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THE EFFECT OF SOME PLANT GROWTH RETARDANTS AND WATER STRESS ON SOME TRAITS OF SORGHUM (*SORGHUM BICOLOR L. MOENCH*) STEM

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Abstract

A field experiment was conducted in the research farm of Field Crops Department - College of Agricultural Engineering Sciences - University of Baghdad (Jadiriya) in the spring season of 2019, in order to try shortening the height of the sorghum (bohooth70). As well as, increasing the stem diameter to reduce lodging, using some growth retardants and water stress according to Randomized Complete Block Design (RCBD) using the split-plot design arrangement with three replicates. The water stress treatments were distributed over the main plots at two levels, full irrigation (irrigation at depletion 50-60% of the available water), and irrigation with half water quantity of the full irrigation treatment. As for the sub plots, it includes the plant growth retardants, including comparison and grafting with calcium carbide (CaC_2) 2 g.plant^{-1}, spraying with Cycocel (CCC) 750 mg.L^{-1}, spraying with Salicylic (SA) 250 mg.L^{-1}, in addition to the treatments of combining treatments with the same concentrations, CCC + SA, CCC + CaC, SA + CaC_2, and CCC + SA + CaC_2.The results showed a significant decrease in the characteristics of vegetative growth in irrigation with the treatment 50%, such as plant height, stem height at the middle of the lower internodes number, number of internodes, stem diameter, stem dry weight and lodging percentage. The growth retardants was significantly increased the stem diameter, while it decreased the lodging percentage, stem dry weight and number of internodes. The treatment of combining the growth retardants treatments (CaC_2+CCC+SA) was significantly superior in reducing plant height and stem dry weight significantly. The interaction between irrigation treatments with growth retardants achieved significant differences in plant height, stem dry weight and lodging percentage.

***Keywords*:** Water Stress, Sorghum, *Sorghum bicolor L. Moench*

Introduction

The Sorghum bicolor L. Moench of genus Sorghum belongs to the poiceae family, which considers as one of the most important economic crops due to its nutritional and forage uses and its entry into multiple industrial fields, it ranked the fifth among the economic crops in the world (wheat, rice, maize, barley, and sorghum). Globally, both sorghum and maize production reached 1124 million tons with an increase of 2% in 2019 compared to 2018 production (FAO, 2019). In Iraq, the cultivated area of sorghum crop is 34050 hectares, with a yield of 1.896 ton.ha^{-1} (Agricultural Economics Research Department, 2016). It is one of the C_4 plants on its path to carbon fixation, which is characterized by its tolerance to extreme conditions such as drought and high temperatures. However, there are several varieties of sorghum in Iraq, including kafir, rabih, inkath, and bohooth70, in addition to the two local varieties, Abu akifa and the red seed variety. The variety bohooth70 is characterized by its superiority over the local variety kafir in green forage, but it suffers from a problem of plant height, where its height may reach more than 3 m (Aboud *et al*., 2017), which leads to its lodging during the wind blowing. The use of plant growth retardants may seem to be the best solution, and a number of researchers have used it to shorten the plant height (Tayeh, 2018), but they recommend using other growth retardants as the shortening is still not enough. Calcium carbide CaC_2 is used for fruit ripening, as well as it added to the soil to gives the Acetylene gas that reduces the effectiveness of the organisms existing by nitrification, and thus provides nitrogen instead of wasting (Yaseen *et al*., 2005). Besides its effect similar to ethylene and its conversion to ethylene gas known as its hormonal effects that retardant growth, as it works as an anti-Auxins, known to have a significant effect on increasing stem elongation. The addition of calcium carbide to the soil means that obtaining growth retardants continuously throughout the season, which may increase the harvest index after inhibiting the large growth of the stem and diverting the surplus from the photo-assimilates to the grains. Salicylic SA has many important physiological roles in plant growth, flowering, stomata movement, nutrient absorption, ethylene production, hormonal balance and its effect on the formation of carotene pigments, increasing the speed of photosynthesis, increasing plant tolerance to various environmental stresses and increasing biomass, it prolongs flower life and increases the effectiveness of Nitrate reductase. Furthermore, Cycocel enzyme is one of plant growth retardants that reduce stem elongation by inhibiting cell division in the sub apical meristem region without affecting the apical meristem, and effect on flowering plants by reducing levels of internal gibberellins (Al-Hassani, 1996). The abundance of water is the main determining factor for agricultural production, particularly in arid and semi-arid areas, but with a problem in large elongation, irrigation with half the amount of water needed for full irrigation may achieve two objectives: reducing plant height and providing 50% of the water. This study aimed to try shortening the height of sorghum (bohooth70) and converting part of the photo-assimilates to increase the stem diameter instead of using it to increase the elongation of the plant stem that is subject to lodging using growth retardants and irrigation by 50% of the full irrigation.

Materials and Methods

A field experiment was carried out during the spring season of 2019 in the research farm of Field Crops Department - College of Agricultural Engineering Sciences - University of Baghdad (Jadiriya), in order to try shortening the height of the sorghum (bohooth 70). As well as, convert part of the photo-assimilates to increase the stem diameter instead of using it to increase the elongation of the plant stem that is subject to lodging using growth retardants and irrigation by 50% of the full irrigation. The Randomized

Complete Block Design (RCBD) applying the split-plot design arrangement was used, where the first treatment is full irrigation (irrigation at depletion 50-60% of the available water) and returned to the limits of field capacity, and the second treatment is irrigation with half water quantity of the full irrigation treatment. As for the sub plots, it includes the plant growth retardants, including comparison and grafting with calcium carbide (CaC_2), spraying with Cycocel (CCC), spraying with Salicylic (SA). In addition to the treatments of combining treatments with the same concentrations, CCC + SA, CCC + CaC, SA + CaC_2, and CCC + SA + CaC_2 with three replications. The distance between one replicate and another are 1.5 m, each replicate consists of 8 furrows with a length of 2.25 clogged ends, irrigated with small plastic tubes with a diameter of 0.5 is connected to 3 in tubes linked to an electric pump connected to a 3000-liter tank. The experiment land was fertilized with phosphate fertilizer before planting at a quantity of 100 kg $P.ha^{-1}$ in the form of triple superphosphate 45% P_2O_5 by one batch mixed with the soil. As for nitrogen fertilizer, it was added in 400 kg $N.ha^{-1}$ in the form of urea (46% N) in three equal batches, the first at planting, the second was added when the plant height reached 30 cm and the third was added at the start of flowering stage (Ministry of Agriculture, 2006). The Diazinon GR (10% active substance) was used three times, the first in 3-4 leaves, the second two weeks after the first control and third two weeks after the second control to control the corn stem insects (*Sesamia cretica* L.).The sorghum seeds (bohooth70) were planted on 25/3/2019 with 2-3 grains per hole, with a distance of 25 cm between holes and 75 cm between furrows. the plants harvested after their full maturity on 15/7/2019, where the samples were dried in the field for two days and then were transferred to the laboratory, and they were finally dried in an electric oven at a temperature of 70 °C until the weight was constant. However, the treatments were irrigated at the same time that comparison treatment (full irrigation) reached50-60% moisture content of the available water, and according to the amount of water allocated for each treatment. The soil moisture content was evaluated using the gravimetric method (then converted to volumetric water content by multiplying to the soil bulk density) by measuring the soil moisture and following the moisture changes in it to determine the irrigation time. Soil samples were taken by auger before and after each irrigation from 0-0.2 m depth in the germination stage, and the depth of taking samples was increased to 0.3 m in the vegetative growth stage to determine the depth of the added water. Upon depletion 50-60% of the available water, all treatments are irrigating according to the specified amount for the treatment, by adding the depth of water needed to reach the moisture content at the limits of field capacity for the comparison treatment 100% and half the amount for a treatment 50%. Finally, the depth of water to be added to compensate for the depleted moisture was calculated using the following equation

$$d = (\theta_{fc} \times \theta_w) \times D$$

Where:

D: Depth of added water (mm).

θ_{fc} : Volumetric moisture content at field capacity (cm^3cm^{-3})

θ_w : Volumetric water content before irrigation (cm^3cm^{-3})

D: Depth of the effective root (mm).

The depth of the added water is multiplied by the area of the experimental unit to obtain the amount of irrigation water. Equal quantities of water (to the limits of field capacity) were added to all the treatments at planting to ensure the emergence of seedlings.

Treatments

- **Main Factors**

1- Treatment of full irrigation (depletion 50-60% of the available water and returned to the limits of field capacity).

2- Treatment of half of the full irrigation water (50%), the treatments irrigated with half the amount of irrigation water by which the comparison treatment shall be irrigated.

- **Second factor**

1- Comparison treatment: plants were sprayed with only distilled water.

2- Plants were grafted with CaC_2, with an amount of 2 $g.plant^{-1}$, at a depth of 5 cm.

3- Spraying Cycocel CCC at a concentration of 750 $mg.L^{-1}$.

4- Spraying Salicylic SA at a concentration of 250 $mg.L^{-1}$.

5- Spraying Cycocel CCC + Salicylic SA at a concentration of 750 and 250 $mg.L^{-1}$.

6- Spraying Cycocel CCC at a concentration of 750 $mg.L^{-1}$ + grafting$CaC_2$with an amount of 2 $g.plant^{-1}$.

7- Spraying SA at a concentration of 250 $mg.L^{-1}$ + grafting$CaC_2$with an amount of 2 $g.plant^{-1}$.

8- Grafting Calcium Carbide $CaC_2$with an amount of 2 $g.plant^{-1}$ + spraying Cycocel CCC + Salicylic SA with an amount of 2 $g.plant^{-1}$and at a concentration of 750 and 250 $mg.L^{-1}$, respectively.

The addition method

1- Spraying treatments

The plants were sprayed with Cycocel and Salicylic three times on the root, the first spraying at a stage of 4-5 leaves, the second spraying at a stage of 6-7 leaves, and the third spraying at 8-9 leaves. The interaction treatments were sprayed with a difference of one day for each substance to avoid interaction between them, as for the comparison treatment it was sprayed with distilled water only.

2- Ground application treatment

Grafting the soil under the treatment plants with Calcium carbide to about 5 cm and in 5 cm depth for one time only.

Study characteristics

The readings were taken from the intermediate plants (8 plants per treatment) and the arithmetic mean was obtained for each characteristic.

- **Plant height (cm):** The plant's height was measured at the physiological maturity stage for each treatment from the point of stem contact with the soil to the top of the head with the measuring tape (Kharbit *et al*., 2014).
- **The stem height at the middle of internodes number (cm):** The number of internodes in the stem was calculated, starting from the first internode above the soil surface to the last internode at the top of the stem, and the number of internodes divided by 2 and the stem height at the middle of lower internodes number.

- **The number of internodes:** They were calculated starting from the first internode above the soil surface to the last internode at the top of the stem.
- **Stem diameter (mm):** Three measurements were taken for each plant by the (Vernia) at the full flowering stage, the first measurement above the soil surface, the second in the middle, and the third from the last internode, then calculate the average (1963.Quinby).
- **Stem dry weight (g.plant^{-1}):** the leaves, head, and roots were removed from the stem and dried in an electric oven at a temperature of 70 °C, and after the weight was constant, readings are taken.
- **Lodging percentage:** The number of lodging plants was calculated from the total number of plants per treatment and converted to a percentage, as in the following equation:

Lodging percentage % = (number of lodging plants / total number of plants per treatment) x 100

The Genestat was used to statistical analysis of data by using the LSD at level 0.05, and calculating the difference between the average of the treatment (Al- Rawi and Khalaf Allah, 2000).

Results and Discussion

- **Plant height**

The results of Table 1 showed significant superiority of the irrigation treatment 100% in the plant height over the treatment 50% of the full irrigation water. The conditions of water shortage inhibit cell division and elongation, which results in a clear inhibiting to the stem elongation due to the reduction in the number and size of cells (Muhammad and Younis, 1991; Sallah *et al*., 2002). This was consistent with the findings of (Ali, 2017) that the shortage of irrigation water negatively affects the division and elongation of cells, thus reducing the sorghum height. The results of Table 1 indicate that the largest decrease in plant height was in the combining treatment between SA + CCC + CaC_2, with a significant decrease over all other treatments. Followed by CCC + CaC_2 treatment, SA treatment, CaC_2 + SA treatment, the CCC + SA treatment, and the CCC + CaC_2 treatment with the lower percentage than the comparison treatment amounted to 21.45, 17.47, 17.43, 16.65, 16.51, 14.72 and 12.72%, respectively. The reason may be that retardants are causing a failure of the natural elongation of the stem and the plant dwarfing due to inhibition of cell division and elongation in the sub apical meristem (Attia *et al*., 1998). It was observed that the combining of the growth retardants has a major effect in reducing plant height by inhibiting cell division and expansion, as the dual role in inhibiting gibberellin and Auxin appear together, and it is known that Auxin needs gibberellin to show its effect on stem elongation (Taha, 2001).The Acetylene gas is released from Calcium carbide CaC_2 when it contacts with water, and this gas has a similar effect to the effect of Ethylene gas in plants as well as its conversion to Ethylene gas due to some soil microorganism (Al-Fariji, 2019). Ethylene affects plant tissues by inhibiting cell division and the influence of the DNA and its biosynthesis, as it stopping or inhibiting vegetative growth and accelerating reproductive growth processes. As well as, the effecting of Cycocel (CCC) in inhibiting subcellular cell division in the sub apical meristem and inhibiting the biosynthesis of Gibberellin, which reduces the amounts of produced Gibberellin. Moreover, Salicylic (SA)affects cell division as it inhibits plant height and vegetative growth when used in high concentration (Ibrahim, 2013); these results are consistent with (Pirasteh *et al*., 2016, Abd al-Amir *et al*., 2017 and Kumari, 2017) findings. As for the interaction between the two study factors, Chart 1 showed that there was a significant interaction between the two study factors. It can observe that the growth retardants treatments with full irrigation give the interaction treatments of lower height than the comparison treatment with half amount of irrigation water (50% irrigation) with a significant difference and this represented a quantitative interaction between the two study factors. The chart also shows that the growth retardants, whether alone or combined, have affected the inhibiting of stem elongation with the two irrigation levels and with a significant decrease from the comparison treatment swith the same irrigation levels. The lowest value was in the interaction treatment CaC_2 + CCC + SA of 50% irrigation, with a significant difference than all other interaction treatments, while the comparison treatment with full irrigation (100%) gave the highest value of interaction between the two study factors and superior over all other interaction treatments. This indicates the importance of growth retardants in regulating growth even with an abundance of water, which was reflected in increasing the yield and indicates the importance of the presence of the two factors (the amount of irrigation water and plant growth retardants) in reducing plant height.

Table 1 : Effect of the two study factors and their interactions on the sorghum height (cm)

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	257.10	244.92	251.01
2	CaC_2	230.59	197.50	214.05
3	CCC	229.29	208.85	219.07
4	SA	223.55	190.96	207.25
5	CCC+SA	221.54	197.56	209.55
6	CCC+CaC_2	224.84	189.44	207.14
7	CaC_2+SA	220.64	197.76	209.20
8	CaC_2+CCC+SA	211.89	182.41	197.15
L.S.D		9.95		7.29
Average		227.43	201.17	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		5.40		

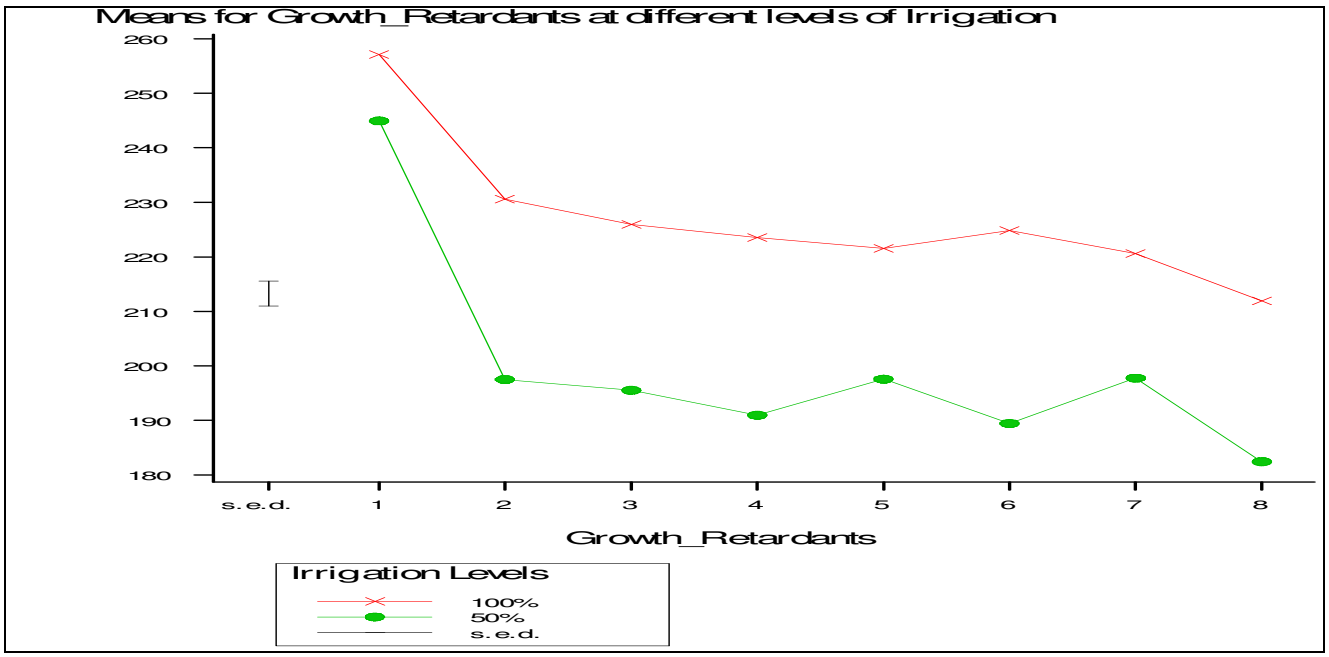

Fig. 1 : Effect of interaction between two study factors on plant height

- **Stem height at the middle of lower internodes number**

Table 2 showed a significant decrease in the stem height in the middle of the lower internodes number in treatment 50% compared to treatment 100%.The reason may be attributed to the effect of water stress on shortening the length of the internodes by affecting the cell division and expansion, and thus the stem was short in the middle of lower internodes number. Besides, it was observed that early treating (before elongation) with water stress had a positive effect in reducing the elongation of internodes, which is the weak point of the plant in resist the lodging, accordingly there is no benefit to be obtained from treating with stress after elongation. It must be mentioned that the role of water stress in displacing the hormonal balance towards inhibiting vegetative growth and reducing elongation. As for the growth retardants, the treatment CCC + SA + CaC_2 gave the lowest stem height at the middle of lower internodes number, although it did not reach to the significance level over the treatments of SA, CCC + SA, CCC, CCC + CaC_2, and SA + CaC_2.However, it significantly reduced the stem height at the middle of lower internodes number compared to the treatment CaC_2, and the latter with the treatments mentioned above had reduced the stem height at the middle of lower internodes number significantly over the comparison treatment that gave the highest stem height at the middle of lower internodes number. The shortening of the lower internodes can represent plant protection against lodging, and this shortening is due to the addition of growth retardants that inhibit the Auxin or Gibberellin synthesis or both (cycosyl represents anti-Gibberellin and CaC_2 is an anti- Auxin by producing ethylene).In addition to the influential role of retardants in reducing the elongation of the lower internodes, where it was observed from the table that the plant height decreased significantly using combined growth retardants in treatment (CCC + SA + CaC_2) compared to the comparison treatment. As the decrease percentage reached 27.31%, when compared with the decrease percentage between the two treatments mentioned in Table 3. Finally, it can be observed that the decrease percentage reached 37.55%, and this indicates that the shortening of the elongation of the internodes was greater in the lower than the upper and it is an advantage to resist lodging, while it was observed that it was not significant between the study factors interaction.

Table 2 : Effect of the two study factors and their interactions on the stem height at the middle of the lower internodes number of sorghum plant (cm)

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	121.67	106.67	114.17
2	CaC_2	100.00	81.00	90.50
3	CCC	98.67	81.00	89.83
4	SA	90.67	80.33	85.50
5	CCC+SA	96.00	79.00	87.50
6	CCC+CaC_2	96.33	83.00	89.67
7	CaC_2+SA	102.67	76.67	89.67
8	CaC_2+CCC+SA	92.33	73.67	83.00
L.S.D		N.S		7.01
Average		99.79	82.67	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		9.47		

- **Number of internodes**

It was observed from Table 3 that the irrigation level 100% exceeded with a significant difference than the treatment 50%.The decrease in irrigation water affects all the growth characteristics, including elongation, so it slows down the plant growth, and thus, it affects the internodes number. It is known that water stress causes internal hormonal imbalances of plants by displacing the hormonal balance towards inhibiting vegetative growth and preparing the plant to enter the fruiting growth stage. As well as the occurrence of confusion in the absorption of the nutrients from the soil due to the absence of water, in addition to that the process of photosynthesis that is negatively affected for many reasons related to water stress, such as closing stomata and less gas exchange. As well as, increased viscosity of the cytoplasm, change in the permeability of cell membranes, a decrease in the efficiency of the transferring photo assimilates processes and others, and the occurrence of oxidative stress due to the increase in free radicals that inhibiting the growth because of destroying cell membranes and protein oxidation. This represents an aspect of water stress damages that may be reflected in the inhibition of the shoot tip, and thus the number of internodes decreased and the leaves in the plant, this result is consistent with the (Jasim, 2018) findings. Plant growth retardants reduced the number of leaves by a significant difference than the comparison treatment and without a significant difference between them, the reason may be due to the effect of growth regulators in inhibiting the biosynthesis of Gibberellin and Auxin. In addition to inhibiting the transport of the product from them within the plant cells and tissues by stimulating the enzymes that decompose and naturally destroy the product within the plant, reducing vegetative growth, dwarfing the plant, and consequently, decrease the number of internodes. This is consistent with (Khafaji, 2014), while it was observed that, it was not significant between the study factors interaction.

Table 3 : Effect of the two study factors and their interactions on the internodes number of the sorghum plant

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	13.66	12.66	13.16
2	CaC_2	12.33	11.00	11.66
3	CCC	12.33	10.33	11.33
4	SA	11.66	10.66	11.16
5	CCC+SA	11.66	10.33	11.00
6	CCC+CaC_2	12.33	11.33	11.83
7	CaC_2+SA	12.00	10.66	11.33
8	CaC_2+CCC+SA	11.33	11.00	11.16
L.S.D		1.05		0.75
Average		12.16	11.00	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		0.71		

- **Stem diameter**

The results of Table 4 showed that the irrigation level 100% exceeded with a significant difference than the treatment 50%, where the decrease in water content due to the absence of water affects the movement of nutrients and the ability of the plant to absorb and benefit from the nutrients. Besides, the absence of water affects the cell division and elongation, since the stem diameter is one of the vegetative growth parameters, as any obstruction to vegetative growth may be reflected in the reduce stem diameter. It was observed that the plant height, the number of internodes and the stem dry weight as shown in Tables 1,3 and 5, respectively have decreased significantly due to the water stress that represents a set of stresses (the stresses that accompany water stress such as nutritional and hormonal. In addition to oxidative imbalances, etc.) that inhibiting growth, including the stem diameter, and thus lead to reduce stem diameter, this result was similar to (Karasu *et al*., 2015) findings. Growth retardants have significantly increased stem diameter compared to the comparison treatment in all treatments, this result consistent with the effects of growth retardants that shorten the stem and increase its diameter to combine two advantages in resist lodging, this result is consistent with (Zadeh *et al*., 2012 and Al-Fariji, 2019). As for the interaction was not significant between the two study factors.

Table 4 : Effect of the two study factors and their interactions on the stem diameter (mm.plant^{-1}) of the sorghum plant.

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	19.22	18.10	18.66
2	CaC_2	21.55	19.22	20.39
3	CCC	21.22	20.00	20.61
4	SA	21.22	20.44	20.83
5	CCC+SA	21.11	20.11	20.61
6	CCC+CaC_2	21.11	20.22	20.66
7	CaC_2+SA	21.55	20.22	20.89
8	CaC_2+CCC+SA	21.55	20.11	20.94
L.S.D		0.689		0.518
Average		21.09	19.80	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		0.071		

- **Stem dry weight**

The results of Table 5 showed that the irrigation level 100% exceeded with a significant difference than the treatment 50%, that reducing the amount of irrigation water to the half has reduced the stem weight by 16.12%. The water deficiency during the vegetative growth stage causes inhibiting the stem growth and decrease dry weight, it has been observed that the plant height and the stem diameter as shown in Tables 1 and 4 is have a significant decrease in the treatment 50%, which are important parameters of decreasing the stem weight. Thus, it can be observed that the decrease in stem dry weight due to the irrigation of the plant with half amount of irrigation water in the comparison treatment (100%). Water stress reduces the deposition of dry matter in the stem, this result is consistent with (Rosenow's, 1993) findings. The growth retardant treatments have significantly decreased the stem dry weight than the comparison treatment and without significant differences between them, by a decreasing percentage ranged between 23.78% in treatment CCC + SA + CaC_2 and by 19.54% in treatment CCC + SA. From Tables 1 and 4 it can be observed that growth retardants have significantly reduced the plant height and stem diameter than the comparison treatment. This may be due to that the growth retardants inhibiting cell division and expansion in the plant stem and as a result decrease the sedimentation of photo assimilates in them that are reflected in decreasing stem dry weight.

As for the interaction between the two study factors, Chart 2 showed that there was a significant interaction between the two study factors. It can be observed that the growth retardants treatments with full irrigation gave less stem dry weight than the comparison treatment with half amount of irrigation water (50%) by a significant difference and this represented a quantitative interaction between the two study factors. The chart also showed that the growth retardants, whether alone or combined have affected stem dry weight reduction with the irrigation levels and with a significant decrease than the comparison treatments under the same irrigation levels. Besides that, the lowest value was in the interaction treatment CaC_2 + CCC + SA under 50% irrigation with a significant difference from all other interaction treatments. Furthermore, the comparison treatment with full irrigation (100%) gave the highest value of interaction between the two study factors, exceeding all other treatments. This indicates the importance of growth retardants in regulating growth even with an abundance of water, which reduced the plant height and stem diameter because of the growth retardants inhibiting cell division and expansion in the plant stem, and as a result, decrease the sedimentation of photo assimilates in them that are reflected in decreasing stem dry weight. Also, it indicates the importance of the two factors (the amount of irrigation water and plant growth retardants) in reducing the stem dry weight.

Table 5 : Effect of the two study factors and their interactions on the stem dry weight (g.plant^{-1}) of sorghum plant

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	292.9	273.0	283.0
2	CaC_2	248.8	195.2	222.0
3	CCC	234.3	212.2	223.2
4	SA	226.8	215.7	221.2
5	CCC+SA	241.4	207.4	224.4
6	CCC+CaC_2	245.9	209.0	221.6
7	CaC_2+SA	247.2	196.0	221.6
8	CaC_2+CCC+SA	238.9	192.4	215.7
L.S.D		17.84		13.21
Average		247.0	212.7	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		7.93		

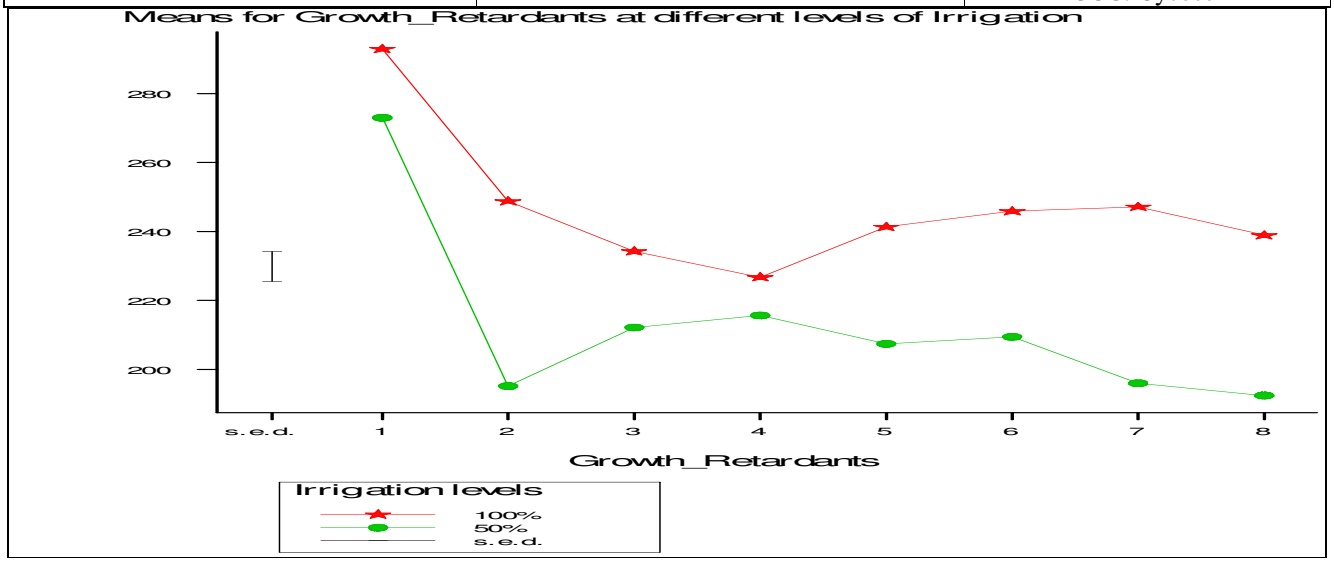

Fig. 2 : Effect of interaction between two study factors on the stem dry weight

- **Lodging percentage**

Table 6 showed that the irrigation level 100% exceeded by increasing the percentage of lodging with a significant difference than the treatment 50%. From the previous Tables, it can be observed that reducing the amount of irrigation water to half in treatment 50% has significantly reduced the plant height as shown in Table 1 by 11.54%. As well as stem height at the middle of lower internodes number as shown in Table 2 by 17.15%, the number of internodes as shown in Table 3by 9.53% and the stem dry weight as shown in Table 5 by 13.84%. On the other hand, the stem diameter decreased as shown in Table 4 by 6.40%. All these data indicate an increase in resistance to lodging when irrigating a plant with half the amount of irrigation water for a treatment 100%, this led to giving a decrease in the lodging percentage reached 89.92% compared to the comparison treatment (100%). Notably that this variety suffers from a high percentage of lodging, but it did not observe clear in this experiment for reasons that maybe the weather represented by wind speed or that the high buildings are close to fields that work as windbreaks. The all growth retardants treatments gave a significant decrease of lodging percentage than the comparison treatment by 0.00%, and this can be explained by the effect of growth retardants inhibiting the action of Gibberellin and Auxin or both, which led to a significant decrease in the stem elongation as shown in Table 1. As well as, the stem height at the middle of lower internodes number is Shown in Table 2, the number of internodes as in Table 3, stem dry weight as in Table 5.Alternatively, there was an increase in the stem diameter in all the growth retardants treatments, which they significantly exceeded the comparison treatment. This interaction treatment is one of the parameters that increase while decreasing stem diameter, height, and weight, which make the plant able to resist lodging, this result is consistent with (Jassem , 2018).As for the interaction between the two study factors, Chart 3 showed that there was a significant interaction between the two study factors. It was observed that all growth retardants treatments with full irrigation (100%) and (50%) gave 0.00%, which is less than the comparison treatment with full irrigation and the comparison treatment with half the amount of irrigation water and by a significant difference between the two study factors. The chart also showed that growth retardants, whether alone or combined, have affected the prevention of lodgin gunder the two irrigation levels with a significant decrease than the comparison treatments under the same irrigation levels and that the lowest value of the interaction was in all growth retardants treatments. Finally, the comparison treatment with full irrigation gave the highest value of interaction between the two study factors exceeding all other interaction treatments. This indicates the importance of growth retardants in regulating growth even with an abundance of water, which was reflected in prevent lodging and increasing the yield by shortening plant height. In addition to planting height at the middle of lower internodes number and increasing the stem diameter, and also indicates the importance of the two factors (the amount of irrigation water and plant growth retardants) in reducing the plant height. The comparison with 50% irrigation gave a significant decrease in the lodging percentage with a significant difference from the comparison treatment with full irrigation by a percentage of 90.00%, which showed the importance of the irrigation factor in reducing lodging.

Table 6 : Effect of the two study factors and their interactions on the lodgingpercentage.plant^{-1} of the sorghum plant

Seq.	Growth retardants	Irrigation treatments		Average
		100%	50%	
1	Comparison	0.3333	0.0333	0.1833
2	CaC_2	0.0000	0.0000	0.0000
3	CCC	0.0000	0.0000	0.0000
4	SA	0.0000	0.0000	0.0000
5	CCC+SA	0.0000	0.0000	0.0000
6	CCC+CaC2	0.0000	0.0000	0.0000
7	SA+CaC2	0.0000	0.0000	0.0000
8	CaC2+CCC+SA	0.0000	0.0000	0.0000
L.S.D		0.035		0.024
Average		0.0417	0.0042	CaC_2: Calcium Carbide SA: Salicylic acid CCC: Cycocel
L.S.D		0.031		

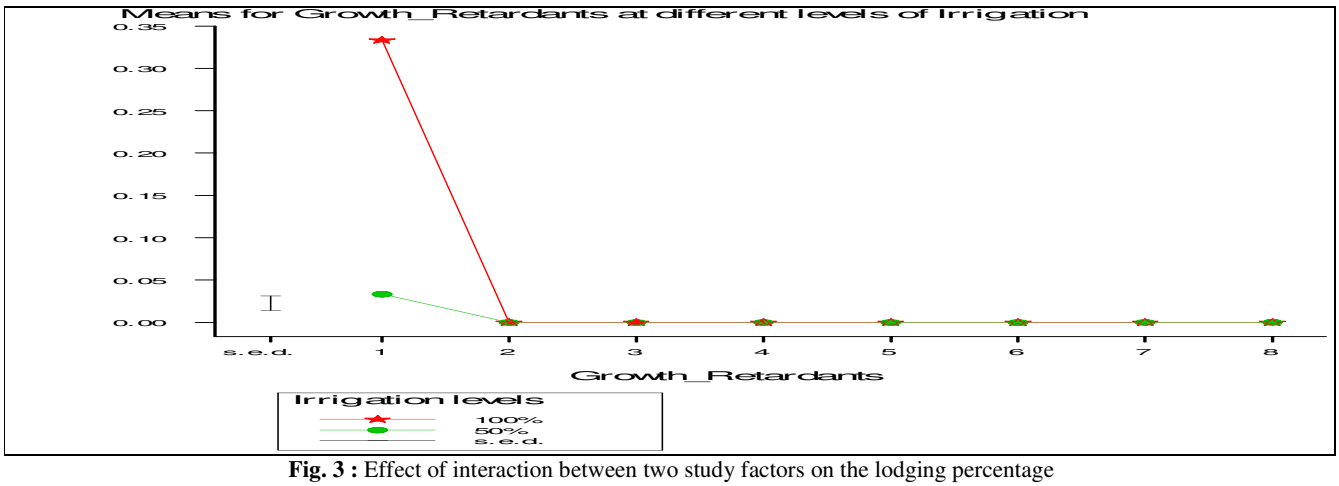

Fig. 3 : Effect of interaction between two study factors on the lodging percentage

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