Evaluation of Superabsorbent Application on Corn Yield under Deficit Irrigation

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Abstract**—**This research was planned in order to study the effect of drought stress and different levels of Superabsorbent and their effect on grain yield, biologic yield and harvest index. In this study, 3 different depths of irrigation were considered as the main treatment I_1, I_2, I_3 as 100, 75 and 50 percent of water requirement of plants respectively and different levels of Superabsorbent were used as secondary treatment (S_0, S_1, S_2 and S_3, equal to 0 (control), 15, 30 and 45 gr/m^2 respectively). According to the results, independent effects of irrigation and Superabsorbent treatments at 1% level on biologic and grain yield of corn were significant. In addition, independent effect of irrigation treatments at 5% level on harvest index was significant. But independent effect of Superabsorbent treatments on harvest index was not significant.

Keywords**—**Corn, Deficit irrigation, Superabsorbent, Yield.

I. Introduction

DROUGHT stress is the most important factor for limiting of plant growth in arid and semi-arid regions [8]. One of the new methods for managing water in soil, is usage of Superabsorbent materials as a storage tank until prevent from wasting water and increase irrigation efficiency [2], [3]. Superabsorbent polymers can absorb large amounts of water or aqueous solutions and swell. They can increase the soil water-holding capacity [9]. The Superabsorbent used in this project, entitled Super AB A 200, made by Rahab Resin, licensed under Polymer and Petrochemical Institute of Iran. This Superabsorbent is tripolymer of acrylamide, acrylic acid and acrylate potassium that is showed in Fig. 1 [3].

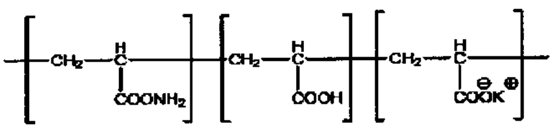

Fig. 1 Chemical structure of Super AB A 200

Water Use Efficiency (WUE) is defined as the ratio of grain yield to water consumption amount by plant. When water resources be limited (without limitation of farmlands), maximum production be achieved when WUE be maximum [18]. Sustainable development in agriculture in arid and semi-arid regions is depended to raising of WUE. WUE shows that how much production will be produced for consumed water amount [4].

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Reference [10] showed that Superabsorbent could raise water retention capability of sandy soils. Reference [4] reported that superabsorbent by increasing of water retention capability of soil prevents from wasting of water and nutrients and raised the efficiency of fertilizers in light soils. Reference [16] reported that superabsorbent by increasing of water retention capability of light soil and preventing from wasting of water and nutrients, raised grain yield of plant. Reference [22] reported that superabsorbent could reduce the harmful effects of drought stress, by sufficient storage of water and nutrients in light soils and increased water retention capability and raised grain yield of plant.

II. Materials and Methods

A. Geographical Location

This study was conducted in a farm that was located at a distance of 10 km from the Ahvaz city of Iran. Gross area of this project was approximately 1072 m^2 with longitude and latitude of 48°46'15'' eastern and 31°48'30'' northern respectively and its height was 11 meters above sea level.

B. Weather Characteristics of the Region

According to the 50-year statistics, the average of annual rainfall was 213 mm, the average of air temperature was 25°C, the average of maximum temperature was 32.8°C and the mean minimum temperature was 17.6°C.

C. Soil and Irrigation Characteristics

Composite samples of five random points from 0-30 and 30-60 cm, depth of cultivated land, in the farm were taken. The results are presented in Table I.

Irrigation water was provided from Karkheh Noor River. Analytical results of irrigation water samples are shown in Table II.

D. Corn Varieties Used in the Plan

Corn variety used in this project, entitled as the SCKaroun701. This variety is a new corn variety that is tolerant to drought stress and suitable for cultivation in subtropical regions that is introduced by Agricultural Research Center of Safi-Abad Dezful, Kuzestan, Iran.

E. Experiment Plan

This plan was performed as a split plot in a randomized complete block design with 12 treatments and 3 replications. Different irrigation water depths considered as the main treatment including I_1, I_2 and I_3 equal to 100, 75 and 50 percent of needed water for the plant respectively. Different levels of Superabsorbent considered as the secondary treatments. They were S_0, S_1, S_2 and S_3 equal to 0 (for control group), 15, 30 and 45 gr/m^2, respectively. Thus, with 12 treatments and 3 replications, a total of 36 plots were tested.

TABLE I
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL BEFORE PLANTING TEST

Relative Frequency and Size of Soil Particles (%)			Soil Texture	Soluble Phosphorus (ppm)	Soluble Potassium (ppm)	Depth (cm)	EC (dS/m)	pH	Organic Carbon (%)
Clay	Silt	Sand							
8	4	88	Sand	10.4	166	0-30	3	8.1	0.42
8	2	90	Sand	14.1	151	30-60	2.8	8	0.35

TABLE II
QUALITATIVE ANALYSIS OF THE WATER

Cations (meq/litr)				pH	EC (dS/m)
K^+	Na^+	Mg^{++}	Ca^{++}		
0.12	20	9	10	7.3	2.9
Anions (meq/litr)				pH	EC (dS/m)
$So_4^=$	Cl^-	Hco_3^-	$Co_3^=$		
16.2	18.1	4	0	7.3	2.9

F. Farming Operations

The size of each plot was 4 * 4.5 m^2 including six lines. The Superabsorbent for each line in each plot was distributed in a depth of 30 cm from the soil surface. The corn variety of this plan (SCKaroun701) was planted manually in March as spring planting and in July as summer planting. The space between planting rows were 75 cm and the space between each plant in each line was 17 cm, so a total density of planting was 78430 plants per hectare. Deficit irrigation treatments were started after 4 to 5 leaf stage (seedling settlement stage).

G. Applying Different Irrigation Treatments in the Farm

This method was according to usage of soil moisture index or soil metric potential. In this method, the soil moisture percentage was measured thorough sampling of plant root (about 80 cm and from 3 plots) per each 20 cm, days before irrigation. When the weight mean of soil moisture reached the allowed depletion (according to full irrigation treatment) the irrigation process happened. Finally, the irrigation cycle was determined based on the non-water stress treatment. At the same time, all of the plan treatments were irrigated through fixed irrigation cycle and different irrigation depths. For applying different water regimes and each treatment coefficient, the following equation used [1]:

$$SMD = (\theta_{fc} - \theta_i).B_d.D_r.f \qquad (1)$$

where SMD: soil moisture deficit (cm), θ_{fc}: field capacity moisture, θ_i: weight percent of available moisture in the soil of farm, f: each treatment coefficient (0.5, 0.75 and 1), B_d: bulk density (gr/cm^3) and D_r: plant root development depth (cm). It should be noted that the deficit irrigation treatments took place in the 4 to 5 leaf stage, after full settlement of seedlings. Because of deep underground water and porous soil texture, groundwater contribution was also ignored. Meantime, rainfall measured by the rain gauge at the farm.

H. Harvest Operation and Yield Measuring

The grain maturity in each planting season is recognizable by formation of black layer in the base of grains. Final harvest was done from 2 m^2 in the middle of each plots. Then, biologic yield (BY) measured and after determination of grain yield (GY), harvest index (HI) was calculated by:

$$HI = \frac{GY}{BY} \times 100 \qquad (2)$$

III. RESULTS AND DISCUSSION

Tables III-V show the comparison of average reciprocal effects between water treatments and superabsorbent.

TABLE III
MEAN COMPARISON OF RECIPROCAL EFFECTS OF FULL IRRIGATION TREATMENTS (I_1) AND SUPERABSORBENT TREATMENTS

I_1				
S_0	S_1	S_2	S_3	Parameters
6.55bc	7.63b	8.76a	9.93a	Grain Yield (t/ha)
12.16bcd	14.16bc	16.24ab	18.4a	Biologic Yield (t/ha)
53.86a	53.88a	53.94a	53.97a	Harvest Index (%)

TABLE IV
MEAN COMPARISON OF RECIPROCAL EFFECTS OF MILD DROUGHT STRESS TREATMENTS (I_2) AND SUPERABSORBENT TREATMENTS

I_2				
S_0	S_1	S_2	S_3	Parameters
4.18de	5.2cd	6.12bc	7.02b	Grain Yield (t/ha)
8.04ef	9.96de	11.48cde	13.14bc	Biologic Yield (t/ha)
51.9a	52.21a	53.31a	53.42a	Harvest Index (%)

TABLE V
MEAN COMPARISON OF RECIPROCAL EFFECTS OF SEVERE DROUGHT STRESS TREATMENTS (I_3) AND SUPERABSORBENT TREATMENTS

I_3				
S_0	S_1	S_2	S_3	Parameters
2.29f	3.05ef	3.74def	4.45cd	Grain Yield (t/ha)
4.92g	6.28fg	7.50fg	8.75ef	Biologic Yield (t/ha)
46.54b	48.5b	49.86ab	50.86ab	Harvest Index (%)

A. Grain Yield

The effect of irrigation treatments on grain yield was significant at 1% level (Table VI). By increasing severity of drought stress, grain yield was significantly reduced. Its reason was because of significantly reduce of number of seeds in corn and thousand seed weight. This result was confirmed by [17], [12], [13], [19], [9] and [23]. In addition, it is reported that drought stress by reducing of leaf area index (LAI) and disturbing in process of uptake and transition of nutrients in plant, reduces grain yield [12], [14], [20]. The highest and lowest grain yield in this research were 6.55 and 2.29 t/ha belonged to full irrigation treatment (I_1) and severe drought stress treatment (I_3) respectively. Effect of Superabsorbent treatments on grain yield was significant at 1% level. The grain yield was reduced by reduction of Superabsorbent. It is caused by nutrients and water storage by Superabsorbent in light sandy soil, preventing from the loss of water and nutrients and creating favorable conditions for growth and preventing from being reduced of number of seeds in corn and thousand seed weight. However, S_3 treatment was the highest average of grain yield with 9.93 t/ha and S_0 treatment was the lowest average of grain yield with 6.55 t/ha, in this research. Reciprocal effect of treatments with grain yield showed that however by increasing severity of drought stress, grain yield was reduced but its gradient was not uniform in all of treatments. For example, there was not significantly difference between I_2S_3 treatment with I_1S_1 and I_1S_0 treatments, so it can be concluded that Superabsorbent has been able to store water and nutrients and release them in drought stress conditions, so, it can provide the suitable conditions at vegetative growth stage and by improving of uptake and transition of nutrients in plant, increase number of seeds in corn and thousand seed weight and finally increases grain yield.

TABLE VI
VARIANCE ANALYSIS OF TREATMENT EFFECTS ON GRAIN YIELD

F Value	Squares Mean	Sum of Squares	Degree of Freedom	Sources of Changes
188.81 **	15.41	46.27	2	Irrigation Water Depth
755.19 **	61.69	185.09	3	Consuming Superabsorbent Levels
2.22 *	0.18	1.45	8	Reciprocal Effect of Irrigation Water Depth and Consuming Superabsorbent
		2.45	30	Experiment Error
		2072.7	45	Total

**: difference is significant at 1%. *: difference is significant at 5%. ns: there is not any significant difference

TABLE VII
VARIANCE ANALYSIS OF TREATMENT EFFECTS ON BIOLOGIC YIELD

F Value	Squares Mean	Sum of Squares	Degree of Freedom	Sources of Changes
367.89 **	185.72	577.16	2	Irrigation Water Depth
130.32 **	48.5	157.5	3	Consuming Superabsorbent Levels
3.97 *	1.29	10.32	8	Reciprocal Effect of Irrigation Water Depth and Consuming Superabsorbent
		5.41	30	Experiment Error
		7199.02	45	Total

**: difference is significant at 1%. *: difference is significant at 5%. ns: there is not any significant difference

TABLE VIII
VARIANCE ANALYSIS OF TREATMENT EFFECTS ON HARVEST INDEX

F Value	Squares Mean	Sum of Squares	Degree of Freedom	Sources of Changes
5.6 *	15.2	45.6	2	Irrigation Water Depth
1.64 ns	4.52	6.12	3	Consuming Superabsorbent Levels
4.12 *	1.46	11.87	8	Reciprocal Effect of Irrigation Water Depth and Consuming Superabsorbent
		30.89	30	Experiment Error
		12574.85	45	Total

**: difference is significant at 1%. *: difference is significant at 5%. ns: there is not any significant difference

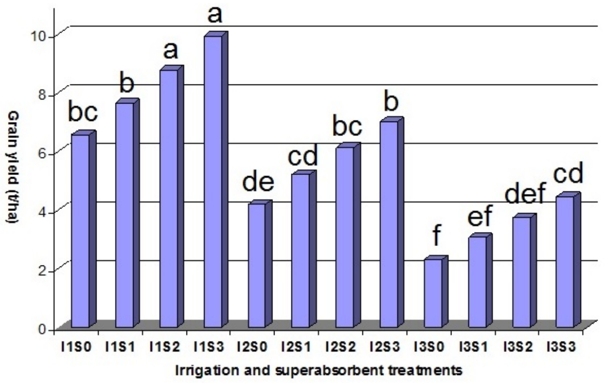

Fig. 2 The comparison of mean reciprocal effect of irrigation and Superabsorbent treatments on grain yield

B. Biologic Yield

The effect of irrigation treatments on biologic yield was significant at 1% level (Table VII). By increasing severity of drought stress, biologic yield was significantly reduced. The highest and lowest biologic yield were 12.16 and 4.92 (t/ha) belonged to full irrigation treatment (I_1) and severe drought stress treatment (I_3) respectively. This result was confirmed by [13], [12], [6], [9], [11] and [15]. Effect of Superabsorbent treatments on biologic yield was significant at 1% level. The biologic yield was reduced by reduction of Superabsorbent. It's caused by nutrients and water storage by Superabsorbent in light sandy soil, preventing from the loss of water and nutrients and creating favorable conditions for growth. However, S_3 treatment was the highest average of biologic yield with 18.4 t/ha and S_0 treatment was the lowest average of biologic yield with 12.16 t/ha, in this research. Reciprocal effect of treatments with biologic yield showed that however by increasing severity of drought stress, biologic yield was reduced but its gradient was not uniform in all of treatments. For example, there was not significantly difference between I_2S_3 treatment with I_1S_2, I_1S_1 and I_1S_0 treatments, so it can be concluded that Superabsorbent has been able to store water and nutrients and release them in drought stress conditions, so, it can provide the suitable conditions at vegetative growth stage and by increasing of LIA and receiving of more sunlight, produces more biomass and finally increases biologic yield.

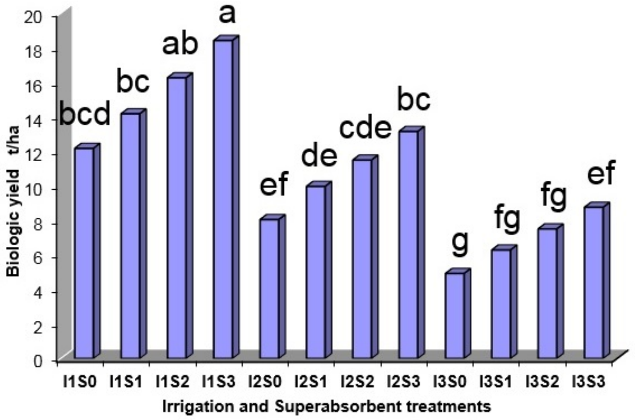

Fig. 3 The comparison of mean reciprocal effect of irrigation and Superabsorbent treatments on biologic yield

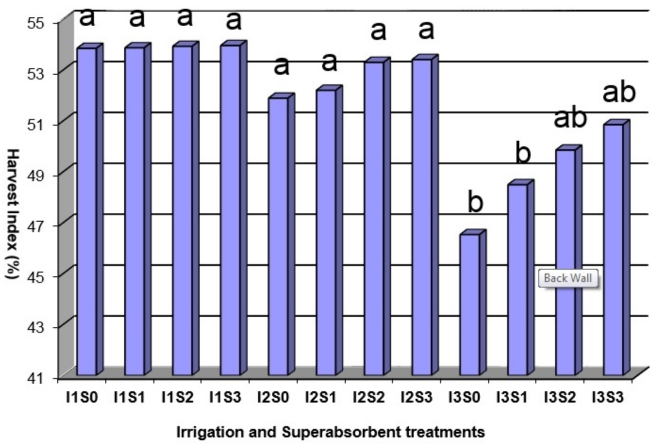

Fig. 4 The comparison of mean reciprocal effect of irrigation and Superabsorbent treatments on harvest index

C. Harvest Index

The effect of irrigation treatments on harvest index was significant at 5% level (Table VIII). Actually, harvest index in full irrigation treatments (I_1) (53.86 %) had not significant difference in comparison with harvest index in mild drought stress treatments (I_2) (51.9 %). However, by applying severe drought stress treatments (I_3) (46.54 %), harvest index was significantly reduced. This result was confirmed by [21], [5], [7] and [12]. Effect of superabsorbent treatments on harvest index was not significant, although by decreasing of superabsorbent, harvest index was reduced. It is caused by nutrients and water storage by superabsorbent in light sandy soil, preventing from the loss of water and nutrients and create favorable conditions for growth and caused that variation of grain yield and biologic yield be very low and close together. About the reciprocal effect of treatments on harvest index, it is noteworthy that although the reduction in irrigation water depth, was caused reduction of harvest index, but this trend was not significant in most treatments and had not the same gradient. For example, the treatment of I_2S_3, had not any significant difference with I_1S_3, I_1S_2, I_1S_1 and I_1S_0, thus we can conclude that the superabsorbent by storage of water and nutrients and release them in drought stress conditions, can provide favorable conditions for plant growth and reduce effects of water stress and prevent from getting disturbed of symmetry between grain yield and biologic yield and finally prevent from significantly reduction of harvest index.

IV. Conclusion

The results showed that by increasing of drought stress, yield showed the decrease. It could be due to the effect of drought stress on stomatal closure and prevention of biochemical process of CO_2 absorption and ultimately reduction of photosynthesis amount and finally being reduced of biologic yield and by reduction of number of seeds in corn and thousand seed weight, the grain yield was reduced. Superabsorbent can store water and nutrients and release them in drought stress conditions, so it can improve the above-mentioned problems for plant and increase biologic and grain yield. Therefore, by using of Superabsorbent, we can get an acceptable biologic and grain yield with less water consumption and increase water use efficiency (WUE). Consequently, by using of Superabsorbent, we can save more water, and extend the cultivated lands by saved water.

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