an increase in the solubility of sucrose and thus reduces the sugar yield. The results obtained are in disagreement with the results found by Pačuta *et al.* (2021) who found the SAPs application recorded an increase in root yield of 4.85 ton/ ha and in white sugar yield of 0.82 ton/ ha.

Furthermore, the irrigation treatments with superabsorbent polymers did not significantly reduce the extractable sugar percentage or sugar yield in the first growth season, while the extractable sugar percentage and sugar yield significantly decreased at IR60% as compared to the application of IR100% in the second growth season (Table 3).The data from the sugar beet variety evaluation revealed that there was no statistically significant difference between varieties in the sugar yield.

The lowest mean sugar yield (3.46 tons/fed) was recorded for the Panther variety in the first season, while the highest sugar yield was recorded for the Kn-627 variety (3.66 tons/fed) in the second season, as shown in Table (3). Curcic *et al* (2018) stated that there were positive correlations between sugar yield and the introduction of genotype, planting date interaction for varying harvest dates, and changing environmental conditions. According to Studnicki *et al.* (2019), there isn't a single cultivar widely adapted to all environmental conditions and yields a comparatively high and stable amount of white sugar.

Table 3. Means performance for effects of superabsorbent conditioners, water stress treatments, Varieties, and season on sugar beet productivity and quality characteristics.

Treatment	Seasons	Root yield (ton/fed)	Sucrose (%)	Purity (%)	Potassium (%)	Sodium (%)	α-amino-nitrogen(%)	Impurity (%)	Extractable sugar(%)	Sugar yield (ton/fed)
Control	2020	20.31^{e}±2.17	20.32^{a} ±1.49	89.57^{a}± 2.44	3.93^{c} ±0.74	0.92^{c} ±0.61	1.5 ^{c} ±0.66	2.09^{e}±0.37	18.23^{a}±1.96	3.71^{a} ±0.6
	2021	21.46^{F}±2.47	20.64^{A}±1.37	88.4^{A}±2.72	4.42^{C} ±0.95	1.21^{E}±0.66	1.54^{CD}±0.61	2.37^{F}±0.48	18.27^{A}±1.57	3.92^{A}±0.57
Rice	2020	21.17^{e}±1.78	18.60^{b} ±1.47	88.15^{b}±1.75	4.43^{b} ±0.69	0.73^{d} ±0.28	1.38^{c} ±0.28	2.19^{e} ±0.26	16.42^{b}±1.52	3.48^{cb}±0.44
	2021	22.1^{E}±2.2	18.9^{B} ±1.4	86.9^{B}±2.24	4.89^{B}±0.89	1.05F±0.44	1.43^{D}±0.37	2.46^{E}±0.39	16.44^{B}±1.42	3.63^{BC}±0.4
RHP1g	2020	22.61^{d}±1.87	16.85^{cd}±0.77	85.97^{c}±1.75	4.59^{b} ±0.63	1.03^{c} ±0.39	1.36^{c} ±0.19	2.35^{d} ±0.26	14.43^{c}±0.91	3.26^{d} ±0.31
	2021	23.0^{D}±1.83	17.14^{D}± 0.89	84.72^{C}±2.36	5.04^{B} ±0.82	1.33^{D}±0.49	1.4^{D}±0.21	2.61^{D}±0.38	14.49^{C}±0.98	3.32^{E}±0.32
RHPU1g	2020	24.95^{b}±2.33	17.33c ±1.41	84.86^{d}± 1.84	4.67^{b} ±0.67	1.51^{b} ±0.35	2.07^{b} ±0.59	2.61^{b} ±0.23	13.88^{cd}±3.32	3.67^{ab}±0.439
	2021	25.4^{C}±2.27	17.54^{C}±1.32	83.34^{D}±2.42	5.12^{B}±0.87	1.92^{B}±0.54	2.19^{B}±0.65	2.91^{B}±0.41	14.20^{C}±2.51	3.71^{B}±0.43
RHP3g	2020	23.99^{c} ±2.02	16.76^{cd}±0.88	85.15^{cd}±2.18	4.52^{b} ±0.89	1.45^{b} ±0.33	1.56^{c} ±0.27	2.48^{c} ±0.33	14.29^{c} ±0.94	3.42^{cd} ±10.3
	2021	24.5^{B}±1.9	16.93^{DE}±0.87	83.64^{D}±2.85	4.98^{B}±1.02	1.77^{C}±0.48	1.68^{C}±0.38	2.76^{C}±0.45	14.16^{C}±0.98	3.46^{D}±0.32
RHPU3g	2020	25.93^{a} ±2.58	16.40^{d} ±1.49	81.54^{e}±3.61	5.22^{a} ±0.99	1.83^{a} ±0.42	2.93^{a} ±0.58	2.98^{a} ±0.38	13.42^{d} ±1.75	3.47^{cb} ±0.56
	2021	26.4^{A}±2.36	16.71^{E}±1.40	80.28^{E}±3.61	5.65^{A}±1.07	2.19^{A}±0.55	2.97^{A}±0.6	3.26^{A}±0.46	13.45^{D}±1.61	3.54^{CD}±0.53
Water stress IR (100%)	2020	22.99^{a}±3.06	18.05 ^{a}±2.05	86.61^{a}±3.38	4.42^{b}±0.85	1.14^{b}±0.55	1.78^{a}±0.72	2.36^{b}±0.41	15.27^{a}±3.2	3.57^{a}±0.47
	2021	23.62^{B}±0.31	18.28^{A}±2.02	85.28^{A}±3.76	4.87^{B}±1.04	1.48^{C}±0.66	1.84^{B}±0.72	2.64^{B}±0.52	15.43^{A}±2.79	3.66^{A}±0.50
IR (80%)	2020	22.96^{a}±2.91	17.67^{b}±1.83	85.77^{b}±3.52	4.62^{ab}±0.92	1.24^{ab}±0.54	1.75^{a}±0.67	2.46^{a}±0.44	15.2^{a}±2.11	3.47^{a}±0.53
	2021	23.6^{B}±2.74	18.00^{B}±1.85	84.46^{B}±3.83	5.09^{A}±1.05	1.58^{B}±0.67	1.82^{B}±0.69	2.75^{A}±0.54	15.25^{A}±2.01	3.58^{AB}±0.52
IR (60%)	2020	23.52^{a}±2.78	17.42^{b}±1.65	85.23^{b}±3.38	4.65^{a}±0.80	1.35^{a}±0.56	1.88^{a}±0.78	2.52^{a}±0.40	14.86^{a}±1.92	3.47^{a}±0.41
	2021	24.1^{A}±2.59	17.64^{C}±1.62	83.92^{C}±3.63	5.08^{A}±0.92	1.68^{A}±0.67	1.95^{A}±0.79	2.79^{A}±0.48	14.83^{B}±1.87	3.55^{B}±0.39
Variety Kn-627	2020	22.51^{c}±2.7	18.26^{a}±1.81	87.2^{a}±2.95	4.07c±0.65	1.25^{a}±0.6	1.88^{a}±0.8	2.29^{c} ±0.4	15.22^{a}±3.67	3.56^{a}±0.43
	2021	23.19^{C}±2.66	18.53^{A} ±1.86	85.85^{A}±3.45	4.54^{D}± 0.86	1.59^{A}±0.73	1.94A±0.82	2.58^{A}±0.52	15.59^{A}±3.02	3.66^{A}±0.44
Mammut	2020	22.89^{bc}±2.59	17.89^{ab}±1.95	86.07^{b}±3.37	4.43^{b}±0.73	1.30^{a}±0.58	1.88^{a}±0.81	2.44^{b}±0.41	15.43^{a}±2.22	3.51^{a}±0.51
	2021	23.52^{C}±2.51	18.14^{B}± 1.95	84.78^{B}±3.69	4.88^{C}±0.91	1.63^{A}±0.68	1.95^{A}±0.8	2.71^{B}±0.51	15.42^{AB}±2.2	3.61^{A}±0.52
Fernand	2020	23.45^{abc}±3.3	17.51^{bc}±1.85	85.66^{b}±3.68	4.67^{ab}±0.92	1.18^{a}±0.51	1.65^{a}±0.64	2.46^{b}±0.43	15.06^{a}±2.15	3.49^{a}±0.42
	2021	23.7^{BC}±2.62	17.85^{BC}±1.82	84.31^{B}±3.78	5.13^{B}±1.01	1.53^{A}±0.64	1.91^{AB}±0.74	2.75^{B}±0.52	15.08^{BC}±2.05	3.55^{A}±0.50
Panther	2020	23.06^{ab}±2.77	17.59^{bc}±1.83	85.65^{b}±3.49	4.66^{ab}±0.86	1.18^{a}±0.52	1.86^{b}±0.74	2.47^{b}±0.42	15.09^{a}±2.09	3.46^{a}±0.53
	2021	24.10^{AB}±2.9	17.78^{C}±1.78	84.32^{B}±3.88	5.13^{B}±1.02	1.53^{A}±0.63	1.74^{C}±0.67	2.74^{B}±0.52	15.04^{BC}±2.07	3.59^{A}±0.42
Dina	2020	23.86^{a}±3.35	17.29^{c}±1.78	84.78^{c}±3.46	4.95a±0.89	1.28^{a}±0.56	1.71^{ab}±0.63	2.58^{a}±0.42	14.72^{a}±2.10	3.48^{a}±0.48
	2021	24.5^{A}±3.12	17.57^{C}±1.71	83.49^{C}±3.72	5.39^{C}±1.02	1.62^{A}±0.68	1.8^{BC}±0.65	2.86^{A}±0.52	14.72^{C}±1.92	3.57^{A}±0.48

Data are presented as means ±SD (standard deviation) at $P \leq 0.05$.

Evaluation of interactions between experimental factors on crop productivity

1- Superabsorbent conditioners × water stress levels

The interaction results of between RHPs or RHPUs and IR levels reflected that, the root and sugar yield was statistically significant at dosages of RHPU and deficient irrigation interaction. As can be seen in Figure (6 A), the highest of sugar beetroot root yield (29.96 tons/fed) was recorded in RHPU3g + IR100% treatment which was statistically similar to RHPU3g + IR60% (25.59 ton/fed). Although, the significantly highest value of sugar yield was recorded in the interaction RHPU (1 g) + IR100% (3.75 ton/fed), followed by RHPU (3 g) + IR80%, then RHPU (3 g) + IR100%, RHPU (1 g) + IR60%, and RHP (3 g) +IR60% (Figure 6B). The results of interaction RHP (1 g) + IR80% did not have a significant effect on root yield values compared to rice husk and IR treatments but it recorded the lowest value of sugar yield (3.18 ton/fed). Nevertheless, tested superabsorbent composite in combination with water treatment gave an increase in the RY values compared to the control treatment. Moreover, there was no significant difference of root yield values in the interaction RHPU (1g) + IR60% (25.27 tons/fed), RHP (3g) + IR60% (25.13 tons/fed), and RHPU (1 g) + IR80% (24.98 tons/fed).

From these results, it can be concluded that the application of RHPs can increase the sugar beet root yield under drought stress treatment. These findings are evident from some of the previous studies carried out by Grad *et al* (2021 a), who reported that the application of a superabsorbent composite based on rice husk loaded with urea at a dose of 4 g improved the quality parameters of the sugarcane varieties in sandy soils.

These superabsorbent conditioners, according to the Guilherme *et al* (2015) have the potential to be environmentally friendly matrices that can be used to supply agrochemical nutrients in controlled amounts while also allowing the process of water diffusion through the 3D matrix.

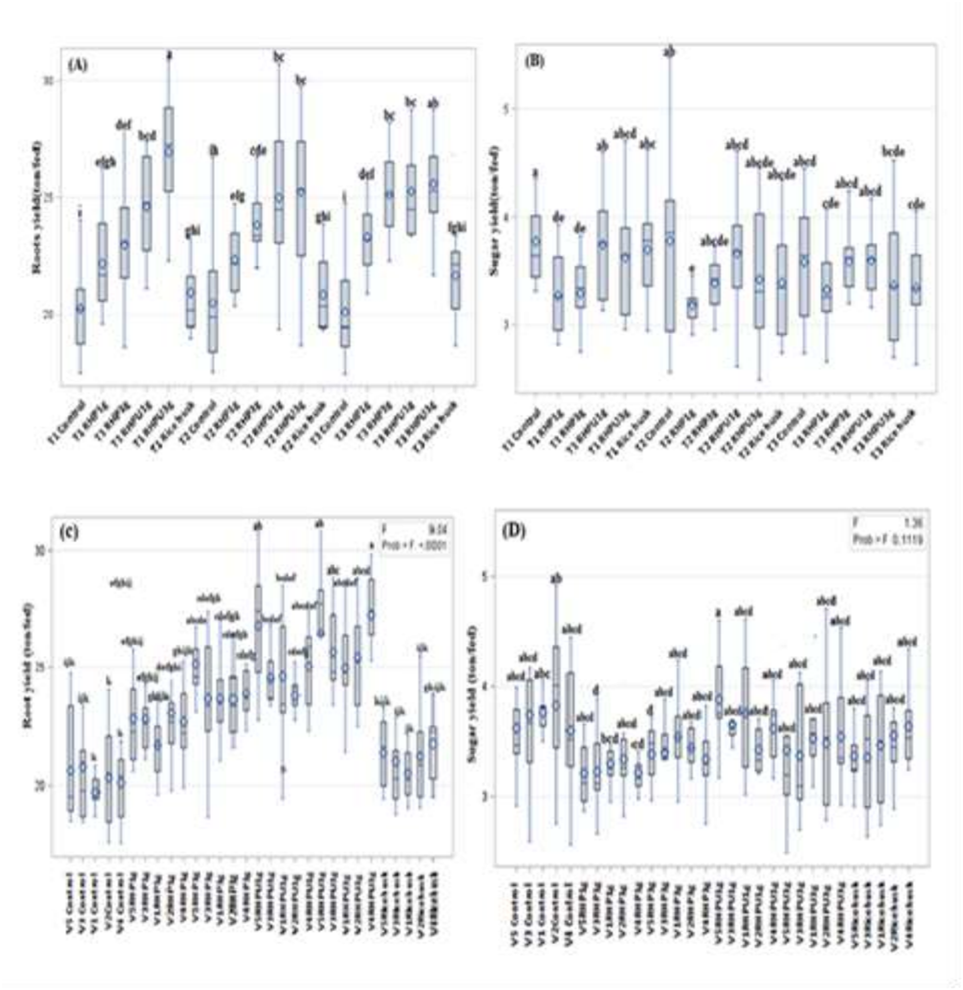

Fig. 6. Root yield (RY) and sugar yield (SY) depending on superabsorbent polymers and water stress levels interactions (A, B), superabsorbent polymers and sugar beet varieties interactions (C, D).

2- Superabsorbent conditioners ×variety

Positive responses to treatments with polymer but with different statistical significances were recorded on all sugar beet varieties in relation to root yield (Figure 6, C). The highest root yield values were recorded in the RHPU (3g) treatment. The RHPU3g + Panther interaction had the highest value of root yield (27.26 tons/fed) which was statistically similar to RHPU1g + Dina (26.80 ton/fed) following by RHPU3g + Dina interaction (26.43 ton/fed), then RHPU3 + Fernand (25.60 ton/fed) and RHPU3g + Mammut interaction (25.39 ton/fed). All varieties recorded the lowest values in control soil. The root yield was the lowest at 19.70 tons/fed in control soil and Kn-627 variety interaction

Data of sugar yield values demonstrated did not significantly affect compared to the control in the interaction treatment and varieties, except in the interaction between RHP1g treatment and both of the Kn-627, Fernand, Panther, and Dina variety (Figure 6, D). The RHPU (1 g) and the Dina variety interaction recorded the highest value of sugar yield (3.88 ton/fed). According to Curcic *et al* (2018), genetic makeup, environmental factors, and interactions all play a role in sugar beet plant growth, development, and yield. Moreover, crop production is always characterized by the distinctive characteristics of the genotype in interaction with the environment, which leads to variations in the outcomes that different genotypes produce under various conditions.

3- Superabsorbent conditioners × water stress levels × varieties

Based on the results of root yield, the combined effect of the interactions RHP dose or RHPU + IR level+ variety on root yield at the first season revealed the RHPU3g + IR100% + Panther interaction recorded the highest value of root yield (28.50 tons/fed) which was statistically similar to RHPU1g+ IR80%+ Dina (28.30 tons/fed). The RHPU3g + IR60% + Dina and RHPU1g IR 60% Dina interactions showed no significant differences in root yield value (27.13 ton/fed and 26.82 ton/fed, respectively) compared to the RHPU1g +IR80% +Dina interaction. The control + IR100% + Kn-627 interaction recorded the lowest value of root yield (19.89 tons/fed). Similar to the 1st season, the RHPU1g +IR80% +Dina interaction resulted in a significant increase in the root yield (28.89 tons/fed) in the 2nd growth season, which increased by 24.20% compared to the control+ IR100%+ Dina. Conversely, the lowest value of root yield (21.76 tons/fed) was recorded in the control + IR100% + Kn-627. It can be concluded that the Dina variety is broadly adapted to all environmental circumstances.

Based on the results of sugar yield, the highest production of sugar yield (4.27 ton /fed) was achieved in the interaction between control + IR100% + Mammut at the first season, which was deceased by 11.64%, and that containing the second season. No significant differences were observed for sugar yield in the RHPU1g + IR 80% + Dina or RHPU3g + IR 100% + Dina interactions compared with the control + IR 100% + Mammut interactions. The impact of the interaction between genotype and environment has received more attention from researchers. However, the yield and quality of the sugar beet are primarily dependent on the environment and variety (Hofmann *et al* 2009).

4- Experimental factors × year

The data shows that the mean values of root and sugar yield were significantly impacted by the growth year. In comparison to the first season, the mean value of root yield increased by 5.52 and 5.57 % to 24.43±2.5 ton/fed and 3.69±0.45 ton /fed, respectively, in the second season (Figure 7). Rashad *et al* (2020) reported similar findings: the superabsorbent polymer enhanced the soil as well as the sugar beet's physiological and yield parameters under deficit irrigation conditions.

Based on the results of this experiment, it can be concluded that the treatment × variety or with year interaction and across three-way interaction had a significant effect on sugar beet traits. As a consequence, the production indices of sugar beet are higher when using RHPU under water deficit. Controlled nutrient release from polysaccharide-based superabsorbent enhanced the functional efficiency of nutrients on soils and improved the physical characteristics of the soil, which are important for the growth and development of plants and cultivars (Hemvichian *et al* 2014). Additionally, it can also increase crop yield and decrease plant mortality in arid regions (Guilherme *et al* 2015).

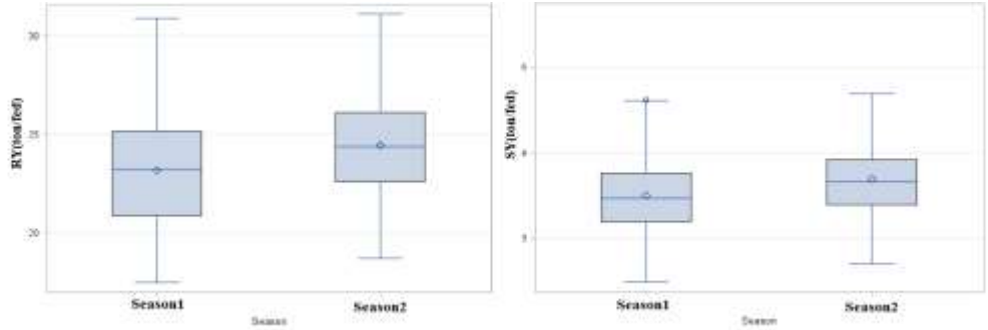

Fig. 7. The effect of the growth season on root and sugar yield ($\alpha \leq 0.05$).

The rice husk and rice husk leaded with urea superabsorbent composites application under deficient irrigation could be arranged in the following descending order as a result of the previous discussion: RHPU3g ≥ RHPU1g > RHP3g > RHP1g for root production, and RHPU1g ≥ RHPU3g > RHP3g > RHP1g in terms of sugar yield.

Correlation analysis of productivity and technological quality characteristics

Correlations are very significant indicators in breeding programs. The results of Pearson's correlation Table (4) represents the positive growth rates among all the studied growth rates except the leaf area index, which indicated a tight and non-significant negative relationship with most crop growth characteristics. It is observed that there was a high significant positive correlation ($p < 0.05$) of the CGR (g/m2/day) with the NAR (g/cm2/day) ($r = 0.95$), followed by the dependence of root weight at 105 days and root weight at 120 days with a value of ($r = 0.92$).

Table 4. Correlation coefficients of crop growth and technological quality characteristics (Char) across two seasons.

Char	LAI	NAR	RGR	CGR	RW 120	RW 105	RW 90	SY	RY	ETS	Imp	AN	Sod	Pot	Pu	Suc
Suc	-0.20***	0.04	-0.14***	-0.09*	-0.23***	-0.26***	-0.29***	0.65***	-0.39***	0.88***	-0.37***	0.18***	-0.31***	-0.31***	0.67**	1
Pu	-0.14**	0.05	-0.20***	-0.09*	0.27***	-0.31***	-0.26***	0.36***	-0.56***	0.74***	-0.93***	-0.43***	-0.74***	-0.82***	1	
Pot	0.03	0.04	0.24***	0.11*	0.25***	0.28***	0.20***	-0.21***	0.35***	-0.44***	0.89***	0.18***	0.47***	1		
Sod	0.17	-0.10*	0.10*	0.03	0.14**	0.19***	0.10*	-0.01	0.54***	-0.43***	0.81***	0.44***	1			
AN	0.08*	-0.15**	-0.06	-0.05	-0.004	0.01	0.04	0.06	0.41***	-0.24***	0.45***	1				
Imp	0.11*	-0.04	0.19***	0.07	0.23***	0.27***	0.18***	-0.13**	0.52***	-0.51***	1					
ETS	-0.19***	0.06	-0.12**	-0.08	-0.20***	-0.23***	-0.24***	0.54***	-0.44***	1						
RY	0.15***	-0.03	0.17***	0.12**	0.22***	0.23***	0.18***	0.40****	1							
SY	-0.07	0.02	-0.02	0.01	-0.07	-0.10*	-0.15***	1								
RW 90	-0.06	0.42***	0.76***	0.49***	0.84***	0.89***	1									
RW 105	-0.080	0.41***	0.81***	0.49***	0.92***	1										
RW 120	-0.07	0.66***	0.89***	0.74***	1											
CGR	-0.03	0.95***	0.78***	1												
RGR	-0.11*	0.73***	1													
NAR	-0.06	1														
LAI	1															

*** , ** and *** indicated significant at 0.05,0.01 and 0.001probaility level**

LAI = Leaf area index, NAR = Net assimilation rate ($mg.cm^{-2}/ d$), RGR = Relative growth rate ($mg. g^{-1}d^{-1}$), CGR = Crop growth rate ($g.m^2/ day$), RW120 = Root weight at 120 days (g), RW 105 = Root weight at 105 days (g), RW 90 = Root weight at 90 days (g), SY = Sugar yield ton/fed, RY = Root yield ton/fed, ETS = Extractable sugar%, Imp = Impurity%, AN = α-amino-nitrogen%, Sod = Sodium%, Pot = Potassium%, Pu = Purity% and SUC = Sucrose%.

With high statistical significance are the values of the correlations expressing the interaction between the root weight at 120 days (RW3) and the RGR (r = 0.895). The crop growth weight CGR has a relatively high positive relationship with the NAR (r = 0.95). Shaban (2021) reported similar findings: the growth rate RGR (g /g/d) was positively influenced by the high statistical significance of the rate of net assimilation (NAR).

Productivity and technological quality characteristics caused high statistical significance and a positive correlation coefficient with different values. Sucrose% is related to a strong, significant and positive correlation with technological quality processes for extracting sugar, purity%, and sugar yield (r = 0.88, 0.67, and 0.65), respectively. Furthermore, a moderate relationship was found between sugar yield with extractable sugar and root yield (r =0.54 and 0.40), respectively. Rašovský *et al* (2022) found a very strong correlation between root yield and white sugar yield and a moderate relationship between sugar content and white sugar yield. These positive correlations have a very good level of mathematical significance for the reliability of the investigational results, as mentioned by Shaban (2021). On the other hand, there is also a strong negative correlation between the purity% and almost technological quality characteristics impurity%, potassium%, sodium%, and alpha-amino (r = 0.93, 0.82, 0.74, and 0.43), respectively. Also, a negative correlation was found between root yield and extractable sugar (r = -0.44). Our result is in agreement with Nassar *et al* (2023), who reported that there are complex interrelationships among the physiological and biochemical characteristics of sugar beet plants under abiotic stress, and supplementary research is required to fully understand these relationships and their implications for plant growth and productivity.

Economic evaluation

The economic analysis indicates that the treatment RHPU(1g) gave the highest net profit and return values of sugar beet , with values in the first season of 29608.7 and 40758.7 LE/fed and in the second season of about 32095.1 and 43245.1 LE/fed, respectively (Table 5). Treatment RHPU (3g) recorded the highest total production cost value, while the control unit produced the lowest. On the other hand, treatment RHP gave the lowest total return and net return when compared to treatment RHPU. The results indicated that treatment RHP 1g in the first season gave the minimum total return (35661.7LE/fed) or net return (24661.7 LE/fed), followed by the rice husk treated control, which was closely followed by treatment RHP 3g (Table 5).

Table 5. Economic analysis of sugar beet production for two seasons.

Superabsorbent conditioners	**Total cost (LE/fed)**	**Yield (ton/fed)**		**Price (LE/ton)**		**Total return (LE/fed)**		**Net return (LE/fed)**	
Season		**20/21**	**21/22**	**20/21**	**21/22**	**20/21**	**21/22**	**20/21**	**21/22**
Control	**10700.0**	**20.3**	**22.6**	**1931.8**	**1995.7**	**39218.5**	**45144.4**	**28518.5**	**34444.4**
Rice husk	**10850.0**	**21.2**	**23.1**	**1760.8**	**1819.4**	**37268.0**	**42057.8**	**26418.0**	**31207.8**
RHP1g	**11000.0**	**22.6**	**23.3**	**1577.2**	**1642.9**	**35661.7**	**38276.7**	**24661.7**	**27276.7**
RHPU1g	**11150.0**	**25.0**	**25.8**	**1633.3**	**1674.7**	**40758.7**	**43245.1**	**29608.7**	**32095.1**
RHP3g	**11000.0**	**24.0**	**25.0**	**1577.0**	**1608.5**	**37829.8**	**40161.9**	**26829.8**	**29161.9**
RHPU3g	**11150.0**	**25.9**	**26.8**	**1540.7**	**1602.4**	**39851.8**	**42934.2**	**28701.8**	**31784.2**

RHP: rice husk superabsorbent conditioner , RHPU: rice husk loading with urea superabsorbent.

CONCLUSIONS

It can be concluded that the application of superabsorbent conditioners based on rice husk loaded with urea (RHPU) yielded better results for plant growth characteristics and increased the productive yield under drought stress than at non-stress, as well as the best values of economic returns, especially in the first season. It can be used as a soil conditioner for the sustained and controlled release of water and nutrients or as a slow-release fertilizer to the sugar beet crop in arid and desert environments. Also, it can be concluded that the Dina variety is broadly adapted to all environmental conditions.

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التأثير المشترك للمتراكبات فائقة الامتصاص واجهاد نقص الماء على الصفات الإنتاجية لبعض أصناف بنجر السكر

وفاء ابراهيم جراد[١]، محمد سعيد القاضى[٢]، الرفاعى قناوى[٣] و منى ابراهيم مسعود[٢]

١. قسم التربية والوراثة, معهد بحوث المحاصيل السكرية, مركز البحوث الزراعية، الإسكندرية، مصر

٢. قسم بحوث الفسيولوجى والكيمياء, معهد بحوث المحاصيل السكرية، مركز البحوث الزراعية، الجيزة، مصر

٣. قسم الكيمياء، كلية العلوم، جامعة طنطا، مصر

تستخدم المتراكبات من البوليمرات فائقة الامتصاص المعتمدة على قش الأرز (RHP) والمحملة باليوريا (RHPU) كمحسنات للتربة لإستدامة إنتاج محصول بنجر السكر فى الأراضى القاحلة. أجريت التجربة الحقلية في منطقة وادي النطرون، مصر (خط الطول ٣٠° ١٣' شرقاً، خط العرض ٣٠° ٢٥' شمالاً) وتم استخدام تصميم القطع المنشقة مرتين بتوزيع القطاعات الكاملة العشوائية فى ثلاث مكررات لدراسة التأثير المشترك RHP وRHPU (٠ جم ، ١ جم، ٣ جم)، بالإضافة إلى قش الأرز (٣ جم) كمعاملة قياسية موجبة مع ثلاث مستويات من الاجهاد المائى (100%، 80%، 60%) باستخدام نظام الري بالتنقيط على بعض الصفات الفسيولوجية والانتاجية وصفات الجودة لخمسة أصناف من محصول بنجر السكر خلال الموسمين ٢٠٢٠/٢٠٢١ و ٢٠٢١/٢٠٢٢. أوضحت النتائج أن المتراكبات RHPU سجلت أعلى قيم فى كلا من مؤشر المساحة الورقية و صافى التمثيل الغذائى ومعدل النمو النسبي ووزن الجذر بعد ١٢٠ يوماً من الزراعة مقارنة بالمتراكب RHP والمعاملات القياسية (الكنترول) عند ١٢٠ يوماً من الزراعة. كذلك اظهرت RHPU تأثير إيجابي على زيادة إنتاجية جذورالمحصول عند معدلات الرى ٨٠% و ٦٠%. فى حين المتراكب RHPU (ا جم) لم يؤثر معنويا على إنتاجية محصول السكر بالمقارنة بالمعاملات القياسية. كما أوضحت نتائج التفاعل بين ٣جم RHPU + معدل الرى ٦٠% تأثير إيجابي معنوي على بعض الصفات الفسيولوجية وإنتاجية محصول الجذور مقارنة بالمعاملة القياسية عند الرى (١٠٠%). كذلك لم توجد فروق معنوية بين قيم إنتاجية المحصول في التفاعلات بين ١ جم RHPU + معدل الرى ٦٠% مع الصنف Dina مقارنة بالتفاعل بين ٣جم RHPU + معدل الرى ١٠٠% للصنف Panther. أوضحت نتائج معامل التلازم ايضا وجود إرتباط معنوى موجب بين صفات النمو والإنتاجية للمحصول وليست بين صفات الجودة. نستنتج من ذلك أن تطبيق RHP المحمل باليوريا (٠,٥ :٠,٥) يؤدى إلى تحسين صفات النمو والإنتاجية مع تحقيق عائد اقتصادى لمحصول بنجر السكر في الأراضي المستصلحة حديثا.

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