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Utilization of hydrogel for reducing water irrigation under sandy soil condition
2- Preliminary study: yield and yield components of rice and barley in sandy soil as affected by hydrogel.

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ABSTRACT

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. Effect of hydrogel in three rates (0.2%, 0.5%, 1%) and control (without) on yield, yield components of rice (*Oryza sativa L.*) followed by barley (*Hordum vulgare* L.) aims for reducing irrigation quantity to 75% from recommended amount under newly reclaimed sandy soil. Two greenhouse experiments were conducted during summer season of 2013 (rice) and winter season 2013/2014 in research and production station of National Research Centre, Al Emam Malek village, Al Nubarie district, Al Behaira Governorate, Egypt. Due to rice experiment results clear that treatment of 1% hydrogel had superiority on other treatments in all yield attributes, it produced the tallest plants (94.40 cm), the highest number of tillers/pot (16.00 g), the highest number of grains/panicle (90.00), the heaviest panicle (2.24 g), the highest grain yield/pot (9.89 g) , the highest biological yield/pot (50.00 g), the highest harvest index (19.78 %) and the highest protein % in grains (10.88%). Due to barley there were significant differences between treatments in leaf area index (cm^2) and total chlorophyll (SPAD) at 90 days after sowing DAS. Data revealed the superiority of treatment of 1 % hydrogel produced plants have highest leaf area 134.70 cm^2 and highest total chlorophyll 49.30 SPAD. There were significant differences between treatments in all studied characters. Treatment of 1% produced the tallest plants 78.00 cm. Treatment of 0.2 % hydrogel revealed the superiority in all other studied characters, it produced highest number of spikes/pot (28.80) ; the heaviest 1000-grains (30.0 g) ; the highest grain yield (30.20 g/pot) ; highest biological yield (130.00 g/pot) and the highest harvest index (23.23 %).

Key words: hydrogel - rice – barley - 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).

Rice (*Oryza sativa* L.) is after cotton, the second most important export crop for Egypt. About 0.5 million hectares are planted annually, giving a total production of some 6.1 million tones. There are good prospects of raising rice production in Egypt by improving cultivation techniques. Rice is considered to be a large water-consuming crop, especially when grown using the conventional irrigation method, with an average of more than 5000 L used to produce 1 kg of grain (Bahgat *et al*., 1996). Many Egyptian growers switched to dry leveling, a method that does not involve soil pudding, for rice cultivation as recommended by the Rice Research and Training Centre in Egypt (Abou El Hassan *et al*., 2006). Rice cultivation under this no pudding transplanting technique is used to save the irrigation water that is needed for pudding prior to transplanting the rice (Kumar *et al*., 2012) as well as reducing the pulk density and increase hydraulic conductivity of the soil (Bajpai & Tripathia, 2000) compared with pudding. Utilization of hydrogel may be an effective tool to insure soil moisture profile in the root zone which in turn in reducing amount of irrigation under sandy soil condition.

Barley (*Hordeum vulgare* L.) is a fast growing, cool season, annual grain crop that could be used as forage as well as cover crop to improve soil fertility (Ghanbari *et al*., 2012). It ranks fifth among crops in grain production in the world after maize, wheat, rice and soybean (Miralles *et al*., 2001; Ofosu-Anim and Leitch, 2009; Zeid, 2011; Soleymani and Shahrajabian, 2011). In 2013-2014, the total production of barley in the world was 140.10 million metric tons. (USDA, 2013). It is an important cereal crop in the world cultivated in temperate and subtropical areas. It ranks fourth with respect to area and production among cereals after wheat, rice and maize. It occupies about 9.4% of the total cereal acreage with about 7.8% of the total cereal production in the world. The total barley production in the world is 135.54 million tons in 2010-2011 (Agro-stats, 2010).The cultivated area of barley in Egypt was 67520, 82504 and 81000 hectares in 2011, 2012 and 2013 seasons. Most of cultivated area was in sandy soil for barley low irrigation requirements compared to other winter crops.

New reclaimed sandy soil in Egypt was sometimes exposed to drought stress at different periods of growth. A possible approach to minimize drought stress that induces crop losses is moisture in root growth zone. Irrigation is used to maintain the soil moisture profile in the root zone to field capacity and satisfied evapotranspiration requirement of each crop on any area, thus, utilization of hydrogel may be an effective tool to insure soil moisture profile in the root zone which in turn in reducing amount of irrigation under sandy soil condition .

Thus the aim of this work was to examine effect of three rates of hydrogel on yield and yield components of rice and barley with reducing irrigation to 75% from recommended.

MATERIALS AND METHODS

Two green house experiments were carried out during summer of 2013 and winter season 2013/2014 in Researches and Production Station of National Research Centre (NRC), Al-Nubaria District, Al Behaira Governorate, Egypt. The experimental soil before added hydrogel treatments was analyzed according to Chapman & Pratt 1978. Soil texture was sandy and its characteristics are shown in Table (1)

Location and climate of experimental site:

This experimental farm (latitude 30˚30'1.4''N, and longitude 30˚19'10.9''E, and mean altitude 21 m above sea level). The data of temperature and relative humidity were obtained from "Local Weather Station inside Researches and Production Station of National Research Centre (NRC). Summer is hot, with no rain, and mean air temperature in June, July, August and September was 25.50, 25.46, 26.06 and 24.71^{o} C, with mean relative humidity of 66.93, 75.47, 76.30 and 73.23. In winter mean air temperature was 18.60, 12.89, 12.45, 13.49 and 16.11 in November, December 2013, January, February, and March 2014, respectively.

Table (1): Mechanical and chemical analysis of experimental soil

Sand %	Silt %	Clay %	pH	Organic matter, %	CaCO3 %	E.C. dS/m	Soluble N, ppm	Available P, ppm	Exchangeable K, ppm
91.2	3.7	5.1	7.3	0.3	1.4	0.3	8.1	3.2	20

Sandy soil from wild zone in NRC station was used in rice experiment. Sowing date was 18 June 2013, earthenware pots 40 cm diameter and 30 cm in depth each one filled with 10 kg sandy soil then, treatment was done in 8 pots (replicates).

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

Treatments were:

A- Control without (hydrogel). B- 0.2% (hydrogel) - C- 0.5% (hydrogel) - D- 1% (hydrogel)

* Treatments were 4, replicates were 8 and experimental design was complete randomize design.

Seedlings of rice crop in age of 30 days, local variety (Giza – 178) transplanted by 3 seedlings/pot, its source was private farm in Shebeen –elkanater zone, Qalubia Governorate – Egypt. Fertilization of NPK at rate of (67:16:24)/feddan (4200 m^2) equal 4.10 g/pot ammonium nitrate 33.5 % N + 1.69 g/pot superphosphate 15.5 % P_2O_5 + 0.85 g/pot potassium sulfate 48 % K_2O. P and K added before transplanting but N was added at three portions at 35, 55and 75 days after transplanting.

Irrigation by drip method was used at rate of 0.067 m^3/pot during season which identifies 75% from recommended dose (0.090 m^3/pot) = (9000 m^3/feddan). Hand hoeing of weeds was done at 21 and 35 days after sowing then, take two rice plants/pot.

At harvest the following parameters were recorded:-

Plant height (cm) – number of tillers/plant – number of grains/panicle - panicle weight (g) –grain yield (g/pot) – biological yield (g/pot) – harvest index = grain yield/pot/biological yield/pot % – protein % in grains.
Due to barley experiment sown date was 16 November 2013, the experimental variety was Giza-123 (local), its source was Ministry of Agriculture, Egypt. The same pots used in rice experiment were used in barley experiment. Irrigation by drip method was used at rate of 0.020 m^3/pot during season which identifies 75% from recommended dose (0.026 m^3/pot). Hand hoeing of weeds was done at 21 and 35 days after sowing then, take three barley plants/pot.

Fertilization of NPK at rate of (45:32:48)/feddan (4200m^2) equal 2.76 g/pot ammonium nitrate 33 % N + 1.68 g/pot superphosphate 15.5 % P_2O_5 + 0.85 g/pot potassium sulfate 48 % K_2O.
At 90 days after sowing (DAS) leaf area (cm^2) and total chlorophyll (SPAD) were determined.

At harvest the Following parameters were recorded:-

Plant height (cm) – Number of spikes/pot – 1000-grains weight (g) – Grain yield (g/pot)– Biological yield (g/pot) – harvest index = Grain yield/biological yield %.

Statistical analysis:

The experimental design was complete randomize design in eight replicates in both experiments (rice – barley). At harvest the obtained data were statistically analyzed according to Snedecor and Cochran (1990), treatments means were compared using least significant differences LSD at probability level of 5 %.

RESULTS AND DISCUSSION

1- Rice:

Data presented in Table (2) show significant differences between treatments in all studied characters. Results clear that treatment of 1% hydrogel had superiority on other treatments in all yield attributes. Treatment of 1% hydrogel produced the tallest plants (94.40 cm), the highest number of tillers/pot (16.00 g), the highest number of grains/panicle (90.00), the heaviest panicle (2.24 g), the highest grain yield/pot (9.89 g), the highest biological yield/pot (50.00 g), the highest harvest index (19.78 %) and the highest protein % in grains (10.88%).

Treatment of 0.5 % hydrogel recorded the second order in all studied characters except for harvest index and protein % in grains it came in the third order. Treatment of 0.2 % hydrogel was second in harvest index and protein % in grains but it recorded the third order in all other characters. Control (without hydrogel recorded the lowest values in all studied characters.

Results revealed that all studied characters increased with increasing hydrogel rates from 0.2 % to 0.5 % to 1 % and the lowest values recorded in the control (without hydrogel), these results were results were in accordance with those obtained by Vieeo *et al*., 2000 who reported that hydrogel amendments in sandy soil promoted seedlings survival and growth when hydrogel was applied in combination with irrigation. Contrasting results may be related to the soil texture, thus hydrogel application in sandy soils promotes an increase in water retention capacity and plant water potential in trial had different concentrations of the hydrogel were added to sandy soils at 0.04, 0.08, 0.12, 0.20 and 0.40% weight by weight. Huttermann *et al*., 1999; Abedi-Koupai and Sohrab 2004 pointed nearly, also, they reported that the hydrogel allowed for 19 days tolerating drought.

Jahangir *et al*., 2008, stated that application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils and it is important in arid and semi-arid regions of the world for enhancing the water management of coarse-textured soils.

It can be concluded that treatment of (1 %) hydrogel addition to sandy soil under trial condition may be effective tool to reduce water leaching from soil. Results indicated that supplement study is needed under field condition with reducing irrigation rates to 75, 50, and 25 % from recommended to test effect of hydrogel on reducing irrigation amount and show clear of hydrogel under field condition.

Table (2): Effect of (hydrogel) rates on yield and yield components of rice in sandy soil (summer season of 2013)

Characters / Treatments	Plant height (cm)	No. of tillers/ pot	No. of grains/ panicle	Panicle weight (g)	Grain yield/pot (g)	Biological yield/pot (g)	Harvest index (%)	Protein % in grains
Control	80.00	10.00	62.00	1.06	4.08	21.50	18.97	10.00
0.2%	82.00	12.40	73.80	1.88	7.12	36.44	19.53	10.82
0.5%	89.20	14.20	82.00	2.10	8.12	44.20	18.37	10.42
1%	94.40	16.00	90.00	2.24	9.89	50.00	19.78	10.88
LSD (0.05)	1.18	0.82	2.16	0.48	1.20	2.48	0.16	0.12

2- Barley:

Table 3 shows the differences between treatments in leaf area index (cm^2) and total chlorophyll (SPAD) at 90 days after sowing DAS. Data revealed the superiority of treatment 1 % which produced plants have highest leaf area 134.70 cm^2 and highest total chlorophyll 49.30 SPAD. Treatment of 0.5% came in the second order, 0.2 % the third and control was the fourth in leaf area. Due to total chlorophyll 0.5 % recorded the second 45.70 followed by 0.2 % (40.06) and control (37.20).

It can be concluded that treatment of 1 % hydrogel saving more moisture in root elongation zoon of Barley plants than other treatments which reflect on Barley leaves growth rate and contents of chlorophyll. Results are near with those obtained by Jahangir Abedi Koupai *et al*., 2008 who reported that the maximum effect of polymer addition on the leaf area is related to control, 6 and 4 kg^{-1}, respectively, also, indicated that there is a significant effect of 66 % evapotranspiration Etc on the leaf area compared with the 33 % Etc.

Table (3) Effect of hydrogel rates on leaf area and total chlorophyll of Barley plants at 90 DAS during winter season of 2013/2014 season.

Characters / Treatments	Leaf area (cm^2)	Total chlorophyll (SPAD)
Control (without hydrogel)	109.61	37.20
0.2 %	113.31	40.60
0.5 %	114.10	45.70
1 %	134.70	49.30
LSD at 0.05 % level	0.84	1.20

Data presented in table 4 show the effect of hydrogel treatments on yield and yield components of Barley plants sown in sandy soil. There were significant differences between treatments in all studied characters. It is clear from data that treatment of 0.2 % hydrogel had superiority in all studied characters, it produced the tallest plants (82 cm) ; highest number of spikes/pot (27.2) ; the heaviest 100-grains (39.8 g) ; highest biological yield (156.8 g/pot) ; highest grain yield (32.4 g/pot) and the highest harvest index (20.66 %). Treatment of 0.5 % recorded the second order in all studied characters, control was the third and 1 % was the fourth in all studied characters. It can be concluded that superiority of 0.2 % treatment may be due to saving balanced moisture compared to other treatments and/or control in root elongation zone of Barley plants during growth stage which pointed in leaf area and total chlorophyll and during maturity which reflect on Barley yield and yield components. Results are in harmony with those obtained by Jahangir Abedi Koupai *et al*., 2008 who reported that application of 4 and 6 g/kg-1 of Superab A200 (polymer) addition in sandy loam soil enhanced the available water content by 2.2 and 2.3 times as compared to the control, also, Allahdadi *et al*., 2005, who studied the impact of Superab A200 (polymer) on *Zea mays* yield and yield components.

Table (4) Effect of hydrogel rates on yield and yield components of wheat plants at winter season of 2013/2014 season.

Chracters / Treatments	Plant Height (cm)	No. of Spikes/ Pot	1000 Grains Weight (g)	Grain Yield (g/pot)	Biological Yield (g/pot)	Harvest Index (%)
Control (without hydrogel)	66.20	16.40	35.20	25.20	139.60	18.05
0.2 %	82.00	27.20	39.80	32.40	156.80	20.66
0.5 %	78.40	23.00	36.00	28.20	140.00	20.14
1 %	60.20	14.80	32.00	22.00	128.20	17.18
LSD at 0.05 % level	1.20	0.82	0.44	0.64	1.08	0.42

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