IOCAG 2022

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Proceeding Paper

Evaluation of Superabsorbent Polymer on Leaf Area Index, Relative Leaf Water Content and Growth Rate of Sesame under Water Deficit Stress Condition †

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† Presented at the 1st International Online Conference on Agriculture—Advances in Agricultural Science and Technology (IOCAG2022), 10–25 February 2022; Available online: https://iocag2022.sciforum.net/.

Abstract: Drought is one of the most important problems of crop production in arid and semi-arid regions of the world. The application of some materials, such as superabsorbent polymers in the soil, increases the water retention in the soil and thus reduces water consumption and leaching of fertilizers, therefore is one of best solution water management in water deficit conditions. This study aimed to investigate the effects of superabsorbent on some characteristics of sesame under different irrigation intervals**.** This experiment was performed in a three replicated-split plot factorial, arranged in RCBD with three drought factors as the main plot (Irrigation interval using cumulative evaporation from class A pan: 80 mm (I_1), 160 mm (I_2), and 240 mm (I_3), and superabsorbent (SAPs) Stockosorb in three levels (0, 100, 200 kg ha^{-1}) (Z_0, Z_1, Z_2) as the subplots. The results showed that water deficit intensively decreased relative water content (RWC), Leaf area index (LAI), and crop growth rate (CGR) in both mild water stress (I_2) and sever water stress (I_3) compare to normal irrigation (I_1). SAPs mitigated the adverse effects of water deficit by improving RWC, LAI, and CGR. Due to the problem of water supply for plants in arid semi-arid regions, the use of 200 kg ha^{-1} superabsorbents with 80 mm evaporation from class A pan be recommended as a successful method to maintain moisture and increase the growth and development of sesame.

Keywords: CGR; RWC; water deficit; superabsorbent

Citation: Gilani, A.; Gholami, A.; Abbasdokht, H.; Tabari, Z.T. Evaluation of Superabsorbent Polymer on Leaf Area Index, Relative Leaf Water Content and Growth Rate of Sesame under Water Deficit Stress Condition. *Chem. Proc.* **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s):

Published: date

1. Introduction

Reduction of precipitation and water scarcity in the world is one of the main factors limiting the development of agriculture in the future, so the most efficient use of water resources will be one of the critical solutions to sustainability [1]. Mild water deficit stress changes Leaf water relations and reduces the relative water content of the leaves, reducing leaf development [2]. As water stress gets more severe, an increase in leaf temperature and, as a result, wilting, complexity, and premature aging of leaves, which also reduces the absorption of active photosynthetic radiation and leads to a leaf loss and reduction of leaf growth, a significant drop in RGR (leaf relative growth rate) and consequently decline in dry matter production)[3]. The use of superabsorbents (SAPs) is extensively used as a reliable solution for plant survival and overcoming water stress conditions. SAPs are hydrophilic three-dimensional network polymers that have favorable features for drought management. These features include high water absorption capacity, water Retention, and slow-release water properties, which reduce the evaporation loss and deep percolation of water soils [4]. The amount of water absorption in these polymers varies from about 20 times to more than 2000 times by their weight, depend on the chemical properties of SAPs as well as the physicochemical properties of the soil and water-absorbing capacity (WAC) ranging from 100–500 g per gram of SAPs[5] (saha2020). Furthermore, they are non-toxic, eco-friendly, and biodegradable polymers which can be considered a proper alternative in water use efficiency management. Apart from that, the added advantage of SAH is its low cost which reduce the cost of production. As we as compatibility with environmental [5]. Application of SAPs has shown encouraging results in reducing the adverse effects of drought on various plants such as maize [6], broad bean [7], canola [8]. The cultivation of the plant species with low water demand and drought-tolerant characteristics in the areas that are constantly subjected to drought can be another appropriate solution for drought stress. Sesame (*Sesamum indicum* L.) is a warm-season annual crop belonging to the Pedaliaceae family which due to its high oil content and good quality of its oil (low cholesterol and the presence of some antioxidants), as well as a good amount of protein, is considered an excellent nutritional source [9]. Furthermore, sesame's drought and heat tolerance properties can help maintain better yield in this plant under water deficit conditions [10]. Regarding the growing concerns about limited water resources and also the positive effects of the application of superabsorbent under drought conditions on the one hand, and the nutritional importance of sesame, on the other hand, This experiment aims to investigate the effect of different levels of superabsorbent polymer on Some traits of sesame under water deficit stress condition.

2. Materials and Methods

This study was carried out in the research field of Shahrood University of Technology, Shahrood, Iran in 2019 (Longitude 54° 59′ 58″, Latitude 36° 29′ 08″, Height 1349 m). This experiment was performed in a three replicated-split plot factorial, arranged in RCBD with three drought factors as the main plot (Irrigation interval using cumulative evaporation from class A pan: 80 mm (I_1), 160 mm (I_2), and 240 mm (I_3), and superabsorbent (SAPs) STOCKOSORB in three levels (0, 100, 200 kg ha^{-1}) (Z_0, Z_1, Z_2) as the subplots. Each experimental plot includes four planting rows with a length of 4 meters, and row spacing was 7 cm (plant to plant) and 50 cm (row to row). For applying drought factors, an empirical equation model was used to calculate the desired evaporation from the evaporation pan by using five years of weather data. Daily meteorological data obtained from a weather station located at the experimental site were used to calculate ETO. In the beginning, all plots were irrigated equally to ensure full germination and favor initial seedling growing, and Irrigation treatments were applied after the complete establishment of seedlings. For SAPs application, the top 5 cm of the soil was removed and mixed with soil in the top 15 cm depth of the sandy soil before cultivation. Dry matter yield was measured after oven-dried at 75 °C to a constant weight. Relative water content (RWC) was measured according to (Barrs and Weatherley (1962).[11] Crop growth rate (CGR) was calculated in 5 stages, the first stage at the beginning of flowering (50 days after planting) and then every 15 days. But the main step in this experiment is 50% encapsulation of the plant, which is the fourth step, and leaf area index (LAI) was measured at 50% encapsulation stage. Data analysis was performed by Statistical Analysis variance (SAS 9.4) (SAS Institute, Cary, USA), and treatments means were compared by using the least significant difference (LSD) test ($p < 0.05$).

2.1. LAI

As can be observed in table1, LAI was significantly affected by irrigation regimes ($p \leq 0.05$) and superabsorbent ($p \leq 0.01$) superabsorbent (Table 1). LAI declined with decreasing water content. So, the highest LAI and lowest LAI were obtained in I_1 and I_3 irrigation regimes, respectively (Table 2). LAI decreased by 16.6 and 25.2% under mild and severe stress conditions, respectively. Munitz et al. (2019) reported a positive linear relationship between Crop coefficient (Kc) which is defined as the ratio between the actual crop evapotranspiration (ETc) and reference evapotranspiration (ETO), therefore it can affect by water consumption [12]. Kalaydjieva et al. (2015) also found that the leaf area index of French bean in severe stress was 30% lower than normal irrigation [13].

Table 1. Results of analysis of variance (mean squared) different levels of irrigation and Superabsobents of LAI, RWC, and CSGR of sesame.

		Mean Squared		
Source	**D.F**	**LAI**	**RWC**	**CGR**
Replication	2	0.95	35.62	15.92
Irrigation (I)	2	1.8 *	1163.75 **	275.22 **
Error a	4	0.03	45.76	9.18
Superabsorbent (Z)	2	0.07 **	533.79 **	76.29 **
(I × Z)	4	0.005	25.51 *	13.62 *
Error a	12	0.013	8.07	1.52

**, * Significant at the 1% and 5% probability levels, respectively.

Table 2. Comparison of the mean of main effects of Irrigation, and Superabsorbents on LAI, RWC, and CGR.

Treatment	LAI	RWC	CGR
Irrigation			
I_1	2.479 [a]	81.06 [a]	15.78 [a]
I_2	2.067 [b]	74.89 [a]	13.9 [a]
I_3	1.852 [c]	65.11 [b]	8.26 [b]
Superabsorbent			
Z_0	2.074 [b]	67.96 [c]	10.52 [c]
Z_1	2.118 [b]	74.33 [b]	12.79 [b]
Z_2	2.202 [a]	78.78 [a]	14.63 [a]

Means with common letters show no significant difference in 5% probability level with LSD test.

2.2. Leaf RWC

Superabsorbent, irrigation regimes and their interactions displayed a significant effect on RWC ($p \leq 0.01$). Mean comparison showed the highest values of LAI were obtained from the application of 200 kg ha^{-1} superabsorbent under I_1 irrigation regime; however, the lowest values of LAI were in non-application superabsorbent under I_3 irrigation regime (Figure 1). Gholinezhad et al. (2020) reported that RWC of sesame in sever and medium drought stress was reduced by 23% and 25% compared to normal irrigation [14].The reduction of RWC due to drought stress positively correlates with soil moisture content [15], it is also reported that the SAPs plays a crucial role in increasing soil and plant water availability as a soil conditioner [10,16].

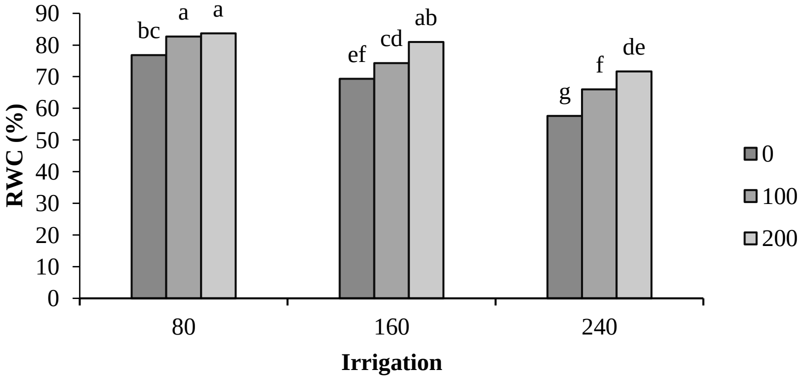

Figure 1. Interaction of irrigation × superabsorbent on relative water content. (Means with common letters show no significant difference in 5% probability level with LSD test).

2.3. CGR

The results of the analysis of variance showed that crop growth rate was significantly ($p \leq 0.01$) affected by irrigation regimes (Table 1). In the fifth growth stage, due to the fall of the leaves and the bursting of the capsules, CGR becomes very negative. Comparison of mean CGR showed that irrigation treatment at 80 mm of evaporation has the highest CGR and grows uniformly. It was also observed that with decreasing water supply, CGR decreased significantly (Figure 2). In the early stages, irrigation regimes had little effect on CGR and were almost linear (uniform); afterward, CGR had a much-reduced trend. It was also observed that the trend of CGR changes in I3 irrigation regime was much slower than other irrigation regimes (Figure 2). During the growing season, when the plant is facing drought stress, the closure of the stomata along with the reduction of leaf water potential limits the stabilization of carbon dioxide in photosynthesis; therefore CGR is reduced. Superabsorbent also had a significant impact on CRG ($p \leq 0.01$). Comparison of means showed that the highest and lowest CGR were obtained from the application of 200 and 0 kg ha^{-1} superabsorbent, respectively (Figure 3). It might be due to an essential role of SAPs in reducing water and nutrient losses and increasing their use efficiency during the growing season through increasing leaf area duration and photosynthesis period, which result in CGR and dry matter accumulation enhancement [16].

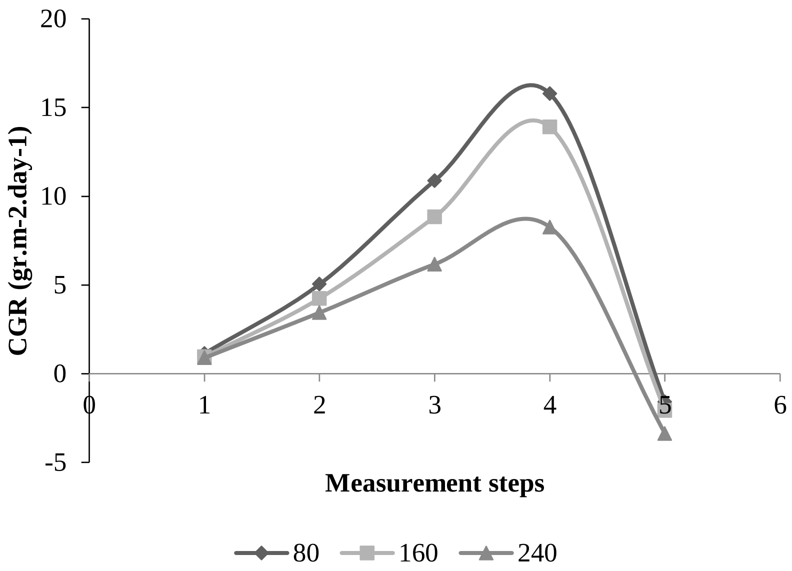

Figure 2. Effect of different Irrigation treatments on the trend of changes in crop growth rate (g/m^{2}d).

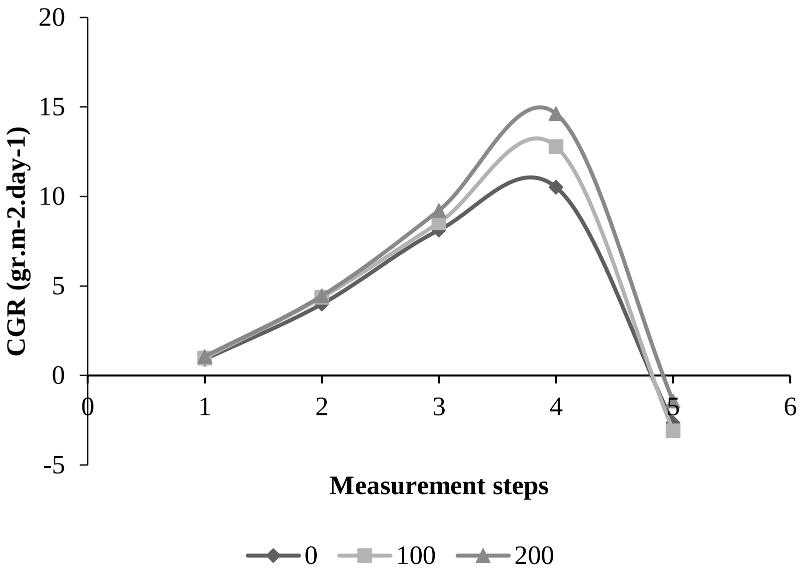

Figure 3. Effect of different Superabsorbents on the trend of changes in crop growth rate (g/m^{2}d).

3. Conclusions

The application of superabsorbent to some extent reduced the damage caused by water shortage under drought stress conditions, thus it seems that the application of superabsorbent polymer in areas with water shortage or dispersion Inadequate rainfall and cultivation of plants is inevitably done in stressful conditions will be useful. Although, the economic benefits and environmental effects of using these materials require further research.

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

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