Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2538-2470 (Online)
Vol. 9, No. 1, 2023
https://jcns.ahvaz.iau.ir/ OPEN ACCESS

Assess Absorbent Super Polymer on Reducing the Effects of Low Irrigation in Cowpea Fields (*Vigna unguiculata* L.)

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RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *30 Dec. 2022*
Received in revised form: *3 Feb. 2023*
Accepted Date: *5 Mar. 2023*
Available online: *30 Mar. 2023*

To Cite This Article:
Kianoush Hamidian. The Effect of Cytokinin and Iron on Seed Yield and Accumulation some Elements in Seed of Chickpea Genotypes under Dry land Conditions. ***J. Crop. Nutr. Sci.,*** 9(1): 33-44, 2023.

ABSTRACT

BACKGROUND: The implementation of irrigation techniques in order to be more productive than water resources is a scientific approach to reducing water consumption.

OBJECTIVES: This research was done with the aim of investigating the effect of different levels of superabsorbent and irrigation management on Cowpea crop production and growth indices in Ahvaz region.

METHODS: Current study was conducted according strip plots based on randomized complete blocks design with three replications during 2019-2020 crop season. The first factor was irrigation includes Furrow full irrigation (control), Fixed alternate furrow irrigation and variable alternate furrow irrigation. The second factor included three levels of super absorbent polymer as non-used super absorbent (control), consumption of 75 and 150 $kg.ha^{-1}$.

RESULT: The results showed that the effect of super absorption was significant on all measured traits including leaf area index, total dry matter, crop growth rate, seed yield, except net photosynthesis rate. The effect of low irrigation was significant on all traits except crop growth rate and net photosynthesis rate. The interaction effect of low irrigation and superabsorbent on all investigated traits was not significant. The highest and lowest in the examined traits were observed in the field with normal irrigation and fixed furrow irrigation, respectively and among the different amounts of superabsorbent, the highest and lowest values in all examined traits except net photosynthesis rate were observed under the application conditions of 150 $kg.ha^{-1}$ and non use of super absorbent. In general, the results of the experiment showed that different irrigation methods had an effect on all the morphological, physiological and yield characteristics of cowpea.

CONCLUSION: The application of superabsorbent improved the physiological and morphological traits in normal irrigation conditions and in fields with low irrigation, it led to the reduction of the effects of drought stress and the improvement of the damages caused by it, which can be of interest to researchers and farmers.

KEYWORDS: *Dry matter, Growth indices, Morphology, Pulse, Seed yield.*

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1. BACKGROUND

Legumes are the main part of the diet of many poor people in the world, because the significant amounts of high-quality protein found in the seed of crops in combination with cereals can provide a valuable biological food composition. Among legumes, soybeans, beans and chickpeas occupy the first to third place in terms of cultivated area (Parsa and Bagheri, 2013). In most parts of the world, water is the limiting factor in the production of agricultural products. Optimum use of water is very important, especially in the regions where dry and semi-arid climate conditions prevail, which covers about two-thirds of the area of Iran. Economics and water management require that the unit volume of water be maximally exploited (Shahram and Daneshi, 2004). Iran is located in an arid and semi-arid region and there is a high probability of drought. Therefore, the implementation of low irrigation techniques in order to increase the efficiency of limited water resources is considered a scientific solution to reduce water consumption. Furrow irrigation is one of the methods of low irrigation and water consumption management solutions in irrigated lands, which can be implemented by irrigating half of the furrows in a fixed or variable manner. In intermittent furrow irrigation, the furrows are irrigated one at a time. In this way, in one irrigation, two side furrows are irrigated, and in the next irrigation, only the middle furrow is irrigated. In this method, half of the root of the plant tolerates only one dry period, which is not a permanent drought and is raised in the next irrigation, and the other half is subjected to drought stress (Abbasi *et al.*, 2015). Bahrani and Porreza (2016) by investigating different types of irrigation methods reported that the highest seed yield and 1000-seed weight of rape were observed in normal irrigation and among the different low irrigation methods, furrow irrigation is one of the variables that has a greater effect on seed, but irrigation with a fixed furrow was better in terms of water consumption efficiency. Sadeghi-Shoae *et al.* (2013) using different irrigation methods on beans announced that the most efficient water consumption in bean cultivation was related to intermittent furrow irrigation, but in terms of seed yield, harvest index and total dry weight there was no significant difference with normal irrigation. Paying attention to the management role of using some modifying additives such as super-absorbent hydrogels for the optimal use of water in agriculture is of particular importance to increase the yield of crops under drought stress conditions (Kabiri, 2002). The use of superabsorbent hydrogels to increase the water holding capacity of soil has been used in the world for many years at a commercial level. In Iran, in recent years, the attention of some researchers has been directed to this issue and research has been conducted in this field as well (Salar *et al.*, 2005). Superabsorbent hydrogels are extremely hydrophilic polymers that, while having a high speed and capacity of water absorption, easily provide water and nutrients dissolved in it to the plant roots when the roots need it. Also, super absorbent polymers, while increasing the water holding capacity in light soils, can also solve the problem of permeability of heavy soils and the problem of breaking fertilizers. Superabsorbents have a special place in agriculture because they quickly absorb hundreds of times their weight in water and become a durable gel (Nazarli, 2010). Harvey (2002) stated that the use of super absorbent in red beans increases dry matter and increases resistance to drought in this plant. Mokhtari *et al.* (2015) investigated the effect of different levels of drought stress and superabsorbent hydrogels on the yield and yield components of pinto beans and reported that superabsorbent materials also had a significant effect on the increase of all studied traits except pod length. Despite the fact that Iran is located in the arid and semi-arid region of the world and the lack of water resources and frequent droughts in different parts of the country, the use of superabsorbent combined with the change of irrigation management to solve the damages of drought and lack of soil moisture has received less attention. 2.

2. OBJECTIVES

This research was done to investigate the effect of different levels of superabsorbent and irrigation management on Cowpea crop production and growth indices in Ahvaz region.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was conducted in a farm 12 km away from Ahvaz city during 2019-2020 crop season. Considering importance of soil condition for physical and chemical characteristics of the soil, samples were taken from the farm soil at a depth of 0-30 cm. The results of the test site soil are shown in table 1.

Table 1. Physiochemical characteristics of the soil in the experimental area

Texture	Clay (%)	Silt (%)	Sand (%)	Potassium ($mg.kg^{-1}$)	Phosphorus ($mg.kg^{-1}$)	O.C (%)	pH	Salinity ($ds.m^{-1}$)
Clay Loam	35	44	21	178	9.4	0.65	7.22	4.88

This experiment was carried out in the form of strip-chopped blocks in the form of a randomized complete block design (RCBD) in three replications. The first factor in vertical plots includes Furrow full irrigation (control), Fixed alternate furrow irrigation and Variable alternate furrow irrigation. The second factor in horizontal plots included three levels of super absorbent polymer as Non-used super absorbent (control), consumption of 75 and 150 $kg.ha^{-1}$.

3.2. Farm Management

Land preparation operations included plowing, disc, leveler and creation of ridges by furrower machines. Before planting, the required phosphorus fertilizer from the triple superphosphate source was spread in the field in the amount of 150 $kg.ha^{-1}$ of super phosphate fertilizer and 100 $kg.ha^{-1}$ of urea fertilizer along with the disc. After preparing the land and before planting the seeds, specific amounts of superabsorbent were spread by hand for each plot using the conventional method of the region and were placed at the appropriate depth along with the disk. The distance between planting lines was 0.65 meters and the distance between seeds on the planting line was 15 cm. The seeds used were first disinfected by bionutrient before planting. Cowpea seeds were planted manually in rows and stacks at a density of 10 plants per square meter. Irrigation treatments were applied from the time of 8 leaves.

3.3. Measured Traits

In order to determine the changes in the growth process and check the physiological indicators, the three samplings were carried out in the vegetative stage, flowering and at the time of pod formation. The first sampling was done before flowering and two weeks after the 8-leaf stage (40 days after planting), the second sampling was done at the flowering stage and with the appearance of the first flower, and the third sample was taken about three weeks after flowering and at pod formation stages. By measuring three factors including leaf area, leaf dry weight and total dry matter, the physiological parameters of growth including LAI, NAR, CGR and RGR were obtained using the following equations. To determine the leaf area of the linear relationship S= K. L.W was used in which S, L and W were the leaf area, L and W respectively, the maximum length and width of each leaf and K= 0.75 correction coefficient. The leaf area index was calculated from leaf area ratio to ground level. Crop growth rate and net assimilation rate were measured according fallowing formula (Buttery, 1970; Enyi, 1962):

Equ.1. CGR ($g.m^{-2}.day^{-1}$) = TDM_2-TDM_1/T_2-T_1

TDM_1= Primary dry weight (g), TDM_2= Secondary dry weight (g)

T_1= initial sampling time, T_2= Secondary sampling time

Equ.2. NAR ($g.m^{-2}.day^{-1}$) = CGR* $LnLA_2-LnLA_1/LA_2-LA_1$

Equ.3. CGR = Growth rate in grams per day per square meter

LA_1 = Initial leaf area, LA_2 = Secondary leaf area

In order to determine the seed yield, when all the leaves turned yellow, an area equal to 2 m^2 was harvested from each plot, and then the obtained seed yield was weighed.

3.4. Statistical Analysis

The data collected was analyzed statistically by Minitab software (Ver.14). Duncan's multiple range tests at 5% probability level was used to compare significant differences among means.

4. RESULT AND DISCUSSION

4.1. *Leaf Area Index (LAI)*

The results of analysis of variance showed that the effect of low irrigation and super absorbent polymer on LAI was significant in different stages of growth, but the interaction effect of low irrigation and super absorbent polymer was not statistically significant (Table 2). The highest LAI among different irrigation methods in different growth stages was obtained in furrow full irrigation, customary in region, and the lowest LAI was obtained in fixed alternate furrow irrigation (Table 3).

Among the low-irrigation methods, variable alternate furrow irrigation had a greater effect on cowpea LAI, and fixed alternate furrow irrigation had the least effect (Table 3). Cakir (2004) reported that moisture deficiency reduces LAI by reducing production and growth and increasing senescence of leaves. Pandey *et al*. (2000) applied low irrigation in different stages of cereal growth and reported that severe water shortage leads to reduction of plant leaf area. Also, with the reduction of the irrigation cycle, the intensity of the stress in the plant increases and the competition for water absorption increases between aerial and underground parts in the plant, and in this competition, the plant allocates a greater share of photosynthetic materials to the roots, and as a result, less photosynthetic material reaches to the aerial part, including the leaves, which caused a decrease in the LAI. The decrease in the LAI with the increase in the intensity of water deficit stress can be mainly attributed to the reduction in leaf size due to the lack of adequate moisture to maintain the turgor pressure for the growth of leaf cells during the vegetative growth cycle (Sakinejad, 2003). According to the obtained results, the application of superabsorbent had a significant effect on increasing the LAI in different stages of cowpea, which increased the LAI by increasing its amount (Table 3).This effect is mainly due to the absorption of considerable amounts of water in the superabsorbent building and subsequently placing the absorbed water at the disposal of the plant roots, As a result, the plant has produced more leaf area. An increase in leaf area leads to an increase in light absorption and ultimately to an increase in the crop growth rate. Some researchers reported that the application of 75 $kg.ha^{-1}$ of superabsorbent significantly increased the growth indices, including the LAI, compared to the control (Fazeli Rostampour *et al*., 2012), which was consistent with the results of this research.

Table 2. Result of analysis of variance effect of treatment on studied traits

S.O.V	df	Leaf area index			Total dry matter		
		Vegetative growth	Flowering stage	Podding stage	Vegetative growth	Flowering stage	Podding stage
Low irrigation (L)	2	0.378148^{**}	0.163559^{**}	0.43094^{**}	164919^{**}	219008^{**}	241893^{**}
Error (I)	4	0.003704	0.006843	0.00894	7298	9735	7593
Super absorbent (S)	2	0.207037^{**}	0.127737^{**}	0.23686^{**}	36804^{**}	50846^{**}	56529^{**}
Error (II)	4	0.005926	0.003037	0.00224	713	834	642
L × S	4	0.001481^{ns}	0.002687^{ns}	0.00059^{ns}	1732^{ns}	2246^{ns}	1911^{ns}
Error III	8	0.002037	0.003979	0.00429	812	995	1225
CV (%)	-	11.9	11.8	12.7	12.1	8.5	10.5

^{ns}, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Continue table 2.

S.O.V	df	Crop Growth Rate	Net Assimilation Rate	Seed yield
Low irrigation (L)	2	8.5038 ns	0.13274 ns	7035 **
Error (I)	4	1.3477	0.13408	1343
Super absorbent (S)	2	1.9140 *	0.04528 ns	16747 **
Error (II)	4	0.2047	0.04268	159
L × S	4	0.1140 ns	0.01556 ns	94 ns
Error III	8	0.1022	0.01429	195
CV (%)	-	8.1	9.4	10.3

ns, * and **: no significant, significant at 5% and 1% of probability level, respectively.

4.2. *Total dry weight* (*TDW*)

The results of analysis of variance showed that the effect of low irrigation and superabsorbent polymer on total dry weight was significant in different stages of growth, but the interaction effect of low irrigation and superabsorbent polymer was not statistically significant (Table 2). The highest TDW among different irrigation methods in different stages of growth was obtained in furrow full irrigation conditions and the region's custom, and the lowest TDW was obtained in fixed alternate furrow irrigation (Table 3).

Table 3. Mean comparison effect of different level of Biofertilizer and Phosphorus fertilizer on studied traits

Treatments	Leaf area index			Total dry matter ($gr.m^{-2}$)		
	Vegetative growth	Flowering stage	Podding stage	Vegetative growth	Flowering stage	Podding stage
Low irrigation						
Furrow full irrigation	2.65 a	3.54 a	2.66 a	460.83 a	652.28 a	812.18 a
Fixed alternate furrow irrigation	2.25 c	3.27 c	2.23 c	196.50 c	349.20 c	493.18 c
Variable alternate furrow irrigation	2.37 b	3.37 b	2.39 b	277.97 b	436.62 b	587.02 b
Super absorbent						
Non- used super absorbent	2.26 c	3.26 c	2.27 c	247.22 c	402.80 c	549.56 c
75 ($kg.ha^{-1}$)	2.45 b	3.41 b	2.43 b	312.99 b	482.24 b	634.91 b
150 ($kg.ha^{-1}$)	2.56 a	3.50 a	2.59 a	375.10 a	553.05 a	707.91 a

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

Continue table 3.

Treatment	Crop Growth Rate ($g.m^{-2}.day^{-1}$)	Net Assimilation Rate ($g.m^{-2}.day^{-1}$)	Seed yield ($kg.ha^{-1}$)
Low irrigation			
Furrow full irrigation	11.25 a	3.62 a	2853.4 a
Fixed alternate furrow irrigation	9.31 c	3.39 a	1108.2 c
Variable alternate furrow irrigation	10.15 b	3.45 a	1732.6 b
Super absorbent			
Non- used super absorbent	9.71 c	3.50 a	1453.2 c
75 ($kg.ha^{-1}$)	10.43 b	3.55 a	1926.5 b
150 ($kg.ha^{-1}$)	10.57 a	3.41 a	2314.5 a

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

Among the low-irrigation methods, variable alternate furrow irrigation had a greater effect on dry weight of whole beans, and fixed alternate furrow irrigation had the least effect. In low-irrigation conditions, due to the lack of water in the soil, the water potential of the leaves is greatly reduced. In addition, in the condition of lack of water, due to the induction of abscisic acid (ABA) hormone, the stomata are closed, and in this way, the plant keeps its transpiration low. In such a case, the stomatal conductance decreases and leads to a decrease in the absorption of carbon dioxide and, as a result, a decrease in the production of dry matter (Gholami Salkoye *et al*., 2011). Based on the obtained results, the use of super absorbent had a significant effect on increasing the accumulation of total dry matter in different stages of cowpea, and with the increase of its consumption, the TDW increased (Table 3). The use of superabsorbent by providing the amount of water required for growth and dry matter production can increase biological yield with more growth and as a result more dry matter production. It seems that by adding superabsorbent polymers to the soil, the water holding capacity in the soil increases and the plant has access to water for a longer period of time. Also, the superabsorbent polymer absorbs nutrients needed by plants and gradually releases them and makes them available to the plant, thus preventing the leaching of these elements (Rajabi *et al*., 2012), and the conditions for improving and increasing the TDW are provided. Other researchers in the study of the application of superabsorbent polymer on soybean plant also reported that superabsorbent causes a significant increase in total dry matter, which was consistent with the results of this research (Yazdani *et al*., 2007).

4.3. *Crop Growth Rate (CGR)*

The results of analysis of variance (table 2) showed that the effect of low irrigation on the CGR from flowering to fruiting was not significant. The effect of superabsorbent polymer on the CGR from flowering to fruiting was significant. The interaction effect of low irrigation and superabsorbent polymer had not significant effect on the CGR. Among the different irrigation methods, the highest CGR was achieved in furrow full irrigation, and the lowest CGR was obtained in fixed alternate furrow irrigation (Table 3). Among the low irrigation methods, irrigation varibale alternate furrow irrigation s had a greater effect on the CGR of cowpea, and fixed alternate furrow irrigation had the least effect (Table 3). It seems that the increase in drought stress during plant growth causes the competition for water absorption between the aerial and underground parts of the plant to increase, and in this competition, the plant allocates a greater share of photosynthetic materials to the roots and as a result, less photosynthetic materials reaches to the aerial part and slows down the CGR. But when the humidity was perfect, the CGR was at its highest value. Moghimi *et al*. (2014) announced in an experiment on sorghum that a 50% reduction in the amount of water required during the growth period caused a significant reduction in the CGR, which was similar to the results of this research. Moisture stress by reducing the area of green leaves causes a decrease in the photosynthesizing area and as a result, a decrease in dry matter production (Boomsma and Vyn, 2016), hence the CGR was always lower during the plant growth period in low irrigation conditions than furrow full irrigation conditions. In this research, the highest CGR among different amounts of super absorbent was related to the application of 150 $kg.ha^{-1}$ of super absorbent and the lowest effect was due to the treatment without super absorbent (Table 3). Its reason is related to the faster establishment of canopy, or in other words, the higher leaf area index of this treatment, and the low CGR in the control treatment is due to the lower leaf area index of this treatment. It has been stated that superabsorbents with high cation exchange capacity are able to absorb large amounts of water in addition to absorption of large amounts of water, effective and useful cations in plant growth and by preventing their wastage, provide these materials to the plant when necessary. The findings of this research confirm the results of Fazeli Rostampour *et al*. (2012). Also, other researchers reported that in corn, different levels of superabsorbent improved the absorption of water, nutrients and the ease of absorption of the macro and micro nutrients led to the improvement of plant growth characteristics (Eneji *et al*., 2013).

4.4. *Net Assimilation Rate (NAR)*

The results of analysis of variance showed that the effect of low-irrigation, superabsorbent and the interaction effect of low irrigation and superabsorbent polymer on NAR were not statistically significant (Table 2). But the results of mean comparisons showed that the highest and the lowest of NAR among different amounts of super absorbent was obtained in the treatment of 75 and 150 $kg.ha^{-1}$ of super absorbent, respectively (Table 3). It seems that by increasing the amount of superabsorbent up to 150 kg/ha due to the increase in leaf area index and shading on the lower leaves, its amount decreased slightly (Table 3). The control treatment (without the use of super absorbent) also has a low absorption rate due to the lack of super absorbent and then the lack of moisture for the proper development of the green surface of the plant and reducing the amount of photosynthesis has a low absorption rate. Habibpoor Kashefi *et al*. (2016) in the study of the effect of superabsorbent polymer on the net photosynthesis rate of red bean reported that the use of superabsorbent increased the chlorophyll of the leaf and thus the NAR due to the absorption and retention of more water around the root of the plant. The results of this experiment also showed that despite the non-significance of the effect of low irrigation, the highest rate of NAR was related to the treatment of furrow full irrigation of furrows and the lowest rate of NAR in the condition of fixed alternate furrow irrigation (Table 3). This state is due to the supply of water needed by the plant and the increase in the amount of chlorophyll, resulting in an increase in the NAR.

4.5. *Seed yield*

The results of analysis of variance showed that the effect of low irrigation and superabsorbent on seed yield was significant, but their mutual effect was not statistically significant (Table 2). The highest seed yield in different irrigation levels was achieved with a mean of 2853 $kg.ha^{-1}$ in furrow full irrigation conditions and the lowest gran yield was 1108 $kg.ha^{-1}$ in fixed alternate furrow irrigation conditions (Table 3). Among the methods of low irrigation and application of water shortage stress, the highest seed yield was obtained with an average of 1732 $kg.ha^{-1}$ in the variable furrow irrigation method (Table 3). The reduction of yield in the stress treatment can be considered due to the severe reduction of photosynthesis and the stop of chlorophyll formation, the reduction of the activity of nitrate regenerating enzymes and the increase of hydrolyzing enzymes such as amylase. The results of this experiment are in agreement with the findings of Lotfi Agha *et al*. (2017), who stated that the highest seed yield was related to the furrow full irrigation treatment, which did not have a significant difference with the variable alternate furrow irrigation treatment, and the lowest seed yield was obtained in the fixed alternate furrow irrigation treatment. Kang *et al*. (2007) compared the effect of irrigation of all the furrows and the alternate furrow irrigation in corn and concluded that variable alternate furrow irrigation treatment, while increasing seed yield, has saved 50% of water consumption. They introduced the method of variable alternate furrow irrigation as an effective procedure to reduce the amount of water consumed by corn in dry areas, which was consistent with the results of this research on cowpea. Also, Gebeyehu (2006) reported that beans are sensitive to water deficit throughout the growing period. Lack of water, especially at seed filling period, significantly reduced the seed yield. Water shortage stress reduces the yield of legumes by reducing one or more yield components, such as the 1000 seed weight, the number of pods per plant, and the number of seed per pod, and the highest yield is obtained when the environmental conditions, including available moisture, should be optimal in all stages of plant growth. The yield reduction under water shortage stress conditions, which is affected by the reduction of yield components, was consistent with the results of other researchers (Bahrani and Pourreza, 2016). The study of Gupta (2000) showed that moisture stress, even for a short period during the flowering period, significantly reduced the opening of flowers and the number of flowers forming seeds, which was similar to the results of this research. Among different amounts of super absorbent, the highest seed yield with an average of 2314 $kg.ha^{-1}$ was related to the application of 150 $kg.ha^{-1}$ of super absorbent polymer, and the lowest seed yield was obtained with an average of 1453 $kg.ha^{-1}$ in the control treatment (Non-used super absorbant) (Table 3). It seems that the reason for the increase in seed yield in the treatment of using 150 $kg.ha^{-1}$ of super absorbent polymer, increasing water storage in the soil and placing more water and nutrients be for the plant.

5. CONCLUSION

The results of this research showed that the full furrow irrigation treatment had the best results in terms of vegetative, physiological and yield characteristics of bean and among the low irrigation methods, variable alternate furrow irrigation had a greater effect on the studied traits. In this research, application of 150 $kg.ha^{-1}$ of superabsorbent had the greatest effect due to the preservation and storage of more moisture around the roots, and it was able to improve the physiological and morphological traits in full furrow irrigation and in the conditions of low irrigation and stress, it led to reducing the effects of stress and improving the damage caused and finally increasing the seed yield. This situation can attract the attention of researchers and farmers of the region.

ACKNOWLEDGMENT

The authors thank all colleagues and participants, who took part in the study.

FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

FUNDING/SUPPORT: This study was done by support of Department of Agronomy, Islamic Azad University, Ahvaz Branch.

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