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TOWARDS SUSTAINABLE IRRIGATION WATER BY USING DIFFERENT POLYMER RATES WITH DEFICIT IRRIGATION LEVELS: CASE STUDY IN EGYPT

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ABSTRACT

The concern of water scarcity and its high usage in agriculture has become a pressing issue. To address this issue, new techniques and ideas must be implemented to conserve water in agricultural production systems. One method that can be used to conserve water is the application of soil conditions management. An experiment was conducted to study the effect of different deficit irrigation regimes and levels of polymers and nitrogen on water use efficiency (WUE), nitrogen use efficiency (NUE), yield, yield components, and sugar beet cultivars' physiology. The study was carried out on sandy soil using a drip irrigation system, and it was designed in a split-plot format. The experiment included 15 treatments, which consisted of three deficit irrigation levels and five polymer treatments per level: P1 (control), P2 (30 kg/fed polymer), P3 (30 kg/fed polymer and 30 kg/fed nitrogen), P4 (60 kg/fed polymer), and P3 (60 kg/fed polymer and 60 kg/fed nitrogen) with three replicates. The results showed that the highest values of WUE were achieved in both seasons when using 70% deficit irrigation with polymer treatments P2, P3, and P5. Additionally, the second season with 85% deficit irrigation with polymer treatments P2, P3, and P5 also had a similar effect on WUE values. The highest values of WUE and NUE were achieved when using 70% deficit irrigation with polymer treatment P5 in the second season. These values were 14.3 and 293.6 kg/m^3 for WUE and NUE, respectively. The use of deficit irrigation, polymers, and nitrogen had a positive impact on the water and nitrogen use efficiency of sugar beet cultivars, which ultimately led to an increase in yield and overall productivity. However, further research is needed to fully understand the limitations and implications of these techniques. It is also important to consider the economic and environmental costs and benefits of these methods before implementing them on a larger scale.

Key Words: Polymer, nitrogen use efficiency, water use efficiency, sugar beet, yield, deficit irrigation.

INTRODUCTION

Global warming is likely to increase irrigation water requirements, **(El-Fakharany and Salem 2021)**. Egypt is currently facing a significant water shortage, with an estimated 13.5 billion cubic meters per year (BCM/yr) and this is expected to continue to increase, as reported by **Omar and Mousa (2016)**. One of the main challenges Egypt faces is population growth and the resulting increase in agricultural water demand, as highlighted by **Satoh and Aboulroos (2017)**. To meet the food demands of the growing population, more desert lands must be cultivated, but sandy soils have poor soil-water-plant relationships. To address this issue, studies have shown that soil conditioners can be an effective technique for improving sandy soil for cultivation. These soil conditioners, such as polymers, can reduce evaporation, increase moisture storage below the roots, and improve the soil's water-holding capacity by up to 85% for sand **(Ghooshchi *et al.*, 2008)**.

Sugar beet (*Beta vulgaris*) is globally recognized as one of the most important crops for producing sugar (**Esmaeil *et al.*, 2020**). Its significance extends beyond sugar production as it is crucial for sustainability in field crop production systems, with root yield and sugar content being key economic parameters (**Wang *et al.*, 2019**). Sugar beet cultivation is widespread due to its adaptability to various climatic conditions and soil types (**Liu *et al.*, 2020**). In Egypt, sugar cane and sugar beet crops are essential to the sugar industry, with sugar beet contributing to over 60% of total sugar production (**Sugar Crops Council Report, 2022**). This highlights the strategic importance of sugar beet in meeting global sugar demands, especially under new soil conditions. However, climate change has significantly impacted the production process of sugar beet and other field crops (**Curcic *et al.*, 2018**). Drought is one of the most important limiting factors affecting sugar beet harvest (**Hosseini *et al.*, 2019**) and the drought consequences may be increased due to climate change (**Gornall *et al.*, 2010**). High temperatures and salinity magnify the development of water deficits when the level of transpiration is higher than water absorption (**Hajheidari *et al.*, 2005**). The resulting water deficit in sugar beet reduces the water potential and relative water content of the leaves, leading to decreased leaf and root growth rates (**Milford *et al.*, 1985**). Additionally, drought stress affects the accumulation of sucrose in storage organs (**Hoffmann, 2010**). Therefore, great efforts have been made to reduce the effect of drought stress on crop yield and quality, especially in regions with less water availability such as most of the Middle East and Africa (**Borišev *et al.*, 2016**). **Paˇcuta *et al.* (2021)** conducted a study to investigate the impact of superabsorbent polymers on leaf area index (LAI), root yield, and white sugar yields in sugar beet plants. The results revealed that the application of superabsorbent polymers significantly affected these parameters, leading to an increase in LAI and root and white sugar yields. However, the sugar content difference between the superabsorbent polymer-treated plants and the control group was not statistically significant.

Similarly, **El-Karamany *et al.*, (2015)** reported that treating sugar beet plants with a watering hydrogel for 48 hours at 90 days after planting (DAS) led to higher fresh biological, fresh shoot, and fresh root yields per plant, as well as larger leaf area. Additionally, watering the plants with hydrogel for 48 hours just before harvest resulted in significantly higher fresh biological yield, fresh shoot weight, and fresh root yield compared to other treatments. Moreover, the treatment with watering hydrogel for 48 hours also resulted in higher impurities and better quality of sugar beet roots due to their technological characteristics. The use of hydrogel for 48 hours also improved the efficiency of fertilizer use, leading to higher nitrogen use efficiency by sugar plants, as indicated by the higher yields of roots compared to the control treatment. The study also examined the amount of irrigation water needed to produce 1 kg of sugar beet yield on sandy soil. The results showed that treating the plants with hydrogel for 48 hours reduced the amount of irrigation water required to produce fresh bio-yield, fresh shoot yield, and fresh root yield by 7.4%, 18.5%, and 25.9%, respectively. Similarly, the amount of irrigation water required to produce fresh bio-yield decreased by 12.1%, 21.2%, and 30% and fresh shoot yield by 9.1%, 18.2%, and 27.3%. In conclusion, the application of superabsorbent polymers and hydrogels can significantly improve the yield and quality of sugar beet plants. The use of hydrogels for 48 hours at specific growth stages can increase fresh biological, fresh shoot, and fresh root yields, LAI, and the efficiency of fertilizer use. Additionally, it can lead to a reduction in the amount of irrigation water needed to produce sugar beet yields. These findings provide valuable insights into sustainable agricultural practices that can reduce water consumption and improve crop productivity.

Effective water management is critical for stable agriculture in various regions, and a variety of technologies are used to achieve this. Soil conditioners and deficit irrigation are considered to be effective strategies for water management due to their properties. Polymer powder is one example of a soil conditioner that is added to the soil and absorbs water. When irrigated, the polymer absorbs the water and transforms it into a gel, which can improve seed germination and emergence, as well as increase yield and fruit output by up to 70% while increasing fertilizer efficiency.

To improve agricultural productivity and soil fertility, various soil conditioners, such as natural and synthetic materials, can be used for soil reclamation. These materials, such as animal manure, crop residues, organic compost, sawdust, and other materials, can be applied to the soil surface or around seedling roots during planting time to improve the physical properties of the soil. These materials can increase infiltration and retention, improve aeration, and reduce soil strength, which is particularly important for improving the crop-growing potential of sandy soils (**Akelah, 2013**). When these absorbent materials are mixed with sandy soil, the soil's capacity to store water is increased, allowing plants to use the stored water for a longer period. Furthermore, soil conditioning can result in favorable changes in soil porosity and improve the germination process, plant growth, nutrient uptake by plants, and water use efficiency (**El-Hady and Abo-Sedera 2006**).

According to **Abobatta (2018),** hydrogels can improve water efficiency in plants by reducing irrigation costs and increasing irrigation intervals, as well as enhancing water retention in the soil. **Ni *et al.*, (2009)** also found that the application of hydrogel can reduce the need for fertilization by preventing nutrient leaching and increasing water consumption efficiency.

El-Gindy *et al.*, (2001) discovered that the addition of soil conditioners, particularly polymers, can improve the water-holding capacity of sandy soil by enhancing soil structure and water retention, leading to decreased leaching and water losses, and increased availability of nutrients and water to the roots. Similarly, **Zhang *et al.*, (2017)** found that polymers can renovate sandy soil, reduce irrigation water consumption, enhance fertilizer retention, and increase plant growth rate. **Albalasmeh *et al.*, (2022)** reported that hydrogel in soil improved soil available water by 49%, and increased water use efficiency from 13% to 41% for sandy soil and from 35% to 67% for silty clay loam soil. Previous studies suggested that soil amendments, including polymers, and conservation tillage can mitigate soil degradation and improve soil water holding capacity in arid and semi-arid regions (**Berek, 2014 ; Xu *et al.*, 2018**). **Zeineldin and Al-Molhim (2021)** found that adding 0.4% polymer enhanced the field water holding capacity of medium sandy soil by 43.6% and improved water use efficiency and fruit yield by 67.7% and 70.4%, respectively, under subsurface drip irrigation, and by 58.6% and 24.2%, respectively, under drip irrigation. With water scarcity expected to continue in irrigated agriculture, the focus is shifting from maximizing production per unit area to maximizing production per unit of water consumed. To achieve this, different water-saving technologies such as deficit irrigation (DI) and regulated deficit irrigation (RDI) are being developed and applied to save water and increase water use efficiency in crops under semi-arid conditions. Deficit irrigation is a strategy that involves applying less than the full crop water requirement (**Al-Solaimani *et al.*, 2017**).

In response to the need to maximize production per unit of water consumed in irrigated agriculture, water-saving technologies like deficit irrigation and regulated deficit irrigation has been developed and implemented in semi-arid regions to save water and increase water use efficiency in crops. According to **Kirda (2002)** and **Moursy *et al.*, (2019)**, water deficit stress or low irrigation can increase water use efficiency and yield per unit of applied water. Under surface drip irrigation, **Gaafar *et al.*, (2014)** found that deficit irrigation led to yield reductions of 11.1%, 5.3%, and 9.7% for seed, oil, and straw yields, respectively, while under subsurface drip irrigation, the reductions were 10.2%, 10.8%, and 9.1%. **Masri *et al.*, (2015)** reported that drip-irrigated sugar beet with 75% of irrigation water requirements had the highest significant leaf area index, sucrose%, purity%, and extractable sugar%. **Abd El-All and Makhlouf (2017)** found that watering at 75% ETc resulted in significant increases in sucrose and extractable sugar. Deficit irrigation increased water use efficiency by 28.54%, 40.98%, and 68.93% at 100%, 80%, and 60% of ETc, respectively, as found by **Alkhasha *et al.*, (2019)**. Moreover, **Moursy *et al.*, (2015)** demonstrated that net return/m3 under deficit irrigation was higher than without deficit irrigation.

This research aims to study the effect of deficit irrigation regimes and levels of polymers and nitrogen on water use efficiency, nitrogen use efficiency, yield, yield components and the physiological of sugar beet cultivars. Water productivity for the assessed sugar beet under a drip irrigation system on sandy soil was investigated.

MATERIALS AND METHODS

The research describes an experiment that was conducted at the Wadi El-Natroon Research Station, Water Management Research Institute and National Water Research Center in Egypt. The soil type was sandy, with 1.8% clay, 3.2% silt and 95% sand. The soil bulk density was 1.56 g/m^3, with a field capacity of 9.1% and a wilting point of 5.9%. The source of irrigation water was an artesian well with a pH of 7.14 and EC 1150 PPM. The experiment was set up in a split plot design with 15 treatments and three replicates. Each plot consisted of five rows with a length of 25 m and a distance of 70 cm between rows and 25 cm distance between plants. The dimension of each plot was 25 x 3.5m and the distance between each plot was 1m. The main plot of the experiment was water regimes (100%, 85%, and 70% of the amount of water applied). While the subplot was the polymer rate [P1, “control”, P2, “powder polymer with 30kg/fed (1gm/plant)”, P3 “powder polymer and N fertilizer with 30+30kg/fed (1+1gm/plant)”, P4, “powder polymer with 60kg/fed (2gm/plant)” and P5, “powder polymer and N fertilizer with 60+60kg/fed. (2+2gm/plant)”]. The sugar beet crop (*mono-germ 4 K 521 variety*) was sown manually on 3rd Oct and harvested on 15th April in both seasons with 30,000 plant/fed. The source of nitrogen was ammonium nitrate (33.5 % N). Super phosphate (15.5 % P_2O_5) was added at the rate of 100 kg/fed before plowing and potassium sulphate (48 % K_2O) was added at the rate of 50 kg/fed. The irrigation system consisted of a 50 Hp centrifugal pump, screen filter, control unit, 110mm main line, 90 and 75mm sup main line, 40mm manifold, and 180 laterals with 25m length on an area of around 0.448 ha. Dripper's lines consist of polyethene with a diameter of 16 mm, GR drippers with 4 l/h discharge, and 25cm between dripper to another as shown in Figure 1 and 2.

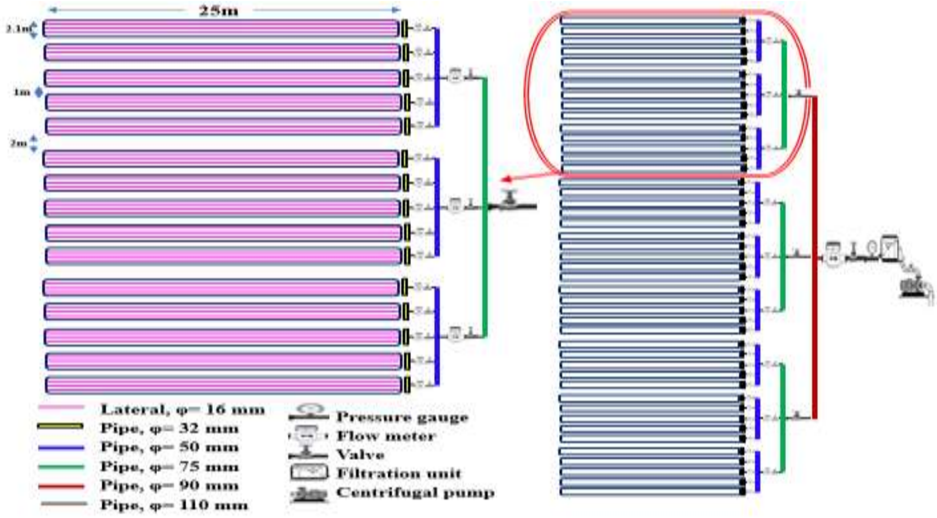

Figure 1: Drip irrigation system components.

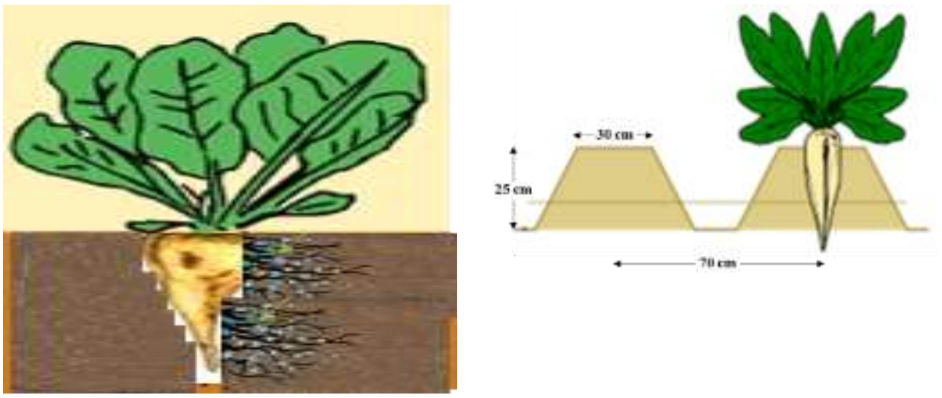

Figure 2: Root zoon absorbed water by polymer and the diagram of furrow.

A dielectric sensor, the Delta Devices model Profile Prob-PR2 (England), was used to determine the moisture content of the plots. The plots were regularly watered when the soil moisture reached 50% and 60% at the initial and later stages, respectively. The amount of water applied was calculated according to **Israelsen and Hansen (1962)**. Water Use Efficiency (WUE), which is the relationship between crop production and the amount of water used, was determined using the equation provided by **Ali and Talukder (2008),** WUE = Yield/Water applied to the field.

Root yield was measured at the physiological stage of the leaves. The harvested area for each plot was 3.5 x 3m, and the root yield of all plots was weighed and recorded separately. To measure the yield components and technology, 10 plants were randomly selected from the middle of each plot. Cost analysis was performed, and the prices of inputs and outputs were calculated for different treatments for the sugar beet crop during the experiments. After 120 days from planting, the leaf area index (LAI) was calculated using the formula: LAI = LA (total leaf area in cm^2) / P (land area in cm^2). During harvest, ten sugar beet roots were randomly collected from each plot to determine the following:

1. Sucrose percentage was measured in fresh minced roots using the "Saccharometer" method described by **Carruthers and Oldfield (1960)**.
2. Extractable sugar percentage (ES%) was calculated using the formula: ES% = Pol - [0.343(K + Na) + 0.094 α-amino N + 0.29], as outlined by **Reinefeld *et al.*, (1974),** where Pol refers to sucrose percentage. Harvesting was carried out in April, where sugar beets from each plot were manually uprooted, topped, weighed in kilograms, and then converted to Mg/fed to determine root yield/fed. Sugar yield/fed (Mg) was computed using the following formula:

Sugar yield/fed (Mg) = root yield/fed (Mg) × (extractable sugar %)

Data analysis was conducted using the statistical software **SPSS** (Release version 18). The least significant difference (LSD) of Duncan's test was used to determine the statistically significant differences between average groups in the ANOVA. The probability levels less than 0.05 as significant.

RESULTS AND DISCUSSION

Figure 3 illustrates the relationship between water use efficiency (WUE) and the amount of applied water, added polymer rates 1 and 2 gm (polymer treatments P2 and P4), added polymer with nitrogen rates 1 and 1 gm respectively (polymer treatment P3), added polymer with nitrogen rates 2 and 2 gm respectively (polymer treatment P5). These treatments were depicted based on nitrogen use efficiency (NUE) values. The data from this figure shows that the highest values of WUE (more than 10 kg/m^3) was achieved in both the first and second seasons when 70% of water requirements were used with polymer treatments P4, P3 and P5. Additionally, the second season with 70% of water requirements with polymer treatment P2 also had more than 10 kg/m^3 of WUE. Furthermore, the second season with 85% of water requirements with polymer treatments P3, P4 and P5 had similar effects on WUE values. On the other hand, the lowest values of WUE (< 7.79 kg/m^3) were observed in both seasons with 70% and 85% of water requirements.

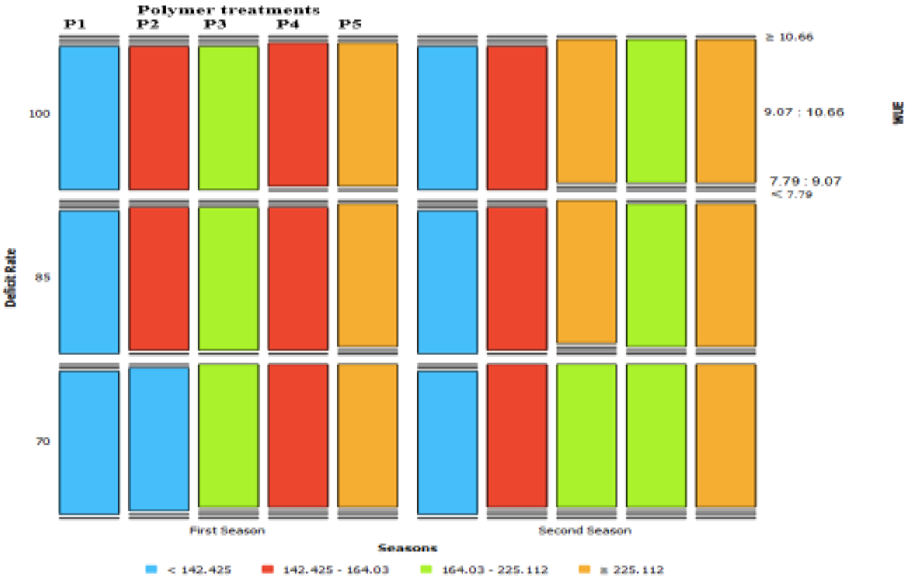

Figure 3: Effect of different deficit rates with different added polymer and nitrogen values for the two seasons.

The relationship between water use efficiency (WUE), nitrogen use efficiency (NUE), and the amount of applied water, based on deficit water rates, is illustrated in Figure 4. The highest values of WUE and NUE were achieved when 70% deficit water was used with polymer treatment P5 in the second season, with values of 14.3 and 293.6 kg/m^3 for WUE and NUE, respectively. The lowest value of WUE was 5.9 kg/m^3 in the first season with 100% deficit and the control treatment. Additionally, the lowest value of NUE was 128.33 in the first season when 85% of water was used. The figure uses colours to indicate the deficit water rates, shapes to represent the treatments, and sizes to represent the NUE values.

Water is a crucial factor that significantly affects the growth and performance of plants, particularly in terms of biotic processes such as photosynthesis, dry matter accumulation, and translocation. This finding is consistent with the results obtained by **Goodman, (1968)**, who indicated that the size and lifespan of sugar beet leaf canopies are strongly influenced by soil moisture and fertility.

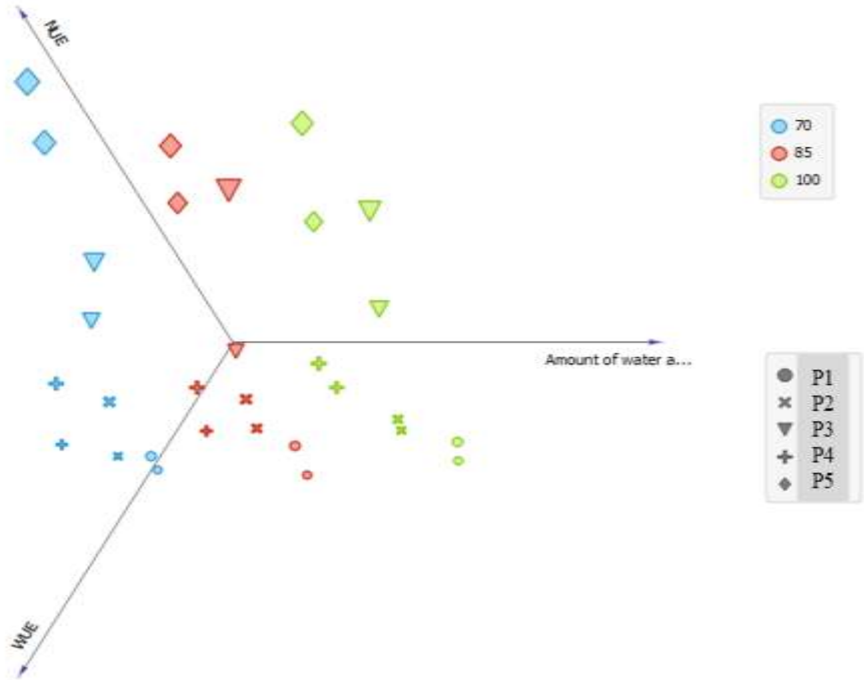

Figure 4: The relation between WUE, NUE and the amount applied water.

Data shows in ***Table 1*** for the first and second seasons, it was found that the application of Deficit irrigation did not result in a significant increase on sucrose. However, when polymer was used, there was a significant effect on sucrose. Additionally, using deficit irrigation in combination with polymer resulted in no significant change.

Table 1: Sucrose percentage under different treatments in the 1st and 2nd seasons.

Polymer / Deficit	1st season					Mean	2nd season					Mean
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5	
70	19.12	16.69	17.4	15.52	16.1	16.97	21.96	18.2	18.52	17.31	17.53	18.70
85	19.93	15.79	15.63	16.5	17.11	16.99	22.84	17.16	18.56	16.67	17.88	18.62
100	18.48	16.17	16.62	16.74	16.34	16.87	21.91	17.07	17.03	17.53	16.97	18.10
Means	19.18	16.22	16.55	16.25	16.52	16.94	22.24	17.48	18.04	17.17	17.46	18.48
L.S.D. 0.05												
Deficit irrigation		N.S						N.S				
Polymer rate		S						S				
Deficit * polymer		N.S						N.S				

In Table 2, it was found in 1st season that the application of deficit irrigation did not result in a significant increase in the percentage of extracted sugar. However, when polymer was used, there was a significant effect on the extracted sugar percentage. Additionally, using deficit irrigation in combination with polymer resulted in no significant change. The highest value of extracted sugar was seen when using only deficit irrigation with 70% water requirements, at 14.56%. In contrast, the lowest value of extracted sugar was obtained under polymer treatment P3 were used in conjunction with deficit irrigation and 85% water requirements, at 13.02%. This resulted in a decrease of 9.5%. The average of deficit irrigation treatments was 14.39%, and the average of deficit irrigation treatments with different polymer and nitrogen treatments was the same. In 2nd season that the application of deficit irrigation did not result in a significant increase in the percentage of extracted sugar. However, when polymer was used, there was a significant effect on the extracted sugar percentage. Additionally, using deficit irrigation in combination with polymer resulted in no significant change. The highest value of extracted sugar was seen when using only deficit irrigation with 85% water requirements, at 20.50%. In contrast, the lowest value of extracted sugar was obtained under polymer treatment P5, were used in conjunction with deficit irrigation and 100% water requirements, at 13.33%. This resulted in a decrease of 7.17%. The average of deficit irrigation treatments was 15.47%, and the average of deficit irrigation treatments with different polymer and nitrogen treatments was the same.

The observed outcomes can be attributed to the fact that the gel treatment had the highest water absorption capacity, leading to greater soil moisture in the root zone. Conversely, the control treatment, which had a lower quantity of water, resulted in reduced crop growth rates, leading to lower root yield. Meanwhile, sucrose concentration increased in the root cells as a result of leaching caused by reduced root water content due to decreased water supply, leading to higher sucrose percentage (**El-Karamany *et al.*, 2015**).

Table 2: Extracted sugar percentage values in the 1st and 2nd seasons

Polymer / Deficit	1st season					Mean	2nd season					Mean
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5	
70	16.79	14.50	14.80	13.32	13.38	14.56	19.67	15.39	15.32	14.33	14.29	15.80
85	17.54	13.32	13.02	13.74	14.22	14.37	20.50	14.25	15.13	13.59	14.45	15.58
100	16.18	13.59	14.00	14.02	13.42	14.24	19.14	14.18	13.87	14.55	13.33	15.02
Means	16.84	13.80	13.94	13.69	13.68	14.39	19.77	14.61	14.77	14.15	14.02	15.47
L.S.D. 0.05												
Deficit irrigation	N.S						N.S					
Polymer rate	S						S					
Deficit * polymer	N.S						N.S					

In Table 3, it was found that the application of deficit irrigation did not result in a significant change in root yield. However, the use of polymers had a significant impact on root yield. Additionally, combining deficit irrigation with polymer resulted in no significant change. The highest root yield in 1st season was observed when deficit irrigation at 70% water requirements was combined with polymer treatment P5, yielding 23.47 Mg/fed. In contrast, the lowest root yield was obtained when only deficit irrigation at 85% water requirements was applied, yielding 17.20 Mg/fed. This resulted in an increase of 6.28 Mg/fed. The mean of only deficit irrigation treatments was 19.81 Mg/fed., and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value. In 2nd season, it was found that the application of deficit irrigation did not result in a significant change in root yield. However, the use of polymers had a significant impact on root yield. Additionally, combining deficit irrigation with polymer resulted in no significant change. The highest root yield was observed when deficit irrigation at 85% water requirements was combined with polymer treatment P3, yielding 26.61 Mg/fed. In contrast, the lowest root yield was obtained when only deficit irrigation as a control treatment with 70% water requirements was applied, yielding 18.37 Mg/fed. This resulted in an increase of 8.24 Mg/fed. The mean of only deficit irrigation treatments was 22.29 Mg/fed., and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value. The rise in root yield observed with high soil moisture and fertility levels under different polymer treatments may have been due to an increase in the number of harvested roots and individual root weight. Soil fertility plays a significant role in stimulating meristematic growth activity, leading to an increase in the number of cells as well as cell enlargement. These findings align with those reported by **El-Sarag (2009), Mahmoud *et al.*, (2014), and Masri *et al.*, (2015).**

Table 3: Root yield values in the 1st and 2nd seasons

Polymer / Deficit	1st season					Mean	2nd season					Mean
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5	
70	17.24	18.74	20.75	19.27	23.47	19.90	18.37	21.57	23.35	22.49	25.57	22.27
85	17.20	19.93	19.42	19.86	21.13	19.51	18.90	21.31	26.61	22.09	23.14	22.41
100	17.42	19.40	21.18	21.87	20.24	20.02	18.52	20.17	25.11	23.36	23.71	22.17
Means	17.29	19.36	20.45	20.33	21.61	19.81	18.60	21.02	25.03	22.64	24.14	22.29
L.S.D. 0.05												
Deficit irrigation		N.S						N.S				
Polymer rate		S						S				
Deficit * polymer		N.S						N.S				

Results indicated that there was a non-significant result in sugar yield, either when using deficit irrigation or polymer treatments or in combination as shown in Table 4. In the 1st season the highest value of sugar yield was observed when deficit irrigation with 70% of water requirements was integrated with polymer treatment P5, at 3.14 Mg/fed. In contrast, the lowest value of sugar yield was obtained when deficit irrigation with 85% of water requirements was integrated with polymer treatment P3, at 2.54 Mg/fed. This resulted in an increase of 0.6 Mg/fed. The mean of only deficit irrigation treatments was 2.84 Mg/fed, and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value.

While in the 2nd season, it was found that when deficit irrigation was applied, there was no significant result in sugar yield. However, when polymer was used, there was a significant effect on sugar yield. Additionally, using deficit irrigation with polymer resulted in a non-significant outcome. The highest value of sugar yield was observed when deficit irrigation with 85% of water requirements was integrated polymer treatment P3, at 4.03 Mg/fed. In contrast, the lowest value of sugar yield was obtained when deficit irrigation with 100% of water requirements with polymer treatment P2 was applied, at 2.87 Mg/fed. This resulted in an increase of 1.17 Mg/fed. The mean of only deficit irrigation treatments was 3.41 Mg/fed, and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value. Based on the data, it is evident that the use of polymers has a significant impact on increasing sugar yield (**Paˇcuta *et al.,* 2021**).

Table 4: Sugar yield values in the 1st and 2nd seasons

Polymer / Deficit	1st season					Mean	2nd season					Mean
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5	
70	2.85	2.71	3.09	2.58	3.14	2.87	3.60	3.32	3.57	3.22	3.66	3.47
85	3.03	2.66	2.54	2.73	3.01	2.79	3.87	3.04	4.03	3.00	3.35	3.46
100	2.81	2.64	2.96	3.07	2.72	2.84	3.55	2.87	3.49	3.40	3.17	3.29
Means	2.90	2.67	2.86	2.79	2.96	2.84	3.67	3.07	3.70	3.21	3.39	3.41
L.S.D. 0.05												
Deficit irrigation		N.S						N.S				
Polymer rate		N.S						S				
Deficit * polymer		N.S						N.S				

In Table 5, the results of the first season showed that when deficit irrigation was applied alone, there was no significant effect on the leave area indicator (LAI) 120 days after planting. The use of polymer had a significant effect on LAI, however, the use of deficit irrigation in conjunction with polymer produced in a non-significant outcome. The highest value of LAI was observed when deficit irrigation with 85% water requirements was integrated with polymer treatment P5, at 6.64. In contrast, the lowest value of LAI was obtained when only deficit irrigation with 70% water requirements was applied as a control treatment, at 3.38. This resulted in an increase of 3.26. The mean of only deficit irrigation treatments was 5.29, and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value.

The second season as illustrated in Table 5 gave similar results to those of the first season. The highest value of LAI was observed when deficit irrigation with 70% water requirements was integrated with polymer treatment P5, at 6.87. In contrast, the lowest value of LAI was obtained when only deficit irrigation with 70% water requirements was applied as a control treatment, at 3.14. This resulted in an increase of 3.72. The mean of only deficit irrigation treatments was 5.48, and the mean of deficit irrigation with different polymer and nitrogen treatments was the same value.

Overall, the results from Tables 5 indicate that while using deficit irrigation alone did not have a significant effect on LAI, the addition of polymer significantly improved LAI. However, using both the deficit irrigation and the polymer together did not produce a significant difference. The highest values of LAI were observed when deficit irrigation was combined with a specific amount of polymer and nitrogen, with the highest value being 6.87 in the second season. The lowest values of LAI were obtained when only deficit irrigation with 70% water requirements was used as a control treatment, resulting in an increase of 3.72 in the second season. The average deficit irrigation treatments were only about 5.29 and 5.48 for the first and second seasons, respectively. It was also found that the average deficit irrigation with polymer and nitrogen treatments was similar. **Kim *et al.*, (2017)** reported that plant growth and CO_2 absorption are largely limited by drought, and the leaf area index (LAI) can be used to evaluate this response. Similarly, **Wiegand *et al.*, (1983)** found that drought and its effects on plant growth and development can be assessed using LAI. **El-Kady *et al.*, (2019)** also reported a similar trend, where increasing irrigation water requirements led to significant increases in LAI of sugar beet plants. **Moursy and El-Kady (2019)** further supported these findings by detecting significant increases in LAI of sugar beet plants as irrigation water requirements increased.

Table 5: Leave area indicator after 120 days (LAI) for the 1st and 2nd seasons

Polymer / Deficit	1st season					Mean	2nd season					Mean
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5	
70	3.38	4.75	6.11	5.84	6.38	5.29	3.14	4.56	6.74	5.53	6.87	5.37
85	4.07	4.86	5.75	5.29	6.64	5.32	3.76	4.69	6.03	5.84	7.06	5.48
100	3.63	4.96	5.45	5.75	6.53	5.26	3.76	5.19	6.46	6.02	6.61	5.61
Means	3.69	4.85	5.77	5.62	6.52	5.29	3.55	4.81	6.41	5.80	6.84	5.48
L.S.D. 0.05												
Deficit irrigation	N.S							N.S				
Polymer rate	S							S				
Deficit * polymer	N.S							N.S				

CONCLUSION

The use of soil conditions in the management of agricultural production systems can play a vital role in addressing the issue of water scarcity and the consumption of most water resources by agriculture. The present study was carried out in a split-plot design with 15 treatments, including three deficit irrigation levels and five treatments per level.

The use of deficit irrigation, polymers and nitrogen can significantly increase the water and nitrogen use efficiency of sugar beet cultivars, leading to an increase in yield and overall productivity. The results showed that the highest values of water use efficiency were achieved when using 70% deficit irrigation with polymer treatment P3, P4, and P5 in both seasons, while the second season with 85% deficit irrigation with polymer treatment P2, P3, and P5 also had a similar effect on WUE values. Furthermore, the highest values of WUE and nitrogen use efficiency were achieved when using 70% deficit irrigation with polymer treatment P5 (60kg polymer and 60 kg nitrogen) in the second season, with values of 14.3 and 293.6 kg/m^3 for WUE and NUE, respectively.

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نحو مياه ري مستدامة باستخدام معدلات بوليمر مختلفة مع مستويات ري ناقص دراسة حالة في مصر

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لقد أصبح القلق من ندرة المياه وزيادة الكميات المستخدمة منها في الزراعة قضية ملحة، ولمعالجة هذه المشكلة يجب تطبيق تقنيات وطرق جديدة لترشيد إستخدام المياه في أنظمة الإنتاج الزراعي. وإحدى هذه الطرق التي يمكن استخدامها لترشيد إستخدام المياه هي تطبيق إدارة المياه والتربة. ولذلك فقد أجريت تجربة لدراسة تأثير إستخدام الرى الناقص مع مستويات البوليمرات والنيتروجين على كفاءة استخدام المياه والإنتاجية لمحصول بنجر السكر. وقد أجريت الدراسة فى تربة رملية باستخدام نظام الري بالتنقيط،وكان التصميم الاحصائي المستخدم هو القطع المنشقه مرة واحده بعدد 3 مكررات لكل معامله.

تضمنت التجربة 15 معاملة تمثلت فى ثلاث مستويات للرى الناقص (70،85،100%) وخمس معاملات من البوليمرات بمعدلات: P1 (بدون بوليمر) ، P2 (30 كجم/فدان بوليمر) ، (P3 30 كجم/فدان بوليمر + 30 كجم نيتروجين) ، P4 (60 كجم/فدان بوليمر) ، P5 (60 كجم/فدان بوليمر + 60 كجم نيتروجين) . وقد أظهرت النتائج أن أعلى قيم لكفاءة إستخدام المياه تم تحقيقها في كلا الموسمين عند استخدام الري الناقص بنسبة 70% مع P2 ،P3 ، P5. بالإضافة إلى ذلك، فإن الموسم الثاني الذي شهد عجزًا في الري بنسبة 85% باستخدام P2 ،P3 ، P5 كان له أيضًا تأثير مماثل على قيم كفاءة إستخدام المياه. وقد تم تحقيق أعلى قيم لكفاءة إستخدام المياه و كفاءة استخدام السماد النيتروجينى عند استخدام الري الناقص 70٪ مع P5 في الموسم الثاني. وكانت هذه القيم 14.3 و293.6 كجم/م^3 لكل من كفاءة إستخدام المياه و كفاءة استخدام السماد النيتروجينى على التوالي. وكان لاستخدام الري الناقص والبوليمرات والنيتروجين تأثير إيجابي على كفاءة استخدام الماء والنيتروجين لمحصول بنجر السكر، مما أدى في النهاية إلى زيادة الإنتاجية والإنتاج الإجمالى. ومع ذلك، هناك حاجة إلى مزيد من البحث لفهم كامل للقيود والآثار المترتبة على هذه التقنيات، ومن المهم أيضًا النظر في التكاليف والفوائد الاقتصادية والبيئية لهذه الأساليب قبل تنفيذها على نطاق أوسع.