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Utilization of Hydrogel for Reducing Water Irrigation Quantities on Two Wheat Cultivars Grown under Sandy Soil Conditions

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Abstract: Two field experiments were conducted at Researches and Production Station of National Research Centre (NRC), Alemam Malek village, Al-Nubaria district, Al Behaira Governorate, Egypt in two winter of 2014/2015 and 2015/2016 seasons. Each experiment included two factors:- 1- Two cultivars (Sids-12 and Gemmeiza-11) 2- Five irrigation quantities four with hydrogel (25% recommended irrigation quantity = 525 m^3/feddan) - (50% recommended irrigation quantity = 1050m^3/feddan) - (75% recommended irrigation quantity = 1575m^3/feddan)- (100% recommended irrigation quantity = 2100m^3/feddan) and (100% recommended irrigation quantity = 2100m^3/feddan without hudrogel as control). The experimental design was split plot design in 3 replicates where irrigation treatments were distributed in main plots and cultivars were randomly arranged in the sub plots. The obtained results showed that Gemmeiza-11 produced taller plants had higher no. of spikes/m^2; grain yield/spike; grain, straw, bio- yields/fed. but Sids-12 produced higher spiklets/spike; bio-yield/tiller and harvest index. Data revealed that the treatment of 75% recommended irrigation quantity with hydrogel surpassed the other treatments in most studied characters and 50% came in the first order in plant height, spike length and spikelet's/spike but the best straw yield/fed. recorded by 100% recommended irrigation. Interaction of Sids-12 x 75% water irrigation quantity produced the highest values in both important characters grain and straw yields/feddan with increase in rate 41.1 % and 35.6% compared to control.

Key words: Hydrogel · Wheat cultivars · Water irrigation · Grain yield and quality

INTRODUCTION

Wheat is the most important and widely grown cereal crop in the world through many properties and uses of its grains and straw. Decreasing the gap between production and consumption is the main objective under Egyptian conditions. It could be achieved by increasing cultivated area, promising varieties and reducing irrigation and fertilizers.

Wheat production in Egypt increased from 2.08 in 1983 to 9.27 million ton in 2014. This increase was achieved by increasing wheat area from 1.83 to 3.42 million fed. /year in the same period [1].

Varieties are one of the most important factors for horizontal expansion and increasing wheat production, through its variability in yield, drought and salinity tolerant, Metwally *et al*., [2]; Sultan *et al*., [3]; Zaki *et al*., [4]; Abdel-Ati and Zaki [5].

Wheat plants are sometimes exposed to drought stress in desert land under Egyptian condition at different periods of growth especially under sandy soil condition which use sprinkler and/or drip irrigation system. 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. Hussein [6], Mousa and Abdel-Maksoud [7], EI-Afandy [8] and Fang *et al*., [9] found that subjecting wheat plants to drought-stress resulted in a significant reduction in grain yield and its components of wheat.

Hydrogel is a promising approach to minimize drought stress that induces crop losses from moisture in root growth zone. Hydrogels are super absorbents that absorb and store water hundreds of times their own weight, i.e. 400-1500 g water per one dry gram of hydrogel Johnson, [10]; Bowman and Evans [11]. Water held in the expanded hydrogel is intended as a soil reservoir for

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maximizing the efficiency of plant water uptake. Hydrogels have been used to establish tree seedlings and transplants in the arid regions of Africa and Australia to increase plant survival Save *et al.,* [12]; Specht and Harvey Jones [13]; Callaghan *et al.,* [14, 15] found that hydrogel amendments in sandy soils promoted seedlings survival and growth under arid conditions, while Viero *et al.,* [16] 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.,* [17]; Abedi-kaoupai and Sohrab [18] while in loamy and clay soils the effect may be negligible. Jahangir *et al.,* [19] revealed that application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils.

Hydrogel can be used as low input technology in agriculture by improving water use efficiency in arid land and sandy soil especially with low salt concentration saline water irrigation also, decreasing Nitrogen leaching from sandy soil instead of high cost of other methods as use split N application and/or utilize slow-release fertilizers. Under same condition in Egypt Waly *et al*., [20] pointed the excellent effect of hydrogel on rice and barley also, Waly *et al*., [21] resulted best effect on wheat and sunflower both experiments in pot trials also, in Egypt El-karamany *et al*., [22] on sugar beet; El-karamany *et al*., [23] on sunflower and Waly *et al*., [24] on potato in field trials revealed positive effect of hydrogel in reducing irrigation quantity, increasing the water-holding capacity, water use efficiency, preventing nutrient leaching and fertilizers use efficiency also, decrease nutrients lost from rooting zone in sandy soil. Therefore the objective of this study to investigate the role of hydrogel as super water absorbent on yield and yield components of two wheat cultivars with reducing recommended water irrigation quantity.

MATERIALS AND METHODS

Field experiment was conducted at researches and production station of National Research Centre NRC, Al Emam Malek Village, Al-Nubaria District, Al Behaira Governorate, Egypt. Sowing date was 17 and 15 November in both seasons. Two wheat cultivars Sids-12 and Gemmeiza-11 sown by broadcast method in the seeding rate of 60 kg/feddan under sprinkler irrigation system, distance between valves (sub line) was 8 m and between sprinklers (3/4 inch) was 10 m. Area irrigated by each valve consisted of 5 sprinklers was 8 m width x 50 m Length = 400 m^2. Experiment included two factors:-

- Cultivars were two (Sids-12 and Gemmeiza-11)
- Irrigation quantity were five treatments:

Percentage of recommended irrigation quantity (%)	25 %+ hydrogel (4 g/m^2)	50 %+ hydrogel (4 g/m^2)	75 % + hydrogel (4 g/m^2)	100 % + hydrogel (4 g/m^2)	100 % without hydrogel
Water amount (m^3)					
Valve read	50	100	150	200	200
Water amount per feddan (4200 m^2)	525	1050	1575	2100	2100

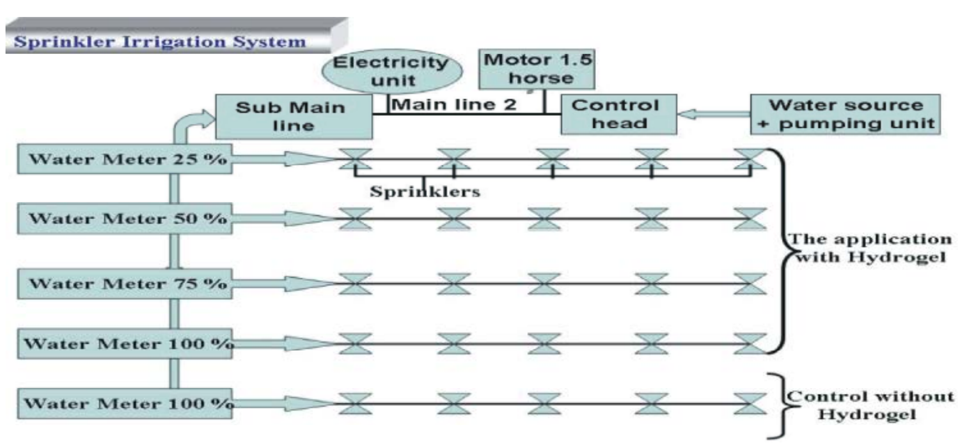


Fig. 1: Automatical sprinkler irrigation system.

Table 1: Mechanical and chemical analysis of soil according to Chapman and Pratt [25].

Sand (%)	Silt (%)	Clay (%)	Ph	O.M (%)	Ca Co3	E.c ds/m	N (ppm)	P (ppm)	K (ppm)
92.3	3.1	4.6	7.4	0.3	1.3	0.3	8.0	3.0	19.8

Table 2: Meteorological data for AL-Nubaria region in two winter of 2014/2015 and 2015/2016 seasons.

Date	T_{max} (°C)	T_{min} (°C)	Wind speed, m s^{-1}	Sunshine (h)	Rainfall, mm	Humidity (%)	Radiation $MJm^{-2}day^{-1}$
November, 2014	22.7	11.5	4.4	10.1	0.0	84.0	9.7
December, 2014	21.7	8.6	4.5	9.6	0.1	80.6	8.8
January, 2015	18.4	6.9	3.4	9.7	0.9	78.6	8.9
February, 2015	18.9	8.0	4.3	10.4	1.0	80.0	10.4
March, 2015	22.4	10.1	4.7	11.4	0.1	80.5	48.3
April, 2015	22.6	10.7	4.4	12.7	1.0	79.5	17.1
May, 2015	32.2	16.5	4.5	12.9	0.0	38.6	27.3
November, 2015	22.8	11.1	4.5	10.0	0.1	85.1	9.8
December, 2015	22.0	9.2	4.3	9..7	0.2	81.0	8.9
January, 2016	17.9	7.3	4.0	9.6	15.0	61.2	12.0
February, 2016	23.1	9.1	3.8	10.4	0.0	53.9	11.4
March, 2016	25.3	10.9	4.2	11.4	2.0	46.1	19.3
April, 2016	32.2	14.0	4.2	12.8	0.0	38.6	24.4
May, 2016	33.2	17.0	4.5	12.0	0.0	38.6	27.3

Irrigation automatically system (IAS): was used as show in Figure (1) as follows:

- Main water pumping unit (20 horse) – 2- Main line 4 inch.
- Main line of IAS was 2 inch – 6 bar. 4- Control head 1.5 inch (Made in Turkey)
- Motor 1.5 horse – 220 volt – Calbida NGM 32E. 6- Electricity unit (5 control key 220 volt). 7- Water meter (Made in Turkey). 8- Sub main line (1.5 inch – 10 bar). 9- Sprinklers 3/4 inch.

Hydrogel Preparation: Super absorbance starch (Hydrogel), in double jacketed reactor (60 litter capacity) equipped with condenser, variable speed motor temperature controller and heater, was added 40 litter water and 4 kg starch, the temperature was raised to 95 °C for 30 minutes (starch gelatinization), the temperature of the content was adjusted again to 55 °C with addition of 20 cm^3 of emulsifier, followed by the addition of acrylonitrile (AN) 4kg. The obtained product was agitated for 20 minutes, followed by the addition of suitable redox system as polymerization initiator during 30 minutes. After which the polymerization reaction was continued for another 3 hours, followed by the addition of 0.6- 0.7 equivalent to the AN amount of Na OH or K OH. the temperature was raised again to 90 °C until the obtained ammonia was seased.. The obtained hydrogel was filtered, dried and milled.

Materials Used Commercial Product Without Purification: Acrylonitrile (AN), Corn starch, Sodium hydroxyl and emulsifier.

The experimental design was sub plot design; which irrigation treatments in the main plots and cultivars randomly arranged in sub plots in 3 replicates.

Mechanical and chemical analyses of experimental soil before addition of hydrogel are presented in Table (1).

Harvest date took placed at 140 days after sowing (DAS). Ten plants were harvested randomly from each treatment and the following characters were determined 1- plant height (cm) 2- spike length (cm) 3- No. of spikelet's/spike 4- biological yield/ tiller (g) 5- grain yield /spike (g). One $meter^3$ harvested to determine 6- No. spikes/m^2. The whole area of each treatment was harvested to determine characters measured per feddan (fed.) 7- Biological yield/fed. 8- Grain yield/fed. 9- Straw yield/fed. 10- Harvest index determined as ratio of grain yield/biological yield %. 11- Irrigation water use efficiency (IWUE).

Feddan (local area unit) = fed. = 4200 m^2.

The data were statistically analyzed as split plot design according to Snedecor and Cochran [26] Means were compared by using least significant difference (LSD) at 5%.

RESULTS AND DISCUSSION

Effect of Cultivars: Data presented in Table (3) show the cultivars differed significantly in yield and yield components under sandy soil condition. Varietal differences showed that Gemmeiza-11 had superiority in the most important characters in wheat; it produced

Table 3: Effect of cultivars on yield and yield components of wheat under sandy soil condition. (Combined of 2014/2015 and 2015/2016 winter seasons)

Characters	Wheat cultivars Sids-12	Gemmeiza-11	$LSD_{0.05}$
Plant height (cm)	75.6	80.4	1.2
Spike length (cm)	10.33	9.93	n.s
No. spikes/m^2	251.01	291.34	1.82
No. spikelet's/spike	13.07	12.13	0.24
Biological yield/ tiller (g)	10.3	9.4	0.2
Grain yield /spike (g)	4.51	4.54	n.s
Biological yield (ton/fed)	2.98	3.08	0.03
Grain yield (ton/fed)	1.277	1.282	n.s
Straw yield (ton/fed)	1.7	1.8	0.02
Harvest Index (%)	42.85	41.62	0.16
IWUE (%)	103.14	103.71	n.s

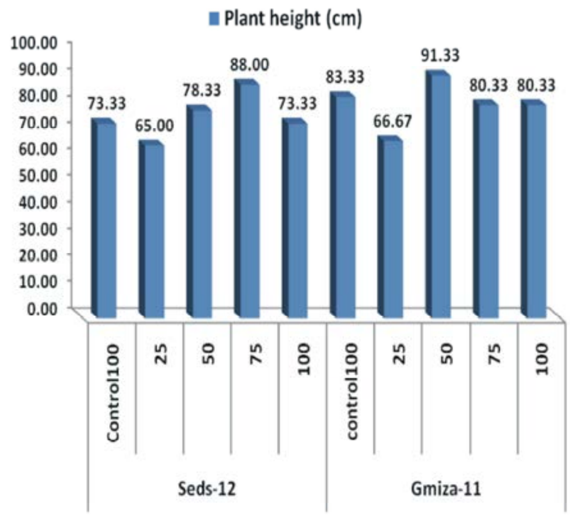
Table 4: Effect of irrigation quantities on yield and yield components of wheat under sandy soil condition. (Combined of 2014/2015 and 2015/2016 winter seasons)

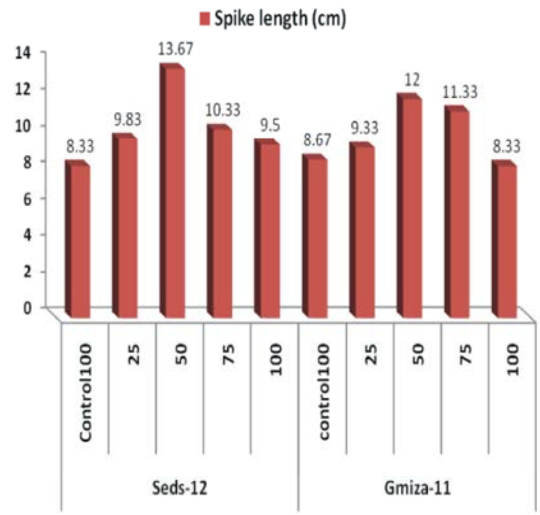
Characters	Water irrigation quantities control	25	50	75	100	$LSD_{0.05}$
plant height (cm)	78.33	65.84	84.83	84.17	76.83	3.22
spike length (cm)	8.5	9.58	12.84	10.83	8.92	0.48
no. spikes/m^2	255.57	219	279.36	317.04	284.91	5.36
no. spikelet's/spike	11.5	10.33	15.5	13.34	12.34	0.32
biological yield/ tiller (g)	9.25	7	11	11.5	10.5	0.74
grain yield /spike (g)	4.6	3.73	4.79	4.82	4.69	0.12
Biological yield (ton/fed)	2.86	2.26	3.39	3.4	3.24	0.01
grain yield (kg/fed)	1.16	0.8	1.52	1.58	1.33	0.02
straw yield (ton/fed)	1.7	1.46	1.87	1.82	1.91	0.01
Harvest Index (%)	40.67	35.27	44.93	46.47	41.02	0.84
IWUE (%)	55.24	152.38	144.76	100.95	63.81	12.16

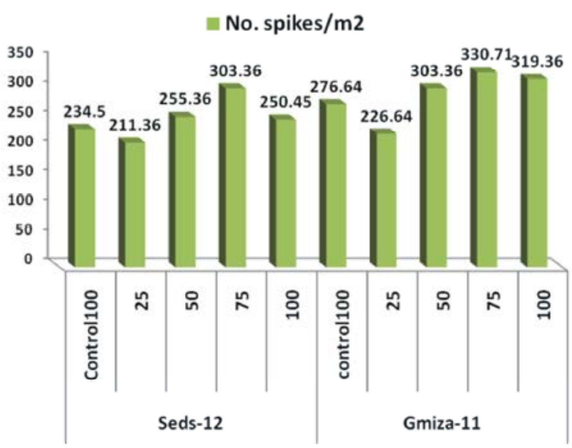
higher grains per spike or per feddan also higher straw and biological yields per feddan. It is clear from data that these increase was due, Gemmeiza-11 produced taller plants, higher number of spikes/m^2; higher grain yield/spike; higher grain yield (ton/fed.); higher biological yield (ton/fed.) and higher straw yield (ton/fed.) than Sids-12. Sids-12 cultivar surpassed Gemmeiza-11 in spike length; number of spikelet's/spike; biological yield (g/tiller) and harvest index (grain yield per feddan/biological yield per feddan). thus, it can be concluded that Gemmeiza-11 had more adaptability to environment condition in trial zone. Metwally *et al*., [2]; Sultan *et al*., [3]; Zaki *et al*., [4]; Abdel-Ati and Zaki [5] reported varietal differences in wheat under Egyptian conditions.

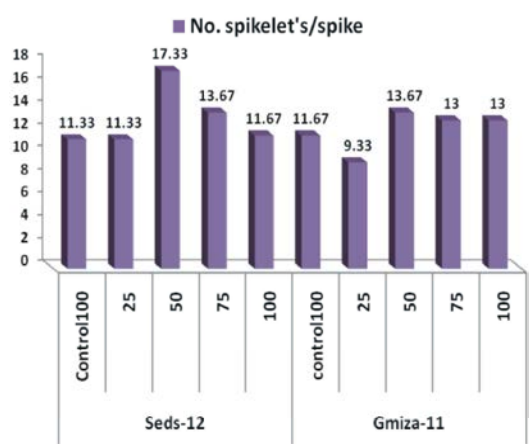
Effect of Water Irrigation Quantities: Data presented in Table 4 show the significant differences between water irrigation treatments 25%, 50%, 75% and 100% of the recommended water irrigation requirements combined with hydrogel addition and the control treatment. Data revealed that treatment of 75% water irrigation quantity with hydrogel produced the highest number of spikes/m^2 (317.04); the highest grain yield/spike (4.82g); the highest biological yield/tiller (11.5) and /feddan (3.40 ton); highest grain yield/feddan (1.548 ton) also, the highest harvest index (46.47%). Meanwhile, the treatment of 50% recommended irrigation quantity produced the tallest plants (84.83 cm); the highest spike length (12.84 cm) and the highest no. of spikelet's/spike (15.5). Wheat treatment with 100% recommended water irrigation quantity + hydrogel gave the heaviest straw yield per feddan (1.91 ton). Wheat treatment with 25% water irrigation quantity + hydrogel gave the highest value of irrigation water use efficiency (152.38 %).

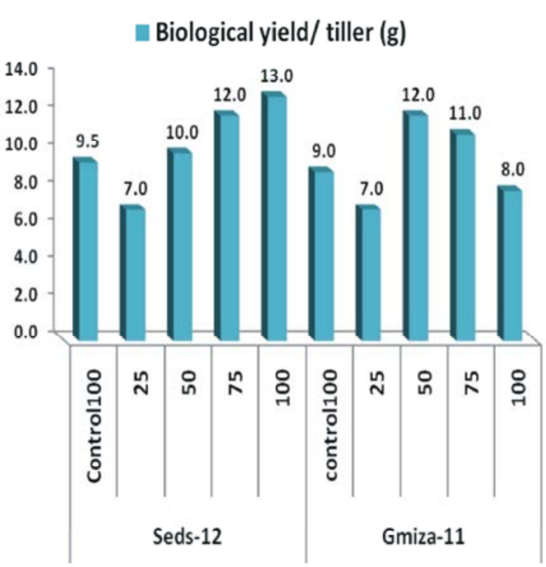
Effect of Interaction Between Wheat Cultivars and Irrigation Quantities: Table (5) and Fig. 2 showed significant effect of interaction between the two wheat cultivars and different water irrigation quantities with hydrogel on yield and yield components. Data revealed that the interaction of Gemmeiza-11 x 50 % water irrigation

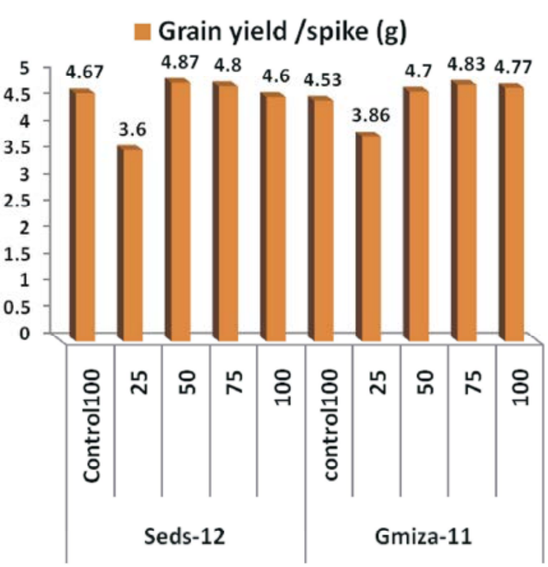

Plant height (cm)
73.33 65.00 78.33 88.00 73.33 83.33 66.67 91.33 80.33 80.33
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11


Spike length (cm)
8.33 9.83 13.67 10.33 9.5 8.67 9.33 12 11.33 8.33
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11


No. spikes/m2
234.5 211.36 255.36 303.36 250.45 276.64 226.64 303.36 330.71 319.36
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11


No. spikelet's/spike
11.33 11.33 17.33 13.67 11.67 11.67 9.33 13.67 13 13
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11


Biological yield/ tiller (g)
9.5 7.0 10.0 12.0 13.0 9.0 7.0 12.0 11.0 8.0
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11


Grain yield /spike (g)
4.67 3.6 4.87 4.8 4.6 4.53 3.86 4.7 4.83 4.77
Control100 25 50 75 100 control100 25 50 75 100
Seds-12 Gmiza-11

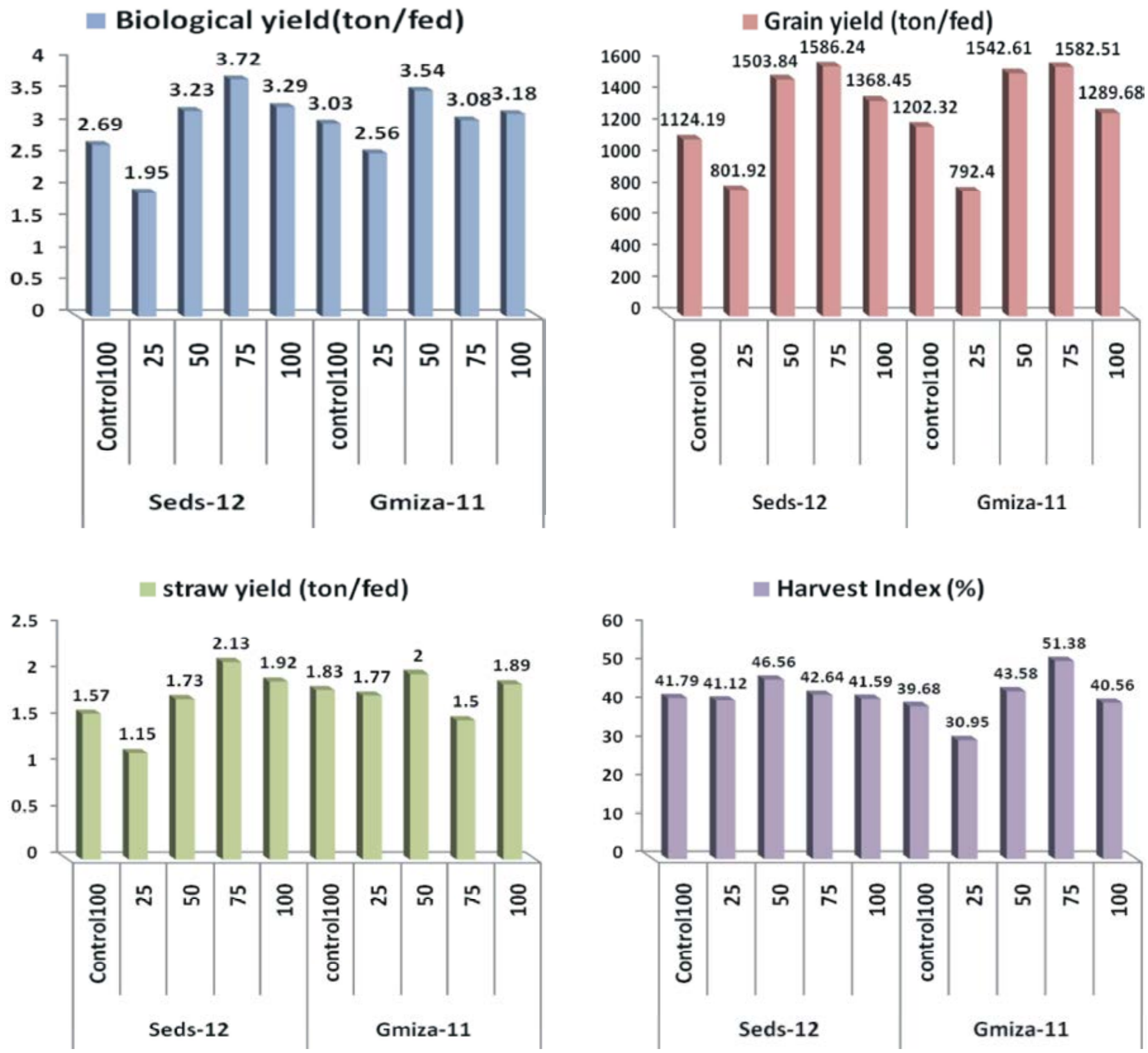


Fig. 2: Interaction between cultivars and irrigation quantities on yield and yield components of wheat under sandy soil condition. (Combined of 2014/2015 and 2015/2016 winter seasons).

Table 5: Interaction between cultivars and irrigation quantities on yield and yield components of wheat under sandy soil condition. (Combined of 2014/2015 and 2015/2016 winter seasons).

Varieties	Irrigation	Plant height cm	Spike length cm	No. spikes/m^2	No. spikelet's /spike	Biological yield/ tiller (g)	Grain yield /spike (g)	Biological yield /(ton/fed)	Grain yield /(ton/fed)	Straw yield (ton/fed)	Harvest Index %	IWUE %
Sids-12	Control	73.33	8.33	234.50	11.33	9.50	4.67	2.69	1.12	1.57	41.79	53.33
	25	65.00	9.83	211.36	11.33	7.00	3.60	1.95	0.80	1.15	41.12	152.38
	50	78.33	13.67	255.36	17.33	10.00	4.87	3.23	1.50	1.73	46.56	142.86
	75	88.00	10.33	303.36	13.67	12.00	4.80	3.72	1.59	2.13	42.64	100.95
	100	73.33	9.50	250.45	11.67	13.00	4.60	3.29	1.39	1.92	41.59	66.19
Gemmieza-11	control	83.33	8.67	276.64	11.67	9.00	4.53	3.03	1.20	1.83	39.68	57.14
	25	66.67	9.33	226.64	9.33	7.00	3.86	2.56	0.80	1.77	30.95	152.38
	50	91.33	12.00	303.36	13.67	12.00	4.70	3.54	1.54	2.00	43.58	146.67
	75	80.33	11.33	330.71	13.00	11.00	4.83	3.08	1.59	1.50	51.38	100.95
	100	80.33	8.33	319.36	13.00	8.00	4.77	3.18	1.29	1.89	40.56	61.43
LSD $_{0.05}$	1.20	0.64	4.40	0.24	0.32	0.11	0.10	0.02	0.10	0.12	17.19	

quantity and hydrogel application gave the tallest plants (91.33 cm). The interaction of Gemmeiza-11 x 75% water irrigation quantity and hydrogel produced the highest number of spikes per meter (330.71) and recorded the highest harvest index (51.38 %). Interaction of Sids-12 cultivar x 100% recommended irrigation quantity gave the highest biological yield per tiller (13.00 g). Sids-12 x 50% recommended irrigation quantity and hydrogel produced the tallest spikes (13.67 cm); highest number of spikelet's/spike (17.33) and highest grain yield per spike (4.87). Due to the end product interaction of Sids-12 x 75% recommended irrigation quantity and hydrogel produced the highest grain yield/feddan (1586.24 kg); highest straw yield/feddan (2.13 tons) and highest biological yield/feddan (3.72 tons). Also, 25% water irrigation quantity with hydrogel gave the highest value of Irrigation water use efficiency (IWUE) with both wheat cultivars (152.38 %)

CONCLUSSION

It could be concluded from this study that hydrogel application have evident benefits for the wheat as the main crop grown in the new lands. The study indicated the variability of the combined application of hydrogel and water deficit conditions.

Addition of hydrogel at the rate of 4 g/m^2 in soil can be effective tool for increasing grain yield and straw yield per feddan with different ratios besides saving 25 % or 50 % from recommended irrigation quantity under sprinkler irrigation method.

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