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Utilization of hydrogel for reducing water irrigation under sandy soil condition 5-Yield and yield components of potato (*Solanum tuberosum* L.)as affected by hydrogel and drought stress in sandy soil.

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ABSTRACT

Field experiment was carried out during summer season of 2014 in research and production station of National Research Centre NRC, Al Emam Malek village, Al Nubarie district, Al Behaira Governorate, Egypt. Effect of hydrogel at rate of 8 g/m2 and control (without) and four irrigation quantity (100%, 75%, 50% and 25% from recommended quantity) which were 3000 ; 2250 ; 1500 ; 750 m^3/feddan on yield, yield components of potato (*Solanum tuberosum* L.) variety (sponta) was studied under newly reclaimed sandy soil. 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. Data clear that hydrogel at the rate of 8g/m2 recorded higher values than control in all studied characters. Treatment of 100% recommended irrigation quantity recorded the best values in all studied characters except IWUE. Reducing irrigation to 75% from recommended produced results identify 89% in plant height; 92% in no. of branches/plant; 89% in no. of tubers/plant; 84% in tubers fresh yield/plant; 86% in tubers fresh yield /feddan and 45% in IWUE from the best.Interaction of hydrogel 8 g/m2 and 75% recommended irrigation quantity recorded results identify 90% to 99% from the best and reduced 25% from irrigation quantity. IWUE increased with decreased irrigation quantity either sole or in combination with hydrogel treatment.

Keywords: Hydrogel - Potato- Irrigation quantity - Drought stress

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INTRODUCTION

Potato (*Solanum tuberosum* L.) rates fourth among the world agricultural products in production volume Faberio *et al*., 2001. According to World Potato Centers research, worldwide demand for potatoes will exceed that of rice, wheat or corn by 2020. Potato is considered one of the most important vegetable crops in Egypt. Its harvested area was $178x10^3$ ha in 2013 season produced 48 x 10^5 tones, Faostat 2014.Yuan *et al*., 2003 revealed that potato (*Solanum tuberosum* L.) is a relatively sensitive plant to water stress and is widely planted in different soils. Shalhevet 1983 stated that potato is a temperate crop, that grows and yields well in cool and humid climates or seasons, yet it is grown in climatic regions from its tropics to the sub-polar, and comprises a major food crop in many countries. Opena and porter 1999 stated that potato is relatively sensitive to moisture stress because it has a sparse root system and approximately 85% of the root length is concentrated in the upper 0.3 m soil layer. (Stalham and Allen 2001) pointed that the maximum rooting depth of potato ranged from 59 to 140 cm indicating that potatoes can root to considerable depths and thereby have access to large volumes of water to satisfy the potential demand for water created by the atmospheric conditions and the size of the canopy. The size of the wetted zone can be increased if irrigation is frequent Eric *et al*., 2004. High frequency irrigation enhanced potato tuber growth and water use efficiency, Feng-Xin *et al*., 2006. A possible approach to minimize drought stress that induces crop losses is moisture in root growth zone.

The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability. 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 the 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 hydrogel 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 benefits of hydrogel such as reducing surface soil water evaporation, decreasing fertilizers leaching, enhancing growth and yield has been documented by different researchers. Hydrogel 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).

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. Waly *et al*., 2015a concluded that treatment of (0.2 % hydrogel to soil) weight /weight may be effective tool to reduce water leaching from soil and recorded 93.4 % in seed yield, 95.3 % in biological yield, 92.9 % in 100 seed weight and 98.3 % in oil % in seeds compared to the treatment of recommended dose of irrigation in sunflower grown in greenhouse. Waly *et al*., 2015b conducted trial with two crops rice in summer and barley in winter they revealed that treatment of 1% hydrogel to soil weight / weight in rice crop had superiority on other treatments, it produced the tallest plants, the highest no. of tillers/pot, the highest no. of grains/panicle, the heaviest panicle, the highest grain and biological yield/pot, the highest harvest index and the highest protein % in grains. Due to barley data revealed the superiority of treatment of 1 % hydrogel produced plants have highest leaf area (cm^2) and highest total chlorophyll (SPAD) also, the tallest plants. Treatment of 0.2 % hydrogel produced highest no. of spikes/pot; the heaviest 1000-grains; the highest grain, biological yields and the highest harvest index. El-karamany *et al*., 2015 in field trial on sugar beet clear that treatment of watering hydrogel for 48 hours at 90 DAS produced the highest fresh biological, shoot and root yields per plant also, leaf area and total chlorophyll, at harvest it produced highest fresh biological yield; fresh shoot weight; fresh root yield ton/fed. and root diameter but control (without hydrogel) recorded the highest root/shoot and root length. Due to technological characters of sugar beet roots treatment of watering hydrogel for 48 hours recorded the highest impurities and quality but recorded the lowest amino N; Na and near the lowest in K. Due to fertilizers use efficiency treatment of watering hydrogel 48 hours raised N,P and K use efficiency by sugar beet 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.

Thus the aim of this work was to examine effect of hydrogel in two rates (8 g/m^2 -control without) and four irrigation quantity (100%, 75%, 50% and 25% from recommended irrigation quantity which were 300, 2250, 1500, 750 m^3/fed. respectively on yield, yield components of potato (*Solanum tuberosum* L.) variety (sponta) under newly reclaimed sandy soil.

MATERIALS AND METHODS

Field experiment was carried out during summer of 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)

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

Sand %	Silt %	Clay %	pH	Organic matter, %	CaCo^3 %	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

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)

Temperature averages (^{o}c) during trial period were March (25.0) – April (25.5) – May (25.6) – June (26.2). Humidity average (%) were March (67.0) –April (75.8) – May (76.0) – June (76.5) respectively.

The experiment design was complete randomized block design in three replicates Snedecor and Cochran (1990). Area of each plot was 45 m^2 (6 rows x 0.50m width x 15m length). Ditches 0.5 m in width were done and hydrogel treatments were added in the ditches then covered with soil to make rows. Potato seed (variety Sponta imported from Netherland) pieces were hand-cut to average weight about 30 g per seed piece, planted on 15 March for nursing the buds, and then planted to the field plots on 20 March at about 0.1 m depth below the soil surface. Distance between rows was 0.5 m and plants with a 0.25 m spacing between plants in a row. The density of plants was 8/m^2. There are eight treatments that they are two factors:-

- Hydrogel in the rate of 8 g/m^2 – control (without hydrogel)
- Recommended irrigation quantity (3000 m^3/feddan) – 75% recommended (2250 m^3/fed.) – 50% recommended (1500 m^3/fed.) – 25% recommended (750 m^3/fed.) respectively.

Soil was immediately irrigated after sowing using sprinkler irrigation system. Plants were thinned to one plant per hill 35 days after sowing (DAS). Fertilization of NPK at rate of (45:32:48)/feddan (4200m^2) in the form of ammonium nitrate 33%N ; superphosphate 15.5%P_2O_5 and potassium sulfate 48%K_2O. All cultural practices for potato were done. The potato tuber harvested on 1 July.

At 100 DAS total yield of each plot (45 m^2) was harvested to determine tubers fresh yield per feddan and ten plants were randomly chosen from two central rows in each plot then the following characters were determined:-1-Plant height(cm.) 2-Number of branches/plant. 3-Tubers fresh yield/plant. 4- Number of tubers/plant. 5- Tubers fresh yield (ton/fed.) 6- Irrigation Water Use Efficiency (IWUE).

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

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 %.

Irrigation water use efficiency = (IWUE) is the relation between yield and quantity of irrigation consumed. Days after sowing (DAS). Sponta is imported variety from Holland.

RESULTS AND DISCUSSION

Effect of hydrogel

Data presented in Table (2) and figure (1) show significant differences between treatment of hydrogel at the rate of 8 g/m^{2}and control (without hydrogel) in all studied characters.

Table (2): Effect of (hydrogel) on yield and yield components of potato in sandy soil (summer season of 2014).

Hydrogel	Plant height (cm)	Number of branches /plant	Number of tubers /plant	Tubers fresh yield (kg/plant)	Tubers fresh yield (ton/fed.)	Irrigation Water use efficiency (IWUE)
without	34.0	3.44	8.17	0.529	7.85	4.18
With 8 g/m^2	48.4	5.58	16.65	1.150	13.80	7.36
LSD 5%	4.20	1.24	2.48	0.420	2.60	0.36

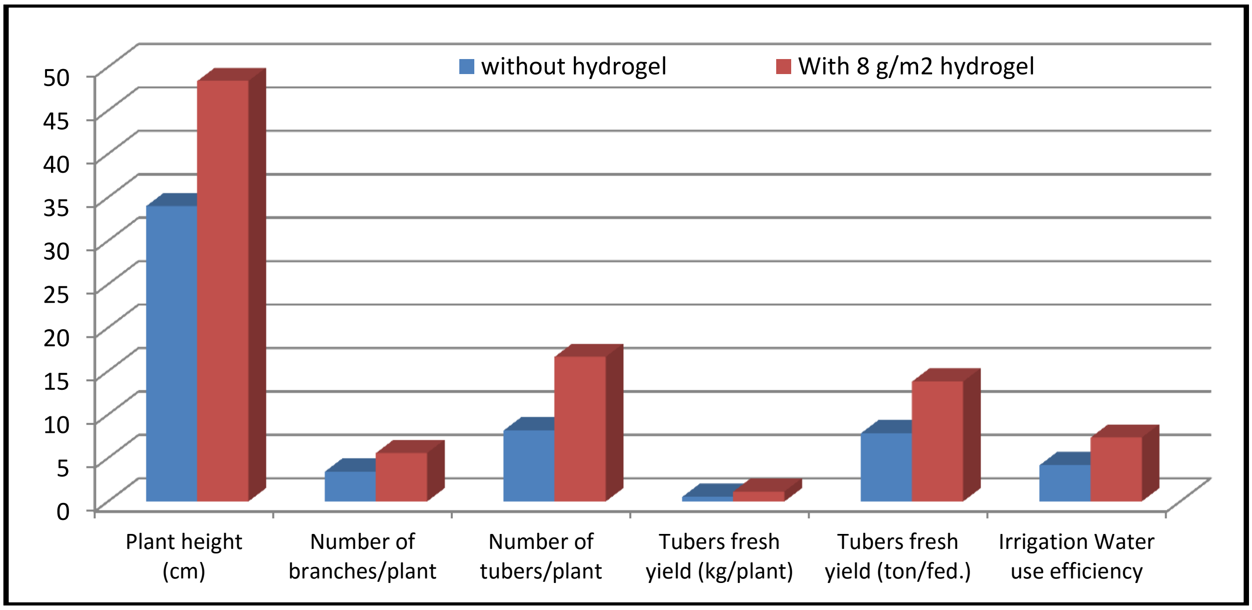

Figure (1) Effect of hydrogel on yield and yield components of potato.

It is clear from data in Table 2 that treatment of addition hydrogel at the rate of 8 g/m^2 surpassed control (without hydrogel) in all studied characters. It produced the taller plants than control by 142% the higher number of branches per plant by 162% ; the higher number of tubers/plant by 203% ; the higher tubers fresh yield/plant by 217% also, the higher tubers fresh yield per feddan by 175%. Results were in accordance with those obtained by Callaghan *et al*., (1988, 1989) who found that hydrogel amendments in sandy soils promoted seedlings survival and growth under arid conditions. Viero *et al*., (2000) under similar conditions found an increase in seedling growth when hydrogel was applied in combination with irrigation. Jahangir *et al*., 2008 revealed that application of hydrogel can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils. Waly *et al*., 2015a concluded that treatment of (0.2 % hydrogel to soil) weight / weight may be effective tool to reduce water leaching from soil and recorded increase by 93.4 % in seed yield, 95.3 % in biological yield, 92.9 % in 100 seed weight and 98.3 % in oil % in seeds compared to the treatment of recommended dose of irrigation in sunflower grown in greenhouse. Waly *et al*., 2015b and Elkaramany *et al*., 2015 revealed results near obtained data on rice, barley in greenhouse and sugar beet in field trial.

Effect of irrigation quantity

Data presented in Table 3 and figure (2) show significant differences between treatments in all studied characters. Treatment of 100% recommended irrigation quantity had superiority in all characters. Reducing irrigation quantity to 75% recommended recorded 89% in plant height, 92% in no. of branches/plant, 89% in no. of tubers/plant, 84% in tubers fresh yield/plant and 86% in tubers fresh yield/fed. compared to the best. Reducing irrigation quantity to 50% and 25% from recommended reduced all studied characters in descending order except for irrigation water use efficiency. Results trend is logic because water stress causes reduction of yield by reducing growth of crop canopy and biomass also, water at 3.5 m per day is necessary for evapotranspiration (ET) and maintenance of optimal soil moisture tension (10-50 kpa) in growing potatoes Marutani and Cruz., 1989. Opena and porter 1999 stated that potato is relatively sensitive to moisture stress because it has a sparse root system and approximately 85% of the root length is concentrated in the upper 0.3 m soil layer.

Table (3): Effect of irrigation quantity on yield and yield components of potato in sandy soil (summer season of 2014)

Water requirements %	Plant height (cm)	Number of branches /plant	Number of tubers /plant	Tubers fresh yield (kg/plant)	Tubers fresh yield (ton/fed.)	Irrigation Water use efficiency (IWUE)
100	48.0	5.41	16.00	1.10	13.90	4.63
75	43.0	4.99	14.20	0.92	11.90	5.28
50	41.0	4.66	12.75	0.78	9.85	6.56
25	33.0	3.00	6.70	0.56	7.65	10.20
LSD 5%	1.20	0.64	1.32	0.24	1.20	1.48

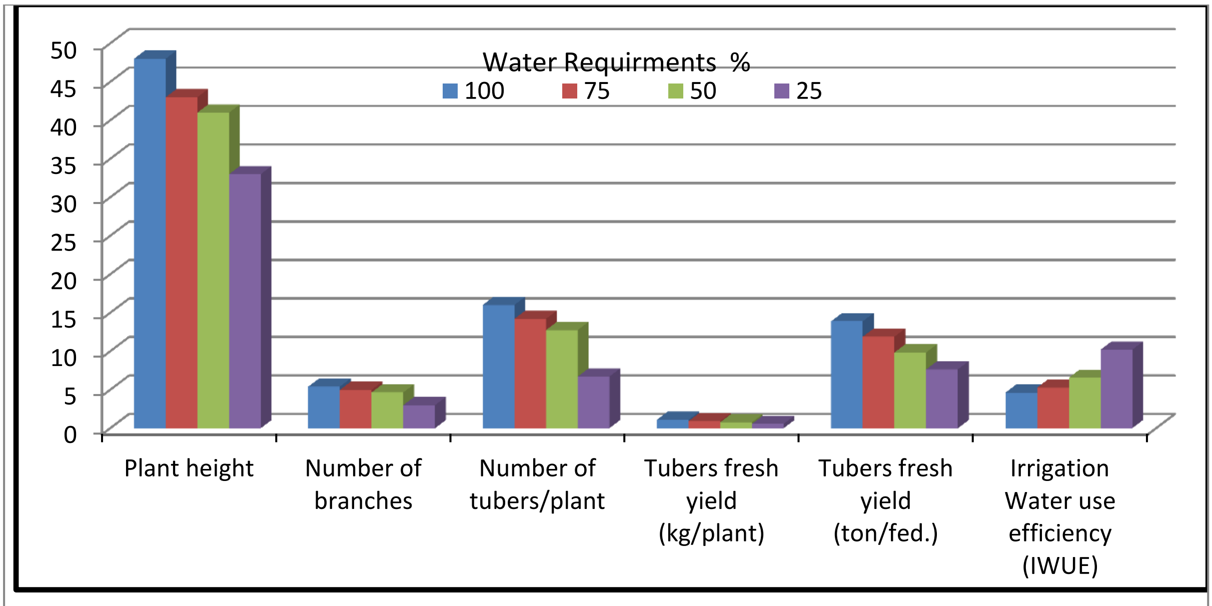

Figure (2) Effect of Irrigation quantity on yield and its components of potato.

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Interaction of hydrogel and irrigation quantity.

Data presented in table 4 and figure 3 show significant differences between interactions in all studied characters. It is clear from table 4 that interaction of hydrogel 8 g/m^2 and 100% recommended irrigation quantity produced the tallest plants had highest no. of branches, no. of tubers/plant, highest tuber fresh weight per plant and per feddan. Interaction of hydrogel 8 g/m^2 and 75% recommended irrigation quantity recorded 97% in plant height, 99% in no. of branches/plant, 93% in no. of tubers/plant, 90% in tubers fresh yield per unit area. interaction of hydrogel 8 g/m^2 and 50% recommended irrigation quantity recorded values identify 85% - 97% in all studied characters also, interaction of hydrogel 8 g/m^2 and 50% recommended irrigation quantity recorded values ranged from 50 to 76% from the best.

Table (4) Effect of Interaction between hydrogel and irrigation quantity on yield and yield components of sunflower in sandy soil (summer season of 2014).

Hydrogel	Water requirements %	Plant height (cm)	Number of branches /plant	Number of tubers /plant	Tubers fresh yield (kg/plant)	Tubers fresh yield (ton/fed.)	Irrigation Water use efficiency (IWUE
without	100	43.4	4.62	12.00	0.852	12.20	4.06
	75	35.0	3.84	9.80	0.640	9.00	4.00
	50	31.2	3.32	7.50	0.400	6.50	4.30
	25	26.5	2.00	3.40	0.225	3.70	4.90
with	100	52.4	6.20	20.00	1.342	15.6	5.20
	75	51.0	6.14	18.60	1.200	14.80	6.57
	50	50.0	6.00	18.00	1.160	13.20	8.80
	25	40.0	4.00	10.00	0.900	11.60	15.46
LSD 5%		2.48	0.64	1.24	0.20	1.24	0.48

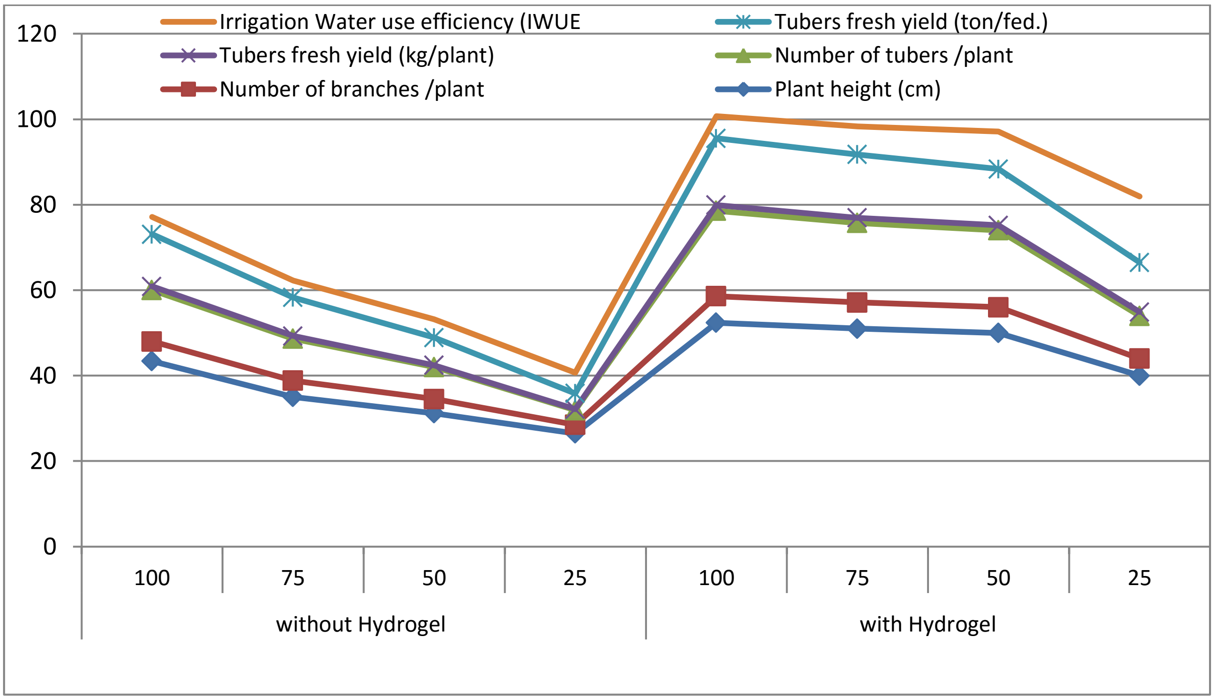

Figure (3) Interaction between hydrogel and water requirements on yield and its components of potato.

It can be concluded that interaction of hydrogel at the rate of $8g/m^2$ and 75% recommended irrigation quantity may be effective tool to reduce water leaching from soil and recorded results near the best treatment and reducing irrigation rates by 25% from recommended quantity without high lost in tuber yield/feddan.

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