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Utilization of hydrogel for reducing water irrigation under sandy soil condition
3- Effect of hydrogel on yield and yield components of sugar beet under sandy soil conditions.

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ABSTRACT

Field experiment was carried out at the Researches and Production Station of National Research Centre (NRC) at Al-Emam Malek village, Al-Nubaria district, Al- Behaira Governorate, Egypt during winter season of 2013/2014 to study effect of hydrogel in three forms (powder – watering gel for 24 hours- watering gel for 48 hours) and control (without hydrogel) on sugar beet variety Baraka. Super absorption hydrogel based on corn starch was produced using ceric ammonium nitrate as initiator for graft copolymerization of acrylonitrile (AN) onto starch at room temperature with ratio 1:1 acrylonitrile to starch for three hours with liquor ratio of 1 starch to 10 water grafted starch was separated by centrifuge follow by saponification in isopropanol at 80 – 85 °C using 0.65 equivalent sodium hydroxyl solution. The obtained hydrogel was dried and milled, the holding capacity reached 450 ml/g hydrogel. Results indicated that there were significant differences between treatments in all studied characters. Treatment of watering hydrogel for 48 hours at 90 DAS produced the highest fresh biological, fresh shoot and fresh root yields per plant also, leaf area and total chlorophyll but recorded the second order in root/shoot ratio. At harvest watering hydrogel for 48 hours treatment significantly surpassed all other treatments in fresh biological yield (33.6 ton) ; fresh shoot weight (8.90 ton/fed.) ; fresh root yield (24.70 ton/fed.) and root diameter (16.40 cm) but control (without hydrogel) recorded the highest root/shoot ratio (75.20) and root length (27 cm). Due to technological characters of sugar beet roots treatment of watering hydrogel for 48 hours recorded the highest impurities (4.58 %) and highest quality (87.03) but recorded the lowest amino N (1.35 %) ; Na (1.14 %) and near the lowest in K (4.06 %). Due to fertilizers use efficiency treatment of watering hydrogel 48 hours raised N,P and K use efficiency by sugar plants to the (36.6 ; 45.9 and 33.5 %) higher than that of control treatment by biological, shoots and roots yields. Irrigation water in (liter) needed to produce (1 kg.) of sugar beet yield grown on sandy soil decrease the amounts of irrigation water by 7.4, 18.5 and 25.9 % for producing the fresh bio-yield 12.1, 21.2 and 30 % for producing the fresh shoots yield 9.1, 18.2 and 27.3 % for producing the fresh roots yield. Economic evaluation is needed for each treatment.

Keywords: hydrogel, sugar beet, sandy soil

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INTRODUCTION

The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability such as most Middle East and African countries. Hydrogels are super absorbents that absorb and store water hundreds of times their own weight, i.e. 400-1500 g water per dry gram of hydrogel (Johnson 1984; Bowman and Evans 1999). Their performance is determined by the chemical properties of the hydrogel, such as molecular weight, formation conditions of hydrogel, as well as the chemical composition of the soil solution or irrigation water. Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake. Commonly used hydrogels can be generally divided into three classes: natural polymers, synthetic hydrogels usually consist of polyacrylamides (PAM) and polyvinyl alcohols. Fully synthetic polymers are chemically cross-linked to prevent them from dissolving in solution (Mikkelsen 1994). The non-cross-linked PAM form is effectively used for soil erosion control, sediment reduction in surface waters and earthen canal bed stabilization (Woodhouse and Johnson 1991).

Callaghan *et al*., (1988, 1989) found that hydrogel amendments in sandy soils promoted seedlings survival and growth under arid conditions, while Viero *et al*., (2000) under similar conditions found only an increase in seedling growth when hydrogel was applied in combination with irrigation. Contrasting results may be related to the soil texture, thus hydrogel application in sandy soil promotes an increase in water retention capacity and plant water potential (Huttermann *et al*., 1999, Abedi-kaoupai and Sohrab 2004) while in loamy and clay soils the effect may be negligible. Jahangir *et al*., 2008 revealed that application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils. Hydrogels have been used to establish tree seedlings and transplants in the arid regions of Africa and Australia to increase plant survival (Specht and Harvey-Jones 2000; Save *et al*., 1995; Callaghan *et al*., 1988, 1989).

Sugar beet (*Beta vulgaris* L.) ranks the second important sugar crop after sugar cane. It produces about 45% of sugar production all over the world. Sugar beet had great importance from its ability to grow in the newly reclaimed soils and lower irrigation requirements under Egyptian conditions as economic crop. The Egyptian Government encourages sugar beet growers to increase the cultivated area in newly reclaimed sandy soils for decreasing the gap between sugar production and consumption (El-Hawary *et al*., 2013) Low water availability is one of the major causes for crop yield reductions affecting the majority of the arable land around the world (Bruce *et al*., 2002 and Ober 2001) as water resources for agronomic uses become more limiting, the development of water use efficiency by roots of sugar beet plant in new reclaimed sandy areas are in importance.

The aim of this study was to determine the effect of using 3 forms of hydrogel as soil conditioner (powder – watering gel 24 hours – watering gel 48 hours) on growth, yield and yield components of sugar beet (Baraka variety) grown under newly reclaimed sandy soil.

MATERIALS AND METHODS

Field experiment was carried out at the Researches and Production Station of National Research Centre NRC at Al-Emam Malek village, Al-Nubaria district, Al- Behaira Governorate, Egypt during winter season of 2013/2014 to study effect of hydrogel in three forms (powder – watering gel for 24 hours- watering gel for 48 hours) and control (without hydrogel) on sugar beet variety Baraka.

In duple jacketed of a capacity 60 litter equipped with condenser, variable speed motor temperature controller adjusted at 30 °C was reactor charged with 4 kg starch slurred in 40 litter water followed by addition of 2 g emulsifier after 10 minutes acrylonitrile (AN) 4 kg added during 20 minutes with continues stirring for three hours. The obtained product was saponified in isopropanol (40 litters) with continues stirring with the addition of 0.65 equivalent sodium hydroxyl tell the color of the product changed from deep brown to yellowish color . The obtained hydrogel was filtered, dried and milled.

Materials used commercial product without purification:

Acrylonitrile (AN), Corn starch, sodium hydroxyl, emulsifier

The experimental treatments were:

Treatment no.1: the control treatment (zero hydrogel).
Treatment no. 2, 3 and 4 conditioned soil with 4 g hydrogel /m^2 soil i.e 16 kg/fed (feddan =fed. = 4200 m^2) applied in three different forms as follows:
Treatment no. 2: the hydrogel was applied to the soil in dry powder form.
Treatment no. 3: the hydrogel was applied in the form of 50 % swelling.
Treatment no. 4: the hydrogel was applied in the form of complete (100 % swelling).

Soil sample was randomly taken from the experimental site at depth of 0-30 cm. the soil is sand in texture more than 85% of particles are >20 micro the main analytical data of the soil are presented in Table (1) (determined by Chapmann, and Pratt, (1978).

Table (1): analytical properties of Al- Nubaria sandy soil.

Sand		silt	Clay	Soil texture
Course >200 µ	Fine >200-20 µ	2-20 µ	< 2 µ	sandy
56.7	34.5	3.7	5.1	

Table (2): Chemical analysis:

pH	EC dS/m	CaCo3 %	O.M %	CECC mol/kg	Macro – nutrients (mg/kg)					
					Total			Available		
					N	P	K	N	P	K
8.0	0.3	1.4	0.3	3.2	260	315	430	8.1	3.2	20

Table (3): Hydro-physical analysis:

Bulk density k gm^{-3}	Total Porosity %	Water holding Capacity %	Field Capacity %	Wilting %	Hydraulic conductivity m day^{-1}	Mean diameter of soil pores µ
1.603	39.47	19.64	8.12	1.31	9.15	18.7

The experiment design was complete randomized block design in four replicates (Gomez and Gomez, 1984). Area of each plot was 42 m^2 (7 rows x 0.6 m width x 10 m length). Ditches 0.6 m in width were done and hydrogel treatments were added in the ditches then covered with soil to make rows. Seeds of Baraka variety was hand seeded in hills 0.30 m between on the third week of October 2013. The soil was immediately irrigated after sowing using sprinkler irrigation system. Plants were thinned to one plant per hill 35 days after sowing (DAS). Fertilizers of NPK were added at the rates of 67 N: 100 P_2O_5: 100 K_2O kg/fed. in the forms of ammonium nitrate 33.5 % N –superphosphate 15.5 % P_2O_5 – potassium sulfate 48 % K_2O. Other cultural practices were done due to those recommended for sugar beet crop usually followed in the region under supervision of Al-Nubaria Company for Sugar Industry according contract between Researches and Production Station of NRC and Al-Nubaria Company for Sugar Industry.

At 90 DAS growth sample was done. Ten plants from central row of each plot were taken and the following characters were determined:-
1- Fresh biological yield (g/plant) 2- Fresh shoot weight (g/plant). 3- Fresh root yield (g/plant).
4- Root/shoot ratio 5- Leaf area (cm^2) and 6- Total chlorophyll in leaves (SPAD) using chlorophyll meter.

At 150 DAS total yield of each plot (42 m^2) was harvested and then the following characters were determined:-

1-Biological yield(ton/fed.) 2- Fresh shoot yield(ton/fed.) 3-Root yield (ton/fed.) 4-Root diameter (cm) 5-Root length(cm) 6- Sucrose % determined by using sacharometer set 7- Amino nitrogen in root juice 8- K% in roots and Na % in roots determined by flame photometer 9- Sugar yield/fed = (root yield X sucrose %).

Statistical analysis:-

The analysis of variance was carried out according to Snedecor and Cochran (1990), least significant differences LSD at probability level of 5 % by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Data presented in Table-4 show the effect of hydrogel treatment on growth characters of sugar beet plants at 90 DAS. It is clear from data in Table-4 that treatment of no. 4 (watering gel for 48 hours) produced the highest fresh biological yield, fresh shoot yield, fresh root yields per plant leaf area and total chlorophyll followed by treatment no. 3 (of watering gel for 24 hours), powder gel came in the third order and control treatment was the fourth.

Table (4): Effect of hydrogel treatments on growth characters of sugar beet at 90 DAS

Character / Treatment	Fresh biological yield (kg/plant)	Fresh shoot weight (kg/plant	Fresh root yield (g/plant)	Root/shoot ratio	Leaf area (cm^2)	Total chlorop hyll (SPAD)
Control 1	0.395	0.165	0.230	1.393	12.22	49
2	0.485	0.245	0.240	0.979	14.95	55
3	0.650	o.325	0.325	1.000	15.35	61
4	0.685	0.340	0.345	1.014	18.10	67
LSD at 0.05	0.088	0.042	0.018	0.010	0.640	0.800

Yield and yield components:-

Data presented in Table 5 show yield and yield components of sugar beet variety Baraka as affected by 3 conditioning the soil with applied hydrogel forms of hydrogel compared to control (without hydrogel). There were significant differences between treatments in all studied characters.

Table (5): Effect of hydrogel forms on yield and yield components of sugar beet at 150 DAS

Character / Treatment	Fresh biological yield (ton/fed)	Fresh shoot weight (ton/fed.)	Fresh root yield (ton/fed.)	Root/ shoot ratio	Root length (cm)	Root diameter(cm)
Control 1	24.60	6.10	18.50	75.20	27	9.20
2	26.70	6.80	19.90	74.53	26	11.30
3	30.10	7.70	22.40	74.41	21	13.20
4	33.60	8.90	24.70	73.51	17	16.40
LSD at 0.05	0.38	0.22	0.34	0.08	0.88	0.76

Table (6): Effect of hydrogel forms on technological characters of sugar beet roots at harvest date (150 DAS).

Character / Treatment	Sucrose (%)	Impurities (%)	Quality	Amino N (%)	Na (%)	K (%)
1	17.00	3.64	85.85	1.75	1.30	4.39
2	16.44	4.15	86.13	1.61	1.38	3.98
3	16.34	4.33	85.37	1.95	1.33	4.26
4	16.96	4.58	87.03	1.35	1.14	4.06

It is clear from data in Tables 5 that treatment no. 4 had superiority in fresh biological, shoot and root yields per feddan (33.60 - 8.90 - 24.70 ton/fed.) followed by treatment no. 3, powder gel and control was the fourth, also, the same trend was recorded in root diameter where, treatment no. 4 was the best and produced roots with diameter 16.40 cm. These results are in harmony with those obtained by Carter *et al*., 1980, Miller and Hang 1980, El-Henawy and El-Hawary 1995, Ramazan *et al*., 2011.

All technological characters were determined by laboratory of Al-Nubaria Company for Sugar Industry. Table 6 show that control treatment surpassed other treatments in sucrose % in roots (17 %), treatment no. 4 produced (16.96 %) which identify 99.7 % from the best treatment, treatment no. 2 recorded (16.44 %) which was 96.7 % from best treatment and treatment no. 3 produced roots contain (16.34 %) which identify 96.1 % from best. Results were in accordance with those obtained by Parashar *et al*., 1976, Parasad and Singh 1983, Ober 2001, Ramazan *et al*., 2011, El-Hawary *et al*., 2013.

Due to a amino N%, Na%, K%, Impurities (%) and quality there were un constant trend, treatment no. 3 recorded the highest a amino N%, powder gel recorded the highest Na%, control (treatment no. 1) recorded the highest K% and the lowest impurities finally the highest quality recorded by treatment no. 4.

It can be concluded that due to growth characters, yield and yield components treatment no. 4 recorded the best characters in all studied characters, these result may be due to the highest water absorption of gel which treatment no. 4 before sowing which resulted in high moisture in root zone of soil but lowest growth, yield and yield components in control treatment may be due to decreasing quantity of water on crop growth rate which led to decreased root yield/fed. On the other hand, sucrose% increased with decreasing water by leaching due to decreasing root water content which led to increase sucrose concentration in root cells.

Fertilizers use efficiency:-

Data of the effect of hydrogel treatments on fertilizers use efficiency by sprinkler irrigated sugar beet grown on sandy soil at AL-Nubaria are given in Table (7) taking into consideration that the values of N, P and K use efficiency reflect the relation between the production and the seasonal amounts of applied fertilizers nutrients in kg $^{-1}$.

Table (7) Effect of hydrogel treatments on fertilizers use efficiency by sprinkler irrigated sugar beet grown on sandy soil at Al- Nubaria (kg kg^{-1}).

No. of treatment	Fertilizer nutrient		
	Nitrogen (N)		
	Fresh biological yield	Fresh shoots yield	Fresh roots yield
1	367.2	91.0	276.1
2	398.5	101.5	297.0
3	449.3	114.9	334.3
4	501.5	132.8	368.7
Phosphorus (P)			
1	562.9	139.6	423.3
2	611.0	155.6	455.4
3	688.8	176.2	512.6
4	768.9	03.7	565.2
Potassium (K)			
1	296.4	73.5	222.9
2	321.7	81.9	239.8
3	362.7	92.8	269.9
4	404.8	107.2	307.6
% of control			
1	100	100	100
2	108.5	111.5	107.6
3	122.4	126.3	121.1
4	136.6	145.9	133.5

Under the conditions of applying the hydrogel as a dry powder form (treatment no. 2) the values of N, P and K use efficiency by the fresh biological yield, the fresh shoots yield and the fresh roots yield were 8.5, 11.5 and 7.6 % over that of the control treatment (non conditioned soil treatment no. 1) relevant values when applying the hydrogel in the soil in the form of 50 % swelling (treatment no. 3) were 22.4, 26.3 and 21.1 % incorporating the hydrogel in the form of complete swelling.

(No. 4 treatment) raised N, P and K use efficiency by sugar beat plants to the 36.6, 45.9 and 33.5 % higher than that of the control treatment by biological, shoots and roots yields, respectively.

Water economy:

Data of the effect of hudrogel treatments on water economy by sprinkler irrigated sugar beat plants grown on sandy soil at Nubaria are given in Table (8) taking into consideration that the values of water economy reflect the relation between the production and the seasonal amounts of applied irrigation water in cubic meters.

Regarding the produced fresh biological yield, values of water economy (kg m^3) were higher than that of the non conditioned soil (treatment no. 1) by 8.5, 22.4 and 36.3 % when applying the hydrogel in dry form), no 3 (applying the hydrogel in the form of 50 % swelling) and no. 4(applying the hydrogel in the form of 100 % swelling), respectively. The same is true for the produced fresh shoots yield where the increase in water economy over that of the control reached 11.5, 26.2 and 45.9 % from the three treatments of applying hydrogel mentioned above, in sequence. Relevant values for producing the fresh roots yield were 7.6, 21.1 and 33.5 %, respectively.

In other words, irrigation water in (L) needed to produce (1 kg) of sugar beat yield grown on sandy soil at Al-Nubaria are given in Table (9). Data show that applying the hydrogel decrease the amounts of irrigation water by 7.4, 18.5 and 25.9 % for producing the fresh biological yield 12.1, 21.2 and 30 % for producing the fresh shoots yield 9.1, 18.2 and 27.3 % for producing the fresh roots yield using the treatments no. 2, 3 and 4, respectively. This means that applying the examined hydrogel under the conditions of the experiment can save more than 30 % of the irrigation water needed to produce sugar beat grown on the sandy area of AL-Nubaria.

Obtained results may be due to that applying the amounts of irrigation water to the conditioned soil with hydrogel in the dry powder form are not enough for complete swelling of the hydrogel. Therefore, applying the hydrogel either in the form of 50 % or 100 % swelling surpassed that of the dry powder form, moreover, producing the hydrogel in swelling form may be more economic where producing the hydrogel in the dry form (draying process) needs ~ 1 dollar kg^{-1} to produce the hydrogel in the form of 50 % swelling and ~ 2 dollars kg^{-1} to produce the dry hydrogel (powder form). On the other hand, applying the hydrogel in swelling forms needs more volumes for packing and more costs for transportation and labors needed to distribute the hydrogel in the soil.

Water requirements for sprinkler irrigation sugar beat grown on sandy soil at Al-Nubaria are given in Table (10). Data show that the seasonal applied irrigation water was 2000 m^3 /fed divided as follows:

1- Initial growing stage (25 days) from 18th of November till 18th of December, 2013, 135 m^3.
2- Crop development stage (35 days) from 13th of November till 18th of December, 2013, 295 m^3.
3- Mid season stage (50 days) from 19th of December, 2013 till 7th of February 2014, 725 m^3.
4- Late season stage (40 days) from 8th of February till 20th of March, 2014 845 m^3.

Table (8): Effect of hydrogel treatment on water economy by sprinkler irrigated sugar beat grown on sandy soil at Al-Nubaria (kg m^{-3}).

Fresh roots yield		Fresh shoots yield		Fresh biological yield		No. of Treatment
% of control	kg m^{-3}	% of control	kg m^{-3}	% of control	kg m^{-3}	
100	9.25	100	3.05	100	12.30	1
107.6	9.95	111.5	3.4	108.5	13.35	2
121.1	11.2	126.2	3.85	122.4	15.05	3
133.5	12.35	145.9	4.45	136.3	16.80	4

Table (9): Effect of hydrogel treatment on irrigation water (L) needed to produce 1 kg of sugar beat yield grown on sandy soil at Al-Nubaria.

Fresh roots yield		Fresh shoots yield		Fresh biological yield		No. of Treatment
% of control	L kg^{-1}	% of control	L kg^{-1}	% of control	L kg^{-1}	
100	110	100	330	100	81	1
90.9	100	87.9	290	92.6	75	2
81.8	90	78.8	260	81.5	66	3
72.7	80	70.0	230	74.1	60	4

Table (10): water requirements for sprinkler irrigated sugar beet grown on sandy soil at Nubaria.

total	Late season			Mid season		Crop development		Initial		Growing stage
	40 days			50 days		35 days		25 days		
	March	February		January	December		November		October	Month
	1-20	8-28	1-7	1-31	19-31	1-18	13-30	1-12	18-31	Period
150	20	20	7	31	12	18	17	12	13	No. of days
	5.8	4.0	4.0	3.0	3.0	3.0	4.0	4.0	5.6	Epan mm day^{-1}
	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	KP
	4.35	3.0	3.0	2.25	2.25	2.25	3.0	3.0	4.2	ET0 mm day^{-1}
	1.0	1.0	1.05	1.05	1.05	0.7	0.7	0.5	0.5	Kc
	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.55	0.5	Kr
	4.35	3.0	3.15	2.35	2.35	1.25	1.65	0.8	1.05	ET crop mm day^{-1}
	1.15 (87 %)									Ks
	1.11 (90 %)									Eu
	10 %									Lr
	6.1	4.2	4.4	3.3	3.3	1.75	2.3	1.1	1.45	Irg mm day^{-1}
	120	80	30	102	39.0	31.5	39.0	13.0	18.8	Mm period
	505	340	130	430	165	130	165	55	80	Irg m^3 /fed
2000	845		725			295		135		

ET0 = reference crop evapotranspiration, Kc = crop coefficient, Kr = reduction factor for the influence of ground cover, Ks= a coefficient for the water storage efficiency of the soil, Eu = application uniformity, Lr = leaching requirements, IRg = gross irrigation requirements

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