Egypt. J. Agron. **Vol. 43**, No. 1, pp. 13-27 (2021)

Egyptian Journal of Agronomy
http://agro.journals.ekb.eg/

Importance of Some Soil Amendments on Improving Growth, Productivity and Quality of Soybean Grown under Different Irrigation Intervals

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EGYPT is currently experiencing water shortage, which causes a threat to crop productivity and efficiency of water use, especially in light of the current climatic changes. A field experiment was done to study effect of irrigation intervals (12, 16 and 20 days), soil amendments (compost, biochar, polyacrylamide "PAM" and hydrogel) beside control and their interaction on root, morpho-physiological, yield and quality traits of soybean.

1- Prolonging irrigation intervals up to 20 days significantly decreased root characters (length and dry weight of root, number and dry weight of nodules/ plant and nitrogenase activity), morphological characters (plant height, leaves number/ plant, leaf area and total dry weight/ plant), physiological traits (relative water content and chlorophyll), yield (pods number/ plant, number and weight of seeds/ pod, 100-seed weight and seed yields/ plant and fed) and quality (protein% and oil and protein yields/fed).

2- Application of soil amendments caused a significant and positive effect on root, morpho-physiological characters as well as yield and seed quality compared to control. Hydrogel application produced the highest values of most abovementioned characters.

3- The interaction revealed that highest values of most characters were obtained when plants were irrigated every 12 days and treated with hydrogel. Plants irrigated every 16 days produced the highest values of root length and oil yield when treated with PAM and hydrogel, respectively.

4- Irrigation every 16 and 20 days can save water amounted to 18.62 and 27.82% compared to irrigation every 12 days, respectively. Irrigation every 16 days associated with hydrogel produced the highest values of water use efficiency (WUE) indicating that it was more effective for productivity and water consumption.

Keywords: Nodulation, Soil amendments, Soybean, Water regimes, WUE, Yield.

Introduction

Soybean (*Glycine max* L. Merrill) is the world's leading source of vegetable oil and its seed contains about 20% oil and 40% protein on a dry weight basis provides approximately 30% of the world's supply of oil. Egypt as one of the countries located in arid to semiarid zone (Darwish et al., 2013), is facing critical water shortage problems. The effect of water scarcity on agriculture has become more serious under the climatic changes, since the agriculture sector consumes about 85% of Egypt's portion of water when compared to other uses. Drought as biotic stress is a major factor limiting for many crop productions in the world. Exposing soybean plants to water stress during growth stages hurt the roots and nodules weight (Hussein et al., 2019), growth traits,

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Received 10/12/2020; Accepted 22/1/2021
DOI: 10.21608/agro.2021.53113.1243

chlorophyll content and relative water content (El-Shafey, 2017), yield and its components (Amiri et al., 2013; Mahmoud et al., 2013) and seed quality (Abd El-Mohsen et al., 2013).

Recently, there are different approaches to alleviate the harmful effect of drought stress by using some soil organic amendments, i.e. compost and biochar as well as superabsorbent polymers, i.e. polyacrylamide (PAM) and hydrogel (carboxymethyl cellulose). The organic amendments contain organic materials produced from recycle agriculture wastes for compost (Meyer-Kohlstoc et al., 2015; Filipovic et al., 2020) and from biomass through pyrolysis in the absence of oxygen for biochar (Wang et al., 2020). These substances improved the physical, chemical and biological characteristics of soils. Moreover, superabsorbent polymers (hydrogel and polyacrylamide "PAM") are compounds that absorb water. PAM (synthetic polymer) and hydrogel (semi-synthetic polymer) are a super high-water retention capacity. Such polymers are cross-linked networks of hydrophilic compound chains. The network can swell in water and hold a large amount of water (Zohuriaan-Mehr & Kabiri, 2008). They increase water retention in soils to find ways to reduce runoff and make water stay in the root zone for crops to use. Once the soil gets dry, the polymers will release the water and slowly bunch up (Rudzinski et al., 2002). Each dry gram of polymer can hold 400-1500 g of water and release 85-95% of the water retained within the granule to growing plants according to its physical and chemical properties (Lather, 2018). The water retention of polymers is high enough to prevent loss through evaporation, but not high to withdrawal the water through the roots. This makes it a magnificent medium for the plants to grow. Synthetic and semi-synthetic polymers are stable in soil with half-life about 3-5 years, and they degrade into ammonium, carbon dioxide and water (Ekebafe et al., 2011).

Therefore, the objective of this study was to evaluate the efficiency of some soil amendments on enhancing nodulation, yield and quality of soybean as well as conserving water under different water regimes.

Materials and Methods

Experimental site and procedures

A field experiment was carried out during the two summer seasons of 2018 and 2019 at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt (latitude 30°31'39''N, longitude 31°04'03''E) to study the effect of some soil amendments on nodulation, morphological and physiological characters as well as yield and quality traits of soybean (Giza 111 cv.) grown under different irrigation intervals. Soil samples of the experimental site were randomly collected from depth 0–30cm before sowing to determine some physical and chemical properties of the soil according to Jackson (1973) and Chapman & Pratt (1978) as given in Table 1.

The experiment included 15 treatments which were the combinations of three irrigation intervals and five soil amendments as follows:

Irrigation intervals

I_1- Irrigation every 12 days (normal irrigation)

I_2- Irrigation every 16 days (moderate drought stress)

I_3- Irrigation every 20 days (severe drought stress).

The time and number of irrigations at each of the tested irrigation interval treatments were noted in Table 2.

Soil amendments

1- Control: Without application.

2- Compost: It applied at a rate of 2ton/fed during soil preparation and mixed with soil at a depth of 10cm from the soil surface.

3- Biochar: It applied at a rate of 1ton /fed during soil preparation and mixed with soil at a depth of 10cm from the soil surface.

TABLE 1. Physical and chemical properties of the experimental soil in the 2018 and 2019 seasons

Seasons	Texture	pH	E.C. (ds/m)	O.M. (%)	Bulk density (g/cm^3)	Field capacity (%)	Permanent wilting point (%)	Available water (%)	Available nutrients (ppm)		
									N	P	K
2018	Clay loam	7.18	0.51	1.75	1.27	39.7	19.6	20.1	35.7	10.4	341.6
2019	Clay loam	7.29	0.48	1.73	1.25	39.3	19.4	19.9	33.2	10.6	338.2

TABLE 2. Time and number of irrigations at each tested irrigation interval treatment

Irrigations No. / Irrigation intervals	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	Total number of irrigations
	Time of irrigation (days after sowing, DAS)									
(I_1) 12 days	12	24	36	48	60	72	84	96	108	**9**
(I_2) 16 days	12	28	44	60	76	92	108	-	-	**7**
(I_3) 20 days	12	32	52	72	92	112	-	-	-	**6**

4- Polyacrylamide (PAM): It broadcasted at sowing time below seeds in the row before seeding at a rate of 4kg/fed.

5- Hydrogel (carboxymethyl cellulose): It broadcasted at sowing time below seeds in the row before seeding at a rate of 4kg/fed.

The physical and chemical properties of soil amendments used in the experiments are shown in Table 3.

The experimental design was a strip plot with three replications. Irrigation intervals were arranged at random in the horizontal plots, whereas soil amendments were assigned at random in the vertical plots.

Crop management

The experimental field was prepared after wheat harvesting. During soil preparation, phosphorus fertilizer was added at the rate of 23.25kg P_2O_5/ fed in the form of calcium superphosphate (15.5% P_2O_5). The area of each experimental plot was 21 m^2, including 7 furrows (5m long and 60cm apart). Seeds of Giza 111 cultivar were sown on April 26th and 24th in the first and second seasons, respectively. At 5 days after irrigation, using the harathi sowing method (sowing dry seeds in a semi wet land), seeds were drilled in one row on top of each furrow at 3cm depth and 5 cm distance between seeds to obtain 140000 plants/fed. The inoculant N_2-fixing bacteria (*Bradyrhizobium japonicum* L.) was added to the seeds before sowing. The inoculant was obtained from the Microbiological Department, Soil, Water, Environ. Research Institute, ARC. Nitrogen fertilizer at a rate of 15kg N/fed, as a starter stimulant dose in the form of ammonium nitrate (33.5 N %) as well as potash fertilizer at a rate 24kg K_2O/ fed in the form of potassium sulfate (48% K_2O) were added to plants prior first irrigation.

Measurements

At 70 days after sowing (DAS), ten plants were randomly uprooted by mattock to estimate root and morpho-physiological characters as following:

Root and nodulation characters

The roots of the plant were cut and dipped in water to remove the soil carefully then washed with distilled water. Root length (cm), root dry weight (g), number and dry weight of nodules /plant and nitrogenase activity (µmole C_2H_4/ g D. wt nodules/ hr) were recorded. Nitrogenase activity was measured chromatography by acetylene reduction assay technique as described by Hardy et al.. (1973) and Somasegaran & Hoben (1985).

Morphological characters

Plant height (cm), numbers of leaves /plant, leaf area/plant (cm^2) and total dry weight /plant (g) were estimated in the shoot of plants.

Physiological characters

Total chlorophyll: It was measured in the leaves with a hand-held chlorophyll meter (SPAD-502, Konica Minolta Company, Japan).

Relative water content (RWC %): Leaves samples of 4th upper leaf/plant were randomly taken to determine relative water content (RWC %) according to the methods described by Barrs (1968) as follows:

$$RWC = \frac{Fw - Dw}{Tw - Dw} X100$$

Leaves fresh weight (FW) was estimated then incubated for 6hrs. in distilled water to obtained leaves turgid weight (TW) and subsequently dried in an oven at 70°C until constant weight to obtained leaves dry weight (DW).

Yield and its components

At maturity (130 and 127 DAS in the first and second seasons, respectively), ten guarded plants were taken randomly to determine the number of pods /plant, number of seeds/pod, 100-seed weight (g) seeds weight /pod (g) and seed yield/plant (g). Seed yield of inner three furrows was determined and converted to ton/fed (fed= 4200 m^2).

TABLE 3. Physical and chemical properties of tested soil amendments

Organic amendments				
Compost			Biochar	
Properties	Values		Properties	Values
	2018	2019		
Bulk density (kg/m^3)	486	492	Bulk density (kg/m^3)	346
pH	6.39	6.51	pH	7.10
EC (dS/m)	2.86	2.43	EC (dS/ m)	2.31
Ash (%)	67.38	68.71	Ash (%)	69.03
Organic carbon (%)	14.83	15.03	Organic carbon (%)	17.03
Total nitrogen (%)	0.87	0.85	Total nitrogen (%)	0.75
C/N Ratio	17.05	17.68	C/N ratio	22.71
Total phosphorus (%)	0.38	0.32	Total phosphorus (%)	0.29
Total potassium (%)	0.84	0.91	Total potassium (%)	0.28
Appearance	dark brown crumbly		Appearance	Black powder

Superabsorbent polymer amendments			
PAM		Hydrogel (carboxymethyl cellulose)	
Properties	Values	Properties	Values
Chem. Formula	(C_3H_5NO) n	Density (g/cm^3)	1.45
Molar mass	71.079 g/mol	pH	6.9 ± 0.5
Conductivity	≤10 µmho	Moisture (%)	4%
Density (g/cm^3)	1.322	Max. absorbency	up to 50 °C
Boiling point	125 °C	Purity	99.5%
Melting point	84.5 °C	Solubility	swells in water
Vapor pressure	0.03 mmHg	Appearance	white granules
Solubility	swells in water		
Appearance	white powder		

Seed quality

At maturity, dried seeds were ground and prepared for chemical analysis. Oil % was determined by Soxhlet extraction apparatus as described by AOAC (2007). Nitrogen % was determined by the Micro Kjeldahl method (AOAC, 2007). Protein % was calculated by multiplying N% by 6.25. Oil and protein yields/fed (kg) were calculated by multiplying seed yield/fed by oil and protein percentages, respectively.

Water relations

The following measurements of water relations were determined for each tested irrigation interval during the two seasons.

Total water use (m^3/fed): A suppressed rectangular weir was installed in the front of the irrigation channels for every irrigation to compute the amount of water used in the three irrigation systems according to the following equation as described by Singh (2012)

$$Q = 1.84\ L\ H^{2/3}$$

where Q: Water flow rate (m^3/sec), L: Length of weir which is equal to the width of the rectangular channel (m), H: Head of water over the weir (m).

Water saved (m^3/fed)= Total water use every 12 Days - Total water use every 16 or 20 Days

Water saved (%) = (Total water use every 12 Days - Total water use every 16 or 20 Days)/ (Total water use every 12 Days) x100

Water use efficiency (WUE) "kg seeds/ m^3 water": was calculated using the following equation as described by Michael (1978):

$$WUE = \frac{Seed\ yield\ (kg/fed)}{Total\ water\ used\ (m3/fed)}$$

Statistical analysis

All measurement data were analyzed according to Snedecor & Cochran (1980). Duncan's multiple range test (Duncan, 1955) was used to compare among the treatments mean at probability 5%. Statistical analysis was done using the Costat software, version 6.400 (Cohort Software, USA).

Results and discussion

Root and nodulation characters

Data in Table 4 reveal that root length, root dry weight, number and dry weight of nodules/ plant as well as nitrogenase enzyme activity at 70 days after sowing (DAS) were significantly decreased when the plants were exposed to drought stress (irrigation every 20 days, I_3) as compared with those irrigated every 12 days (I_1) and 16 days (I_2) in both seasons. However, there are no significant differences between the irrigation intervals of 12 and 16 days on root length and root dry weight/ plant in the two seasons. From these results it can be suggested that prolonging irrigation intervals may be caused a drought stress and decreased the soil moisture in the root zone and consequently led to a decrease in cell membranes, elongation and division and this in turn caused a reduction in root and nodules production as well as the activity of nitrogenase enzyme. In this concern, Hussein et al. (2019) found that exposing soybean plants to drought stress caused a depression in dry weight of root and number of nodules/ plants.

Application of all tested soil amendment compounds caused a significant and positive effect on root and nodulation characters compared to the control treatment in both seasons. In comparison among the tested amendments, the highest increase % were obtained when the plants were treated with each of PAM for root length (31.12%), biochar for the number of nodules/ plant (44.16%) and hydrogel for root dry weight (49.98%), dry weight of nodules/ plant (91.65%) and nitrogenase enzyme activity (62.52%) more than the untreated plants (control), as an average of both seasons. The beneficial effect of soil amendments may be due to that treated soil can be kept large amounts of water and soluble nutrients. The stored water and nutrients are released as needed by plants which maintain their availability to building tissues. The positive effect of amendments on nitrogenase activity might be attributed to their roles on nutrients uptake which led to increases in number and dry weight of nodules/ plant, and consequently nitrogen fixation. In this respect, many investigators reported that soil application of biochar compound could improve soil structure and enhance aggregation and water retention (Baiamonte et al., 2015), physicochemical properties and soil microbial properties (Ding et al., 2016), soil biological community (Grossman et al., 2010) and no. of nodules/ plant (Głodowska et al., 2017; Ma et al., 2019).

The interaction between irrigation intervals and soil amendments was found to be significant for root length and nodulation characters studied (number and dry weight of nodules/ plant as well as nitrogenase enzyme activity) in both seasons (Table 4). However, root dry weight/ plant was not significantly affected by such interaction in the two seasons. Moreover, it can be noticed that the highest values of root length (43.33 and 40.23cm) were obtained when the plants were irrigated every 16 days (I_2) and treated with PAM in the first and second seasons, respectively. On the other hand, the plants irrigated every 12 DAS (I_1) produced the highest values when they treated with biochar for number of nodules/ plant (82.47 and 91.33) or when were treated with hydrogel for dry weight of nodules/ plant (0.610 and 0.724g) and nitrogenase activity (54.68 and 58.19µmole C_2H_4/ g D. Wt nodules/hr.) in the same respective seasons. This means that the abundance of soil moisture associated with application of some soil amendments encouraged the root development and stimulated the nodulation activity in soybean plant.

Morphological and physiological characters

Data in Table 5 showed that the morphological characters (plant height, no. of leaves, leaf area and total dry weight/ plant) as well as physiological traits (relative water content % "RWC" and total chlorophyll "Chl.") were significantly increased when the plants were irrigated every 12 days (I_1). On the contrary, the values of those traits were significantly and gradually decreased by prolonging the irrigation intervals up to 16 days (I_2) and 20 days (I_3). This means that exposing soybean plants to sufficient soil moisture (irrigation every 12 days) which encouraged the root and nodules production as previously discussed in Table 4 may be caused an increase in plant capacity of nutrients absorption, photosynthesis efficiency and consequently increased stem elongation, dry matter production and other plant growth characters studied. In this respect, many researchers found that providing the soil with water abundance enhanced soybean plant height and no. of leaves/ plant (Hussein et al., 2019), leaf area/ plant (El-Shafey, 2017) and total dry weight (Sivapalan, 2001; Ibrahim & Kandil, 2007) as well as chlorophyll and RWC (El-Shafey, 2017).

TABLE 4. Root and nodulation traits of soybean as affected by irrigation intervals, soil amendments and their interaction at 70 DAS in 2018 and 2019 seasons

Treatments \ Characters		Root length/ plant (cm)		Root dry weight/ plant (g)		No. of nodules/ plant		Dry weight of nodules /plant (g)		Nitrogenase (µmole C_2H_4/ g D. Wt nodules/ hr)	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Irrigation intervals (A)											
I_1 (12 days)		34.57 ab	35.78 ab	3.99 a	4.35 a	55.05 a	61.95 a	0.485 a	0.508 a	47.48 a	50.63 a
I_2 (16 days)		36.43 a	37.02 a	3.82 ab	3.81 ab	43.67 b	51.55 b	0.402 b	0.423 b	35.65 b	42.92 b
I_3 (20 days)		33.91 b	35.05 b	3.52 b	3.13 c	30.77 c	36.81 c	0.236 c	0.254 c	28.27 c	35.45 c
Soil amendments (B)											
Control		28.92 e	31.81 c	2.98 c	3.15 c	24.11 c	31.93 d	0.261 c	0.257 e	27.70 e	33.04 e
Compost		32.32 d	35.62 b	3.50 b	3.66 bc	38.69 b	42.91 c	0.373 b	0.391 c	36.22 c	42.77 c
Biochar		35.41 c	35.52 b	3.65 b	3.44 bc	61.80 a	74.07 a	0.437 a	0.440 b	41.26 b	48.10 b
PAM		40.41 a	38.97 a	4.19 a	3.91 b	34.89 b	39.38 c	0.348 b	0.345 d	33.71 d	39.50 d
Hydrogel		37.79 b	37.82 a	4.53 a	4.66 a	56.33 a	62.22 b	0.451 a	0.541 a	46.78 a	51.60 a
Interaction (A X B)											
I_1	Control	26.63 h	28.42 g	3.08 a	3.78 a	31.40 fg	40.80 efg	0.311 d	0.382 ef	36.61 e	42.08 ef
	Compost	28.87 gh	35.67 def	3.98 a	4.11 a	50.07 de	51.20 d	0.491 b	0.485 c	48.66 bc	49.21 c
	Biochar	36.33 cde	37.33 a-d	3.50 a	4.17 a	82.47 a	91.33 a	0.577 a	0.541 b	51.67 ab	56.35 a
	PAM	41.73 ab	39.93 ab	4.43 a	4.56 a	42.13 ef	48.40 de	0.436 c	0.407 de	45.81 c	47.34 cd
	Hydrogel	39.30 bc	37.53 a-d	4.98 a	5.16 a	69.20 b	78.00 b	0.610 a	0.724 a	54.68 a	58.19 a
I_2	Control	31.80 fg	34.33 def	3.11 a	3.23 a	23.87 gh	32.67 gh	0.275 de	0.219 h	26.81 e	33.52 h
	Compost	33.80 ef	35.87 c-f	3.28 a	3.81 a	34.33 fg	42.80 def	0.403 c	0.425 d	32.26 f	44.04 e
	Biochar	35.07 def	35.47 def	3.91 a	3.30 a	64.47 bc	78.73 b	0.438 c	0.508 bc	40.79 d	47.32 cd
	PAM	43.33 a	40.23 a	4.35 a	3.93 a	37.00 f	39.53 e-h	0.398 c	0.426 d	29.13 fg	37.93 g
	Hydrogel	38.17 bcd	39.20 abc	4.45 a	4.76 a	58.67 cd	64.00 c	0.495 b	0.536 b	49.26 b	51.81 b
I_3	Control	28.33 gh	32.67 f	2.76 a	2.44 a	17.07 h	22.33 i	0.197 g	0.170 i	19.68 h	23.52 i
	Compost	34.30 def	35.33 def	3.24 a	3.05 a	31.67 fg	34.73 fgh	0.225 fg	0.264 g	27.73 g	35.06 h
	Biochar	34.83 def	33.77 ef	3.66 a	2.85 a	38.47 f	52.13 d	0.297 d	0.271 g	31.32 f	40.65 f
	PAM	36.17 cde	36.73 b-e	3.79 a	3.24 a	25.53 gh	30.20 hi	0.209 fg	0.203 hi	26.19 g	33.24 h
	Hydrogel	35.90 cde	36.73 b-e	4.14 a	4.05 a	41.13 ef	44.67 de	0.250 ef	0.362 f	36.42 e	44.79 de

TABLE 5. Morphological and physiological traits of soybean as affected by irrigation intervals, soil amendments and their interaction at 70 DAS during 2018 and 2019 seasons

Characters / Treatments		Plant height (cm)		No. of leaves/ plant		Leaf area (cm^2)		Total dry weight / plant (g)		RWC %		Chlorophyll (SPAD value)	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Irrigation intervals (A)													
I_1 (12 days)		108.08 a	113.00 a	31.58 a	30.51 a	837.07 a	850.09 a	42.56 a	35.13 a	84.37 a	84.40 a	39.60 a	39.06 a
I_2 (16 days)		100.04 b	106.15 b	27.05 b	28.30 b	701.69 b	769.80 b	38.87 b	29.51 b	81.64 b	80.25 b	37.14 b	36.59 b
I_3 (20 days)		89.03 c	95.87 c	23.70 c	24.29 c	581.97 c	655.14 c	32.37 c	24.68 c	76.80 c	74.21 c	35.07 c	34.28 c
Soil amendments (B)													
Control		88.57 d	87.69 e	23.67 d	25.30 c	546.38 e	597.31 d	30.10 c	22.67 e	76.79 d	75.80 d	34.70 c	33.76 c
Compost		93.75 c	107.78 c	26.64 c	26.85 bc	648.41 d	730.99 c	36.81 b	30.01 c	81.50 b	79.13 c	37.22 b	36.53 b
Biochar		100.95 b	99.81 d	25.69 c	27.89 b	695.66 c	746.80 c	36.86 b	27.66 d	79.88 c	78.61 c	37.36 b	36.17 b
PAM		103.11 b	113.00 b	29.86 b	27.96 b	778.49 b	838.43 b	42.75 a	33.10 b	82.15 b	80.76 b	37.94 ab	36.90 ab
Hydrogel		113.47 a	116.74 a	31.36 a	30.51 a	865.62 a	878.17 a	43.15 a	35.43 a	84.36 a	83.81 a	39.13 a	38.19 a
Interaction (A X B)													
I_1	Control	94.30 f	97.40 e	27.75 e	27.44 def	636.42 e	665.93 d	34.30 e	28.32 fg	80.76 efg	82.39 bc	36.85 def	35.95 cd
	Compost	102.00 de	112.67 c	31.50 c	29.33 c	778.40 cd	829.69 b	38.85 c	33.65 c	84.36 bcd	83.28 bc	39.66 b	38.22 b
	Biochar	109.92 c	111.48 c	30.50 cd	31.00 b	871.08 b	854.13 b	43.28 b	32.96 cd	82.77 cde	83.05 bc	38.94 bc	37.23 bc
	PAM	112.42 bc	118.44 b	33.25 b	30.89 b	924.95 ab	938.76 a	48.12 a	39.58 a	86.03 ab	84.53 ab	40.24 b	38.15 b
	Hydrogel	121.75 a	125.00 a	34.92 a	33.89 a	974.53 a	961.91 a	48.26 a	41.16 a	87.94 a	88.77 a	42.29 a	40.76 a
I_2	Control	84.75 h	87.55 f	23.75 hi	26.89 ef	547.69 fg	585.68 f	31.29 f	22.16 j	77.19 hi	75.46 ef	34.95 g	33.54 e
	Compost	92.58 fg	110.33 c	25.50 fg	28.00 de	640.34 e	743.24 c	37.35 cd	31.12 de	81.85 def	79.94 cde	37.08 c-f	36.94 bc
	Biochar	107.77 cd	100.28 e	24.83 gh	27.11 def	624.76 e	755.16 c	37.19 cd	25.55 hi	80.70 efg	79.11 cde	37.57 cde	37.04 bc
	PAM	98.19 ef	113.22 c	29.92 d	28.22 cd	793.63 c	842.16 b	44.50 b	33.14 c	83.00 cde	81.85 bcd	37.50 cde	37.39 bc
	Hydrogel	116.92 ab	119.34 b	31.25 c	31.30 b	902.03 b	922.74 a	44.02 b	35.57 b	85.46 abc	84.87 ab	38.59 bcd	38.04 b
I_3	Control	72.83 i	78.11 g	19.50 k	21.56 j	455.02 h	540.32 g	24.72 g	17.53 k	72.41 j	69.54 g	32.29 h	31.80 f
	Compost	86.67 gh	100.33 e	22.92 i	23.22 i	526.51 g	620.04 ef	34.22 e	25.25 hi	78.31 ghi	74.16 f	34.92 g	34.43 de
	Biochar	85.17 h	87.67 f	21.75 j	25.55 gh	591.13 ef	631.10 de	30.10 f	24.46 i	76.17 i	73.67 f	35.58 fg	34.25 de
	PAM	98.73 ef	107.33 d	26.42 f	24.78 h	616.89 e	734.36 c	35.62 de	26.58 gh	77.43 hi	75.89 ef	36.09 efg	35.15 de
	Hydrogel	101.75 de	105.89 d	27.92 e	26.33 fg	720.30 d	749.87 c	37.18 cd	29.57 ef	79.69 fgh	77.80 def	36.50 efg	35.76 cd

The morphological and physiological characters studied herein were significantly increased by soil application of all tested soil amendments compared to untreated plants in favor of hydrogel compound which produced the highest values in both seasons. The increase percentage in the characters studied obtained by the application of hydrogel amounted to 30.62% for plant height, 26.54% for no. of leaves/ plant, 52.71% for leaf area/ plant, 49.83% for total dry weight/ plant, 10.22% for RWC and 12.95% for Chl. content over the control treatment, respectively as an average of the two seasons. The superiority effect of hydrogel pronounced on growth characters herein may be due to that the kinds of hydrogel prepared from different types of cellulose, alone or mixed with its derivatives, such as lignin, chitin, or polyvinyl alcohol. It sticks to plant roots and increasing the water-holding capacity of soil, but when the soil moisture reduces as temperature rises, then hydrogels slowly release moisture back to the plants as it is needed (Wu et al., 2010). In this respect, many investigators found positive effect on growth characters of soybean plants when they were treated with some soil amendments such as hydrogel for plant height (Fidelis et al., 2018), biochar for leaf chlorophyll (Qian et al., 2019) and superabsorbent polymer for total dry matter (Yazdani et al., 2007) as compared with untreated plants.

The interaction between the two experienced factors exhibited significant effect on all morphological and physiological characters studied herein in both seasons (Table 5). It could be concluded that the interaction treatment of irrigation every 12 days (I_1) with soil application of hydrogel compound produced the highest significant values of plant height (123.38cm), no. of leaves/ plant (34.41), leaf area/ plant (968.22cm^2), total dry weight/ plant (44.71g), RWC (88.36%) and total Chl. (41.53), as an average of the two seasons. Reversely, the lowest values of all abovementioned characters were attained when soybean plants were irrigated every 20 days (I_3) in the absence of the tested soil amendments (control treatment). This means that exposing plants to drought stress condition without application of any soil amendment caused an injury effect on the growth of soybean plants. In this concern, Yazdani et al. (2007) reported that irrigation every 6 days and providing the soil with superabsorbent polymer at 225kg/ ha increased the growth attributes of soybean plants, i.e. plant height, total dry matter and leaf area index compared to the control treatment and other irrigation intervals (8 and 10 days).

Seed yield and its components

The data in Table 6 showed that increasing irrigation intervals from 12 to 16 and 20 days caused a significant reduction in seed yield/ plant and its components (number of pods/ plant, number of seeds/ pod, 100-seed weight and seed weight/ pod) in both seasons. Also, it can be noted that seed yield/ fed took the same hurt by prolonging irrigation intervals. The reduction in the values of seed yield/fed amounted to 12.93 and 28.66% in the first season and 11.87 and 26.99% in the second season when the plants were irrigated every 16 (I_2) and 20 days (I_3), respectively compared to those irrigated every 12 days (I_1). From these results, it can be suggested that exposing soybean plants to severe drought stress by prolonging irrigation intervals up to 20 days caused a sharp depression in seed yield/ plant and its main components (no. of pods/ plant and seed weight/ pod) and consequently seed yield/ fed. This depression may be due to a pronounced decrease in the values of morphological and physiological characters as previously discussed in Table 5. Similar results were detected by Amiri et al. (2013) who reported that planting soybean plants under water stress conditions caused a reduction in no. of pods/ plant, seed yield/ plant and seed yield/ fed as well as number of seeds per pod and 100-seed weight.

Data in the same table refer that seed yield/ plant and its components (no. of pods/ plant, no. and weight of seeds/ pod as well as 100-seed weight) were increased by soil application of different tested amendment compounds as compared with the control treatment in both seasons. Moreover, it can be noticed that the highest values were obtained by soil application of hydrogel for number of pods/ plant (48.00 and 50.75), 100-seed weight (14.68 and 14.29g) and seed yield/ plant (19.43 and 20.18g) as well as by the application of PAM for number of seeds / pod (2.47 and 2.45) in the first and second seasons, respectively. However, the rest soil amendments namely biochar and compost took the next rank without significant differences between them mostly in the first and/or second seasons. Moreover, it is obvious that seed yield/ fed was increased by 37.72, 27.13, 20.94 and 12.36% when the plants were treated by hydrogel, PAM, biochar and compost, respectively more than the control treatment, as an average of both seasons. The superiority of seed yield/ fed obtained herein due to the application of tested soil amendments is well agrees with the increases obtained in the number and dry weight of nodules/ plant, nitrogenase activity, growth and photosynthetic pigments as well as yield attributes as previously discussed in Tables 4, 5 and 6. This finding seems to be in confirmation with the results obtained by Fidelis et al. (2018) who reported that soil application of hydrogel caused an increment in no. of pods/ plant and 100 seed weight as well as seed yield/ ha of soybean. Moreover, Arabi et al. (2018) found that no. of pods/ plant and seed yield/ ha of soybean were increased when the plants were soil treated with biochar as compared with the untreated plants.

Concerning the interaction between the two experienced factors, the data in Table 6 show that there are significant differences between the mean values of seed yield/ fed and most of its components studied herein except for number of seeds/ pod and seed weight/ pod in both seasons. From the data obtained herein, it can be found that soil application of hydrogel associated with irrigation every 12 days (I_1) appeared to increase the values of seed yield and yield components compared to the other tested interaction treatments in both seasons. Such interaction treatment (I_1 x hydrogel) produced the highest significant values of number of pods/ plant (54.79 and 56.50), 100 seed weight (15.85 and 15.33 g), seed yield/ plant (22.48 and 23.16 g) and seed yield/ fed (2.086 and 2.149 ton) in the first and second seasons, respectively. Moreover, it is appear that the soil application of hydrogel, PAM or biochar compounds under moderate water stress (irrigation every 16 days) were found to be improved and increased seed yield/ fed and most its components more than that obtained by the control treatment under normal irrigation interval (every 12 days). This means that such tested soil amendments played a beneficial role in absorption and protection of the water and consequently improved the efficiency of soybean plants to tolerate the drought and this in turn increased the crop development and productivity.

Seed quality

The quality characters studied in soybean seeds (oil and protein percentage and their yields/ fed) as affected by irrigation intervals, soil amendments and their interaction in 2018 and 2019 seasons are shown in Table 7.

The data reveal that protein % and yield as well as oil yield/fed were significantly decreased with increasing the irrigation intervals up to 16 and 20 days. The present results of seed protein % may be due to that exposing soybean plants to drought stress by prolonging the irrigation intervals caused a reduction in the carbohydrate accumulation and their translocation to the seeds and consequently decreased seed protein content. Moreover, the decreasing in the oil yield/ fed obtained herein mainly due to the reduction in seed yield/ fed associated with increasing the irrigation intervals as previously discussed in Table 6. On the contrary, the differences among the tested irrigation intervals were not great enough to reach the 5 % level of significance for seed oil % in the two seasons. In this respect, many researchers reported that exposing soybean plants to drought stress condition caused a reduction in protein percentage and yield/ fed (Abd El-Mohsen et al., 2013; Mahrous et al., 2014) and oil yield/ fed (Mahmoud et al., 2013) but could not affect seed oil % (Ibrahim & Kandil, 2007).

The application of different tested soil amendments significantly increased oil yield/ fed as well as protein % and its yield/ fed compared to the control treatment in both seasons. Also, it can be noticed that hydrogel application seemed to be the most effective treatment for increasing oil and protein yields/ fed compared to the rest soil amendments. However, the highest values of seed protein percentage were obtained by the application of compost without significant differences with each of hydrogel and PAM compounds in both seasons. The positive result obtained herein by hydrogel application may be due to its beneficial role in the control of water stress, reducing its impact on productivity, its necessary to characterize the possible changes in the biochemical quality of soybean grains (Nascimento et al., 2019).

TABLE 6. Seed yield and its components of soybean as affected by irrigation intervals, soil amendments and their interaction in 2018 and 2019 seasons

Treatments \ Characters		No. of pods/plant		No. of seeds/ pod		100-seed weight (g)		Seeds weight/ pod (g)		Seed yield/plant (g)		Seed yield/fed (ton)	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Irrigation intervals (A)													
I_1 (12 days)		48.81 a	50.93 a	2.49 a	2.52 a	15.13 a	14.55 a	0.424 a	0.412 a	19.71 a	19.49 a	1.856 a	1.912 a
I_2 (16 days)		43.01 b	46.10 b	2.29 b	2.31 b	13.67 b	13.68 b	0.397 b	0.382 b	17.30 b	17.62 b	1.616 b	1.685 b
I_3 (20 days)		35.18 c	37.59 c	2.18 c	2.23 c	13.25 c	13.18 c	0.375 c	0.367 c	12.91 c	14.43 c	1.324 c	1.396 c
Soil amendments (B)													
Control		35.51 d	37.88 e	2.13 d	2.18 b	13.39 d	13.36 c	0.359 c	0.353 d	13.86 c	13.55 d	1.319 d	1.410 e
Compost		41.79 c	43.13 d	2.28 c	2.38 ab	14.24 b	13.94 b	0.403 ab	0.385 b	15.35 b	16.68 c	1.485 c	1.581 d
Biochar		41.74 c	44.97 c	2.32 bc	2.38 ab	13.63 c	13.65 bc	0.394 b	0.371 c	16.38 b	17.04 c	1.644 b	1.653 c
PAM		44.63 b	47.65 b	2.47 a	2.45 a	14.15 b	13.78 b	0.413 ab	0.412 a	18.20 a	18.43 b	1.696 b	1.772 b
Hydrogel		48.00 a	50.75 a	2.40 ab	2.37 ab	14.68 a	14.29 a	0.425 a	0.415 a	19.43 a	20.18 a	1.849 a	1.907 a
Interaction (A X B)													
I_1	Control	41.54 f	44.38 e	2.25 a	2.30 a	14.55 bc	14.07 cde	0.380 a	0.371 a	16.94 de	15.91 efg	1.479 b-e	1.591 d
	Compost	48.88 bc	49.88 cd	2.45 a	2.60 a	14.84 b	14.82 b	0.408 a	0.407 a	17.85 d	18.48 cd	1.614 b	1.798 c
	Biochar	47.25 cd	51.42 bc	2.50 a	2.55 a	14.97 b	14.41 bc	0.411 a	0.386 a	19.92 bc	18.85 c	2.028 a	1.952 b
	PAM	51.58 b	52.50 bc	2.65 a	2.65 a	15.46 a	14.13 cd	0.458 a	0.447 a	21.39 ab	21.03 b	2.072 a	2.071 a
	Hydrogel	54.79 a	56.50 a	2.60 a	2.50 a	15.85 a	15.33 a	0.463 a	0.451 a	22.48 a	23.16 a	2.086 a	2.149 a
I_2	Control	34.92 hi	37.88 g	2.10 a	2.15 a	13.04 ij	13.15 hi	0.354 a	0.347 a	13.95 gh	13.59 h	1.271 ef	1.353 fg
	Compost	42.38 ef	41.75 ef	2.25 a	2.30 a	14.16 cde	13.78 def	0.410 a	0.384 a	15.78 ef	16.77 ef	1.543 bcd	1.604 d
	Biochar	41.88 f	47.38 d	2.35 a	2.35 a	13.23 hi	13.62 efg	0.393 a	0.372 a	16.01 ef	17.11 de	1.578 bc	1.575 d
	PAM	44.92 de	49.58 cd	2.40 a	2.40 a	13.66 ghi	13.83 def	0.411 a	0.400 a	19.69 c	18.94 c	1.645 b	1.804 c
	Hydrogel	50.96 b	53.92 ab	2.35 a	2.35 a	14.28 cd	14.05 cde	0.414 a	0.408 a	21.10 abc	21.66 ab	2.041 a	2.088 a
I_3	Control	30.08 j	31.38 h	2.05 a	2.10 a	12.60 j	12.88 i	0.341 a	0.341 a	10.68 i	11.15 i	1.206 f	1.286 g
	Compost	34.13 i	37.75 g	2.15 a	2.25 a	13.73 efg	13.23 ghi	0.389 a	0.364 a	12.44 h	14.78 gh	1.298 ef	1.341 fg
	Biochar	36.08 ghi	36.13 g	2.10 a	2.25 a	12.68 j	12.92 i	0.379 a	0.356 a	13.21 gh	15.16 fgh	1.325 def	1.431 ef
	PAM	37.38 gh	40.88 f	2.35 a	2.30 a	13.34 ghi	13.40 fgh	0.371 a	0.390 a	13.53 gh	15.33 fg	1.369 c-f	1.440 ef
	Hydrogel	38.25 g	41.83 ef	2.25 a	2.25 a	13.92 def	13.50 fgh	0.396 a	0.386 a	14.71 fg	15.72 efg	1.421 b-f	1.483 de

TABLE 7. Seed quality of soybean as affected by irrigation intervals, soil amendments and their interaction in 2018 and 2019 seasons

Treatments \ Characters		Oil (%)		Oil yield/fed (kg)		Protein (%)		Protein yield/fed (kg)	
		2018	2019	2018	2019	2018	2019	2018	2019
Irrigation intervals (A)									
I_1 (12 days)		22.87 a	23.77 a	424.47 a	454.48 a	42.42 a	41.57 a	787.32 a	794.82 a
I_2 (16 days)		23.60 a	24.46 a	381.38 b	412.15 b	40.55 b	39.46 b	655.29 b	664.90 b
I_3 (20 days)		22.85 a	23.61 a	302.53 c	329.60 c	37.37 c	37.07 c	494.78 c	517.50 c
Soil amendments (B)									
Control		22.33 a	23.40 a	294.53 d	329.94 e	38.13 c	37.67 c	502.93 d	531.15 d
Compost		22.62 a	23.33 a	335.91 c	368.85 d	41.38 a	40.81 a	614.49 c	645.21 c
Biochar		23.52 a	24.48 a	386.67 b	404.65 c	39.82 b	38.88 bc	654.64 bc	642.69 c
PAM		23.31 a	23.96 a	395.34 b	424.57 b	40.55 ab	39.64 ab	687.73 b	702.42 b
Hydrogel		23.73 a	24.57 a	438.77 a	468.55 a	40.68 ab	39.83 ab	752.17 a	759.56 a
Interaction (A x B)									
I_1	Control	22.07 a	23.00 a	326.42 cde	365.93 fgh	39.68 d	38.97 e	586.87 cd	620.01 ef
	Compost	22.60 a	23.87 a	364.76 bcd	429.18 e	43.93 a	43.42 a	709.03 b	780.69 c
	Biochar	23.53 a	24.53 a	477.19 a	478.83 cd	42.55 ab	40.97 bcd	862.91 a	799.73 bc
	PAM	22.60 a	23.33 a	468.27 a	483.16 bc	42.71 ab	42.37 ab	884.95 a	877.48 a
	Hydrogel	23.53 a	24.13 a	490.84 a	518.55 ab	43.24 ab	42.11 ab	901.99 a	904.94 a
I_2	Control	23.27 a	24.60 a	295.76 ef	332.84 hi	38.18 e	37.79 ef	485.27 ef	511.30 h
	Compost	23.40 a	23.60 a	361.06 bcd	378.54 fg	42.18 bc	41.12 bc	650.84 bc	659.56 e
	Biochar	23.53 a	24.50 a	371.30 bc	385.88 f	40.29 d	39.13 de	635.78 bc	616.30 f
	PAM	23.73 a	24.53 a	390.36 b	442.52 de	40.99 cd	39.67 cde	674.29 bc	715.65 d
	Hydrogel	24.07 a	25.07 a	491.27 a	523.46 a	41.10 cd	39.57 cde	838.85 a	826.22 b
I_3	Control	21.67 a	22.60 a	261.34 f	290.64 j	36.51 g	36.24 f	440.31 f	466.05 i
	Compost	21.87 a	22.53 a	283.87 ef	302.13 ij	38.02 ef	37.89 ef	493.50 def	508.10 hi
	Biochar	23.50 a	24.40 a	311.38 def	349.16 fgh	36.62 fg	36.53 f	485.22 ef	522.74 gh
	PAM	23.60 a	24.00 a	323.08 cde	345.60 gh	37.96 efg	36.88 f	519.67 def	531.07 gh
	Hydrogel	23.60 a	24.50 a	335.36 cde	363.34 fgh	37.72 fg	37.82 ef	536.00 de	560.87 g

The data of interaction between irrigation intervals and soil amendments indicate that the values of protein % and yield/fed as well as oil yield/fed were significantly affected by such interaction, while the differences among the tested interaction treatments were not significant for oil % in both seasons. The best interaction treatments were obtained herein when the plants were irrigated every 16 days and treated with hydrogel for oil yield/ fed (507.36kg) as well as when they were irrigated every 12 days and treated with compost for protein % (43.68%) or with hydrogel for protein yield/ fed (903.46kg), as an average of the two seasons. Moreover, it is interesting to note that all abovementioned seed quality achieved by irrigation every 16 days (moderate drought stress) associated with soil application of the tested soil amendments were superior to those achieved by irrigation every 12 days (normal irrigation interval) without soil amendments (control treatment). From these results, it can be suggested that application of soil amendments could be improved and increased the seed quality characters of soybean plants under moderate irrigation deficit.

Water relations

The amounts of water used, water saved and water saved % of soybean plants as affected by the tested irrigation intervals in the two seasons are presented in Table 8. The data show that prolonging irrigation intervals from 12 (I_1) to 16

(I_2) and 20 days (I_3) caused a reduction in the total amounts for water used from 2386 to 1917 and 1722m^3/fed, respectively, as an average of the two seasons. It can be noticed that irrigation of soybean plants every 16 (I_2) and 20 days (I_3) can be save irrigation water amounted to 444 and 664m^3/fed (18.62 and 27.82%) as compared with irrigation every 12 days (I_1), respectively, as an average of the two seasons. From these results, it can be suggested that the reduction in total amounts of water used as well as the increment of water saved input obtained herein may be due to the decrease in the number of irrigations applied to soybean plants from 9 times (under I_1) to 7 (under I_2) and 6 (under I_3) as shown in Tables 2 and 8. In this respect, other investigators reported that exposing soybean plants to low soil moisture caused a reduction in the water consumptive use (El-Shafey, 2017; Zou et al., 2017).

Table 9 included the data of water use efficiency (WUE) of soybean plants as affected by the tested irrigation intervals, soil amendments and their interaction in the two seasons. The data show that the highest values of WUE were recorded when the plants were irrigated every 16 days (0.843 and 0.857kg seeds/ m^3 water) or when were treated with soil amendment of hydrogel (0.927 and 0.936 kg seeds/ m^3 water) in the first and second seasons, respectively. Moreover, it can be noticed that the values of WUE were more pronounced when the plants were irrigated every 16 days associated with hydrogel compound (1.065 and 1.062kg seeds/ m^3 water) indicating that such interaction treatment found to be more effective for water productivity than the rest interaction treatments.

TABLE 8. The amounts of water used, water saved and water saved % of soybean as affected by different irrigation intervals systems of soybean during 2018 and 2019 seasons.

Irrigation intervals / No. of Irrigations		2018 season			2019 season		
		I_1	I_2	I_3	I_1	I_2	I_3
Water used (m^3/fed)	1st	210	210	210	217	217	217
	2nd	223	243	253	231	239	261
	3rd	238	251	281	229	263	289
	4th	241	376	382	252	381	377
	5th	374	384	339	369	372	352
	6th	350	231	236	361	261	274
	7th	296	221	-	287	234	-
	8th	223	-	-	232	-	-
	9th	213	-	-	225	-	-
Total water used (m^3/fed)		2368	1916	1701	2403	1967	1743
Water saved (m^3/fed)		-	452	667	-	436	660
Saved water (%)		-	19.09	28.17	-	18.14	27.47

TABLE 9. Effect of irrigation intervals and soil amendments and their interactions on water use efficiency (kg seeds / m3 water) of soybean during 2018 and 2019 seasons

Soil amendments	2018 season				2019 season			
	Irrigation intervals				Irrigation intervals			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Control	0.625 e	0.663 de	0.709 cde	**0.666 D**	0.662 h	0.688 gh	0.738 fg	**0.696 E**
Compost	0.682 de	0.805 bc	0.763 bcd	**0.750 C**	0.748 fg	0.815 de	0.769 ef	**0.778 D**
Biochar	0.856 b	0.824 bc	0.779 bcd	**0.820 BC**	0.812 de	0.801 def	0.821 de	**0.811 C**
PAM	0.875 b	0.859 b	0.805 bc	**0.846 B**	0.862 bcd	0.917 b	0.826 de	**0.868 B**
Hydrogel	0.881 b	1.065 a	0.835 b	**0.927 A**	0.894 bc	1.062 a	0.851 cd	**0.936 A**
Mean	**0.784 B$^-$**	**0.843 A$^-$**	**0.778 B$^-$**		**0.796 B$^-$**	**0.857 A$^-$**	**0.801 B$^-$**	

Conclusion

Finally, it can be concluded that tested soil amendments will help in alleviating water stress of crops especially in arid and semiarid regions. It's could reduce the number of irrigations applied to soybean crop. Soil amendment namely hydrogel has shown potential to achieve higher seed yield with limited water by increasing water availability during crop growth stages. Two irrigations during season can be saved without significant decreasing in seed yield/ fed. Thus, such soil amendments can be a real advantage in terms of water saving and yield improving.

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أهمية بعض محسنات التربة في تحسين نمو وانتاجية وجودة فول الصويا تحت فترات ري مختلفة

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تتعرض مصر الآن إلي نقص في المياه مما يسبب خطورة علي إنتاجية المحاصيل وكفاءة استخدامها لماء الري وخاصة في ظل التغيرات المناخية الحالية، لذلك أجريت هذه التجربة الحقلية لدراسة تأثير إضافة أربعة محسنات للتربة وهي الكمبوست، الفحم الحيوى، البولي أكريلاميد، الهيدروجيل بجانب معاملة الكنترول (بدون إضافة للمقارنة) تحت ثلاث فترات ري وهي الري كل 12، 16، 20 يوم وكذلك التفاعل بينهما على صفات الجذر والعقد الجذرية والصفات المورفولوجية والفسيولوجية وصفات المحصول ومكوناته وجودة البذور لمحصول فول الصويا (صنف جيزة 111) ويمكن تلخيص أهم النتائج المتحصل عليها كالتالي:

١- أدت زيادة فترات الري حتي 20 يوماً إلى نقص معنوي في كل من صفات الجذر (طول ووزن الجذر الجاف، عدد ووزن العقد الجذرية الجاف ونشاط إنزيم النيتروجينيز)، الصفات المورفولوجية للنبات (طول النبات، عدد ومساحة أوراق النبات والوزن الجاف الكلي للنبات)، الصفات الفسيولوجية للورقة (المحتوى المائي النسبي والكلوروفيل)، المحصول ومكوناته (عدد القرون للنبات، عدد ووزن بذور القرن، وزن 100 بذرة ومحصول البذور للنبات والفدان) وصفات جودة البذور (النسبة المئوية للبروتين ومحصول الزيت والبروتين/ فدان) وذلك مقارنة بالنباتات التي تروى كل 12 و 16 يوم، بينما لم تتأثر معنوياً صفة النسبة المئوية للزيت بفترات الري المختبرة خلال موسمي الزراعة.

٢- تُشير النتائج إلى أن إضافة أى من محسنات التربة المختبرة كان لها تأثير معنوي علي صفات الجذر، صفات النمو المورفولوجية والفسيولوجية، المحصول ومكوناته، صفات جودة بذور فول الصويا. هذا وقد أعطي إضافة مركب الهيدروجيل أعلى القيم لمعظم الصفات المدروسة مقارنة بباقي محسنات التربة المختبرة الأخرى في كلا الموسمين.

٣- أظهرت نتائج التفاعل أن ري نباتات فول الصويا كل 12 يوماً مع إضافة مركب الهيدروجيل قد أعطى أعلى قيم لكل من الوزن الجاف للعقد الجذرية، نشاط انزيم النيتروجينيز، صفات النمو المورفولوجية والفسيولوجية، عدد القرون/ نبات ، محصول البذور/ النبات ومحصول الفدان لكل من البذور والبروتين، في حين تم الحصول على أعلى قيم لكل من طول الجذر ومحصول الزيت/ فدان عند ري النباتات كل 16 يوماً مع اضافة مركب البولي أكريلاميد ومركب الهيدروجيل على التوالي في كلا الموسمين.

٤- تُشير النتائج إلى أن زيادة فترات الري حتي 16 أو 20 يوماً قد أدت إلى انخفاض تدريجي في كمية مياه الري المستهلكة قدرت بحوالي 18.62 و 27.82 ٪ على التوالي كمتوسط لموسمي الزراعة مقارنة بالري كل ١٢ يوم، هذا وقد أدى ري نباتات فول الصويا كل 16 يوم مع إضافة مركب الهيدروجيل إلى الحصول على أعلى قيم لكفاءة استخدام مياه الري مما يشير إلى أهمية إضافة مركب الهيدروجيل في زيادة نمو وإنتاجية محصول فول الصويا ورفع كفاءة استخدام مياه الري مقارنة بباقي المعاملات المختبرة الأخرى تحت ظروف التجربة بمحافظة المنوفية.