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RESEARCH PAPER

Interactive Effect of Irrigation Skipping and Salicylic Acid on Growth of Sunflower (*Helianthus annuus L.*)

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A B S T R A C T:

Under the semiarid, in the Sulaimani Region, two sites (Rnaya City and Qaladza City) were chosen to conduct the research during summer. It was designed as a split plot factorial arrangement using randomized complete block design (RCBD) with three replications at both locations. The purpose of this experiment was to determine the skipping irrigating effect I_1, I_2, and I_3 with salicylic acid applied S_1 and non-applied S_0 on sunflower growth at three different growth stages (vegetative, flowering, and ache-forming stages), and compared to the effects of full irrigation I_4. Complete irrigation with salicylic acid applied resulted in the best growth, while the lowest growth was recorded by skipping irrigation without salicylic acid application at the flowering stage. The treatments without salicylic acid application were found to be the most effective in conditions of low watering. Moreover, there was a failure in the flowering stage and increasing growth when watering was missed, compared to the vegetative and achene stages. Consequently, it is concluded that avoiding limiting irrigation during the flowering stages can lead to a better production.

KEY WORDS: Irrigation; Water stress; Sunflower growth; Salicylic acid.
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1. INTRODUCTION:

Sunflower (*Helianthus annuus* L.) is one of the most important crops globally, which belongs to the Asteraceae family (Hamad, 2017; Dogara *et al*., 2022).

Sunflower is the fourth largest source of vegetable oil after oil palm, soybean, and rapeseed, which account for more than 87 percent of global vegetable oil production. The oil in sunflower seeds is very high, which that 25 to 48 percent (Rauf *et al*., 2017). A biodiesel or vegetable oil-based fuel made from oilseed sunflowers can be used for many types of vehicles, including farm equipment (Pereyra-Irujo *et al*., 2009). From a harvest area of 26 million hectares, the estimate predicts that 47 million tons of sunflower seeds would be produced worldwide in 2016 (FAO, 2016). It is one of the most important oilseeds to have originated in the temperate and subtropical zones (Usman *et al*., 2010).

Non-oil seed sunflowers are used in baking and as a snack for humans because they have a low oil content (Poormohammad *et al*., 2007). Due to its high amount of unsaturated fatty acids and zero cholesterol level, it is one of the vital oilseed crops that is consumed worldwide (Alberio C, 2014). Oilseeds are a vital part of modern agriculture since they provide nutritious food for both humans and animals that is conveniently accessible. The world's second most valuable traded commodity is oil and its byproducts (Anderson and Beardall, 1999).

Agriculture accounts for 70 percent of freshwater driven from aquifers, rivers, and lakes, and in certain poor nations, up to 90 percent (Connor, 2017). Water scarcity is a major constraint on plant species' global spread and growth, adaptation to water scarcity has had a significant impact on plant evolution (Kursar *et al*., 2009). Water supply is dwindling as a result of dwindling natural rainfall, overextraction of groundwater, increasing population, and rising agricultural

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water usage (Asraf and Ali, 2015). Increasing water production necessitates the use of effective water management systems (Mancosu *et al*., 2015).

Irrigation at the right time and in the right place can have a significant impact on sunflower output. During the first 30 days, the plant utilizes only 20-25 percent of its total water requirements. However, the greatest demand occurs, it is being made, also seed output and oil content are both reduced by a lack of water during this time (Ghani *et al*., 2000). Every step of plant growth, from seed germination to maturity, depends on the availability of water, and agricultural production cannot be achieved without it (Turner, 1991). High ambient temperature and low precipitation in drier and semi-arid regions reduced sunflower oil quality by shortening the time between germination and anthesis and the filling of the achene, as well as by suppressing the lengthening of the stems and the leaf area index (LAI) (Hussain *et al*., 2018).

Sunflower uses about 450 millimeters of water during its life cycle, although this varies by region due to climate (Mozzafari, 1995). According to Dragovi and Maksimovi (1995), a worldwide decline in sunflower yields has been linked to drought. It is widely believed that water stress is the most significant factor limiting crop yields around the world (Petcu *et al*., 2001). Another water-saving strategy in agriculture is called as "deficit irrigation," which refers to watering at a level below the whole crop water need (Bashir and Mohamed, 2014). As one of the major abiotic challenges that plants undergo during their life cycle, drought is one of the most limiting factors to plant growth and productivity, especially in semi- and arid regions. Leaf structure and form, photosynthesis, and temperature regulation are all dependent on water (Fahad *et al*., 2017).

At different phases of development, sunflower is extremely susceptible to water scarcity. During the growing phase of crops, water stress is believed to be the most significant component (Sinclair, 2005). Reduced yields are more common in treatments where the crop has more difficulty accessing water (da Silva *et al*., 2011). Khalilvand and Yarnia (2007) found that plants under drought stress were more resistant to water movement, because when plants are under drought stress, they become more resistant to water flow because their stomata close more tightly than they would under normal conditions. During the germination, seedling, and flowering phases, plants are particularly vulnerable to drought (Ashraf and Mehmood, 1990). Due to dehydration, seeds must compromise to ensure the survival of the seedlings during seed germination (Albuquerque and de Carvalho, 2003). In the flowering stage, stress results in ovarian and embryonic abortions, pollen sterility, and a reduction in leaf area index. It has been estimated that stress during the vegetative phase causes a yield drop of 15-25 percent, however stress can result in a reduction of more than 50 percent if stress occurs during the flowering stage (Reddy *et al*., 2003).

A growth regulator and a messenger molecule like salicylic acid (SA) plays an important role in the development of tolerance under biotic and abiotic stresses (El-Tayeb, 2005), like drought (Senaratna, 2003). Effects of SA on enzymes such as catalase and peroxidase, as well as osmotic regulators such as proline, glycine, or betaine and ameliorated on the effects of drought stress, heavy metals and heat and cold on maize and tomato plants (Hussein *et al.*, 2007). According to Noreen *et al*. (2009), SA stimulates sunflower line growth. Leaf peroxidase activity has enhanced as a result of SA's increased antioxidant capacity. In times of stress, SA boosts the concentration of ABA in the plant and helps to keep stress-related effects to a minimum (Ianovici, 2011) and regrows the plants (Sakhabutdinova *et al.*, 2000). Plants' physiological functions are regulated by salicylic acid (SA), a phenolic molecule having antioxidant capabilities (Mehrabian *et al.*, 2011). Glucosinolate content in the leaves of rapeseed rose after the application of SA, because Brassicaceae leaves contain thio-glucoside. Hydrolysis of glucosinolates releases various chemicals that protect plants against infections and pests when tissues are injured, SA boosts the anthocyanin and chlorophyll content of Spirodella polyrriza, according to Popova *et al*. (1997). It has been shown that salicylic acid can boost the activity of enzymes such as glutathione reductase and ascorbate peroxidase in plants treated with salicylic acid (Manochehrifar, 2010). There was a rise in the transport and manufacture of seed storage proteins, as well as other activities related to seed quality, such as protein biosynthesis, seed primary metabolism, and antioxidant enzyme production (Rajjou *et al.*, 2006). Keeping super oxide dismutase activity for O2 elimination is one way that SA is shown to prevent oxidative damage in studies (Rao *et al.*, 1997).

The highest water efficiency for sunflowers was attained with a minimal number of irrigation treatments (Langeroodi *et al*., 2014). During a drought, the water utilization efficiency is higher than it is under regular irrigation, according to Kassab *et al.* (2012). Water consumption efficiency dropped as the proportion of accessible soil moisture depletion increased, according to Goksoy *et al*. (2004).

The main objective of this study was to investigation of how salicylic acids with various irrigation levels (full irrigation and water stress) affect sunflower growth and their components.

2.MATERIALS AND METHODS

2.1The Experimental Site Location

Sulaimani Governorate is located in northeastern Iraq, on the border with Iran. The first location is Ranya city, which is located 131 kilometers northwest of Sulaimani at (Latitude: 36° 16' 30 N, Longitude: 44° 51' 29 E of 607 masL). The second is Qaldza city, which is located 165 kilometers northwest of Sulaimani at (Latitude: 36° 11' 34 N, Longitude: 45° 06' 29 E of 548 612 masL) (Google Earth App, Version 9.154 2/2022; tobographic-map.com), (Figure 1).

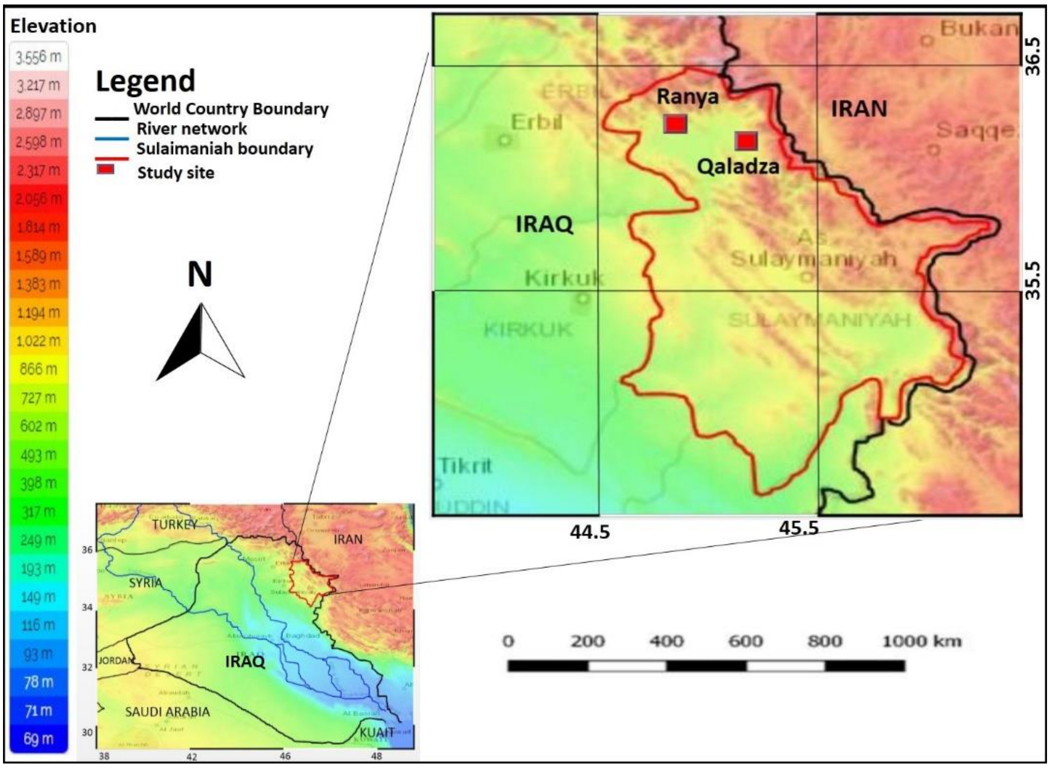

Figure 1. The study locations**.**

2.2The Region Climatic Conditions

Sulaimani Governorate has a semi-arid climate; summers are dry and scorching, while winters are wet and cold. From july to August, the temperature is 39 to 43°C, frequently reaching 50°C. October brings average temperatures of 24 to 29°C, with November bringing a minor cooling down. Spring and winter months receive most rainfall (Kurdistan Regional Government, Director of Agriculture/Agriculture of Meteorology, Raparin, 2021). As illustrated in (Table 1).

Table 1. Average agrometeorological parameters during summer season 2021 at both locations

Locations	Month	Temperature °C		Humidity (%)	Wind speed (ms^{-1})	Precipitation
		Minimum	Maximum			
Ranya	June	22.3	39.83	15.2	1.7	0
	July	26.96	43.26	17.4	1.4	0
	August	26.2	42.36	18.1	1.6	0
	September	19.9	36.63	20.4	1.7	0
Qaladza	June	17.3	38.86	15	1.9	0
	July	21.73	41.56	16.4	1.6	0
	August	23.03	41.43	18.4	1.7	0
	September	16.36	35.33	19.7	2	0

2.3Experimental Treatments

Three replications were used to examine the effect of four irrigation treatments and two salicylic acid levels. Irrigation treatments were classified as three types of skipping irrigation (I_1, I_2, and I_3) and one type of complete irrigation (I_4). During the experiment, two levels of salicylic acid were used: no salicylic acid (S_0) and salicylic acid applied (S_1).

2.3.1Irrigation treatments

Irrigation treatments include four degrees of full and skipped irrigation. Table 2 detailed the irrigation treatments.

Table 2. Details of irrigation treatments

Irrigation symbols	Skipping irrigation stage
I_1	At the vegetative-stage
I_2	At the flowering-stage
I_3	At the achene formation-stage
I_4	Full irrigation (Non skipping irrigation)

2.3.2Salicylic acid treatment

The salicylic acid treatments consists of two levels; the first level was salicylic acid applied with 200 mg L^{-1} according to Sedghi *et al*. (2010) and Noreen *et al*. (2009). The application of SA was applied as a spray on leaves at vegetative stage and flowering stage (Figure 2). The second level was non-applied salicylic acid (Table 3).

Table 3. Detailed the salicylic acid treatments.

Salicylic acid symbols	Salicylic acid treatment description
S_0	Non-applied salicylic acid (spry distil water on leafs)
S_1	Salicylic acid applied

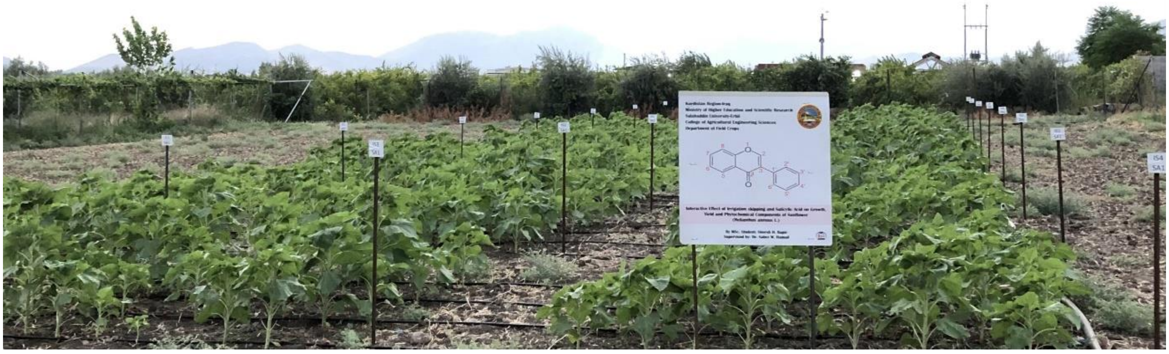

Figure 2. An overview of the experiment.

2.4Experimental Design

Three replications were used for the experiment. It was a split plot factorial arrangement, using a randomized complete block design, the irrigation treatment as the primary plot, and four irrigation treatments (I_1, I_2, I_3, and I_4) were employed. The subplot factorial design included two salicylic acid treatments: no salicylic acid application (S_0) and salicylic acid application (S_1). Figure 3 details it.

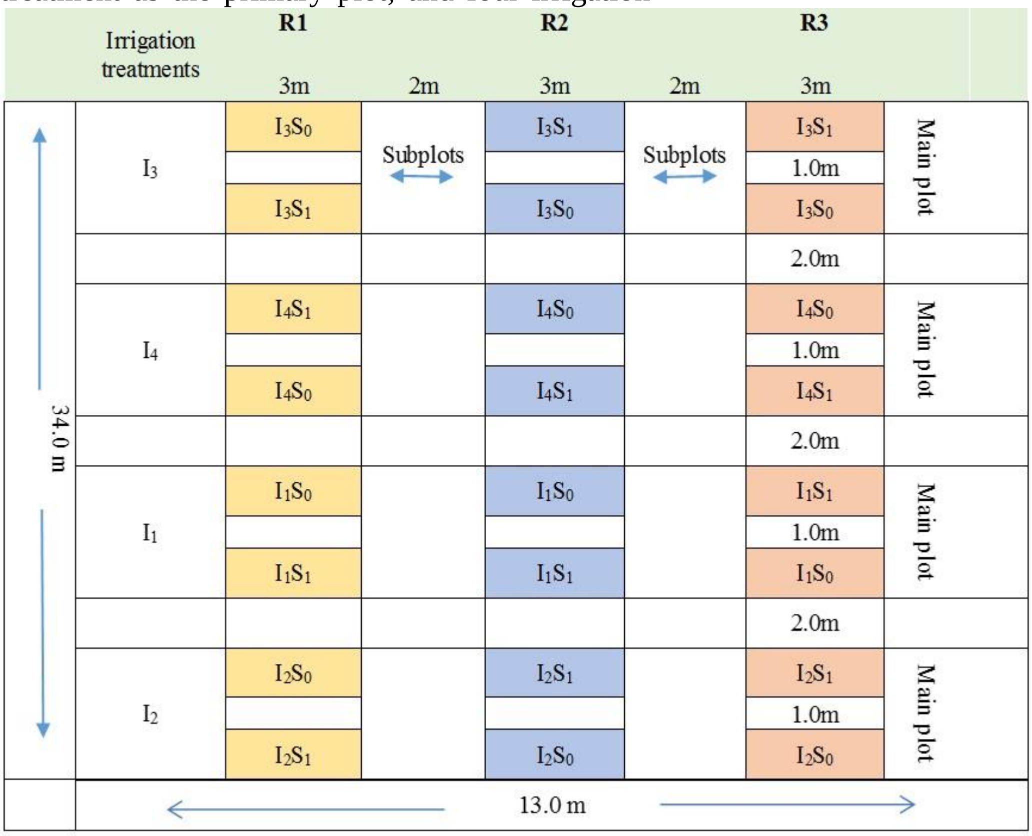

Figure 3. Layout plan of the experimental field at both locations, where S = Salicylic acid, I = irrigation treatments and R = replicates. Main plot area = 3 x 7, while subplot area = 3 x 3 = 9 m^2; distance between main plots = 2m, and distance between subplots=1m

2.5Field Preparation

The study field plowed perpendicularly via a moldboard plow at optimal tillage water content. After leveling the soil surface, the area was divided into three replications, with each replication containing eight experimental subplots of 9 m^2 (3 x 3 m^2). Four rows of plants were planted in each subplot, spaced 0.75 m apart, and at a depth of 4-6cm, three sunflower seeds per hole were placed with a plant spacing of 0.30 m, which resulted in a consistent plant population of

44400 plants/ha across all treatments. When the seedlings reached the four to six-leaf stage, they were thinned to one plant hole^{-1}. Weeding by hand was conducted as needed without pesticide and fertilizer application (Halliru *et al.*, 2021). Sunflower heads were covered with a screen following pollination to protect them from bird attack.

2.6Hybrid Description

It was NS Leviathan, 1st generation and it was produced on May 2021 by Field and Vegetable Crop Institute, Novi Sad-Serbia (NS SEME, 2021).

2.7Sowing Date

Sunflower seeds were sown on the line on June 21 of 2021.

2.8Watering and Restrictions

Watering was achieved via a drip irrigation system that continuously received water from a tank close to the field through drip irrigation tubes to irrigate each sunflower plant (one dripper to one plant) in the various treatments, equally (Figure 4). Dripper points of the selected plots due to skip irrigation were closed at deferent growth stages (Praveen, 2021).

2.9Analytical Methods and Laboratory Analysis

2.9.1Soil analysis

For this experiment, soil samples were taken at 30, 60, and 90 cm depth. A soil sample of approximately 5 kg was collected from each depth of the experimental location by combining subsamples. The samples were cleansed of plant roots and other debris; gently crushed and sieved using a stainless steel sieve with a thickness of 2 mm; and lastly stored for the desired physiochemical investigation.

Particle-size distribution of class textural assessing was carried out according to the international sieve method (2.00, 0.05, and 0.002 mm). The EC and pH of a 1:10 solution of soil and water were determined (Gupta, 2000). The soil organic carbon was determined using the method of wet oxidation following Walkley Black method. CaCO3 percent was determined using a 23c-method developed by the staff of the United States Salinity Laboratory 1954, based on Black *et al*. (1965) description. The moisture content of the soil was determined gravimetrically (Lorenz and Maynard, 1980). On a weight basis, the soil moisture content was determined as (Equation 1). The soil parameter results were summarized in (Table 4).

Table 4. Soil sample physicochemical properties of experiment location

Physicochemical-properties		**Rate**
Particles-size %	Sand	5.8
	Silt	59.7
	Clay	34.5
	Texture	Silty loam
PH		7.59
ECe (deci siemens m^{-1}) or (DS m^{-1})		0.5
O.M. %		0.7
CaCO3 %		8.2
Soil moisture content %		5.7

Figure 4. Watering and restrictions by drip irrigation system

Equation 1. Soil moisture content %

$$\text{Soil moisture \%} = \frac{\text{Wet weigh} - \text{Oven dry weigh}}{\text{Oven dry weigh}} \times 100$$

2.10Growth Parameters

At maturity, when the outer bracts of the flower head turned brown, the back of the heads turned yellowish, and the seeds were easily detachable, the sunflower plants were hand-harvested. The heads were sun-dried to around 10% seed moisture content and then manually threshed to separate the seeds.

Harvesting began on September 26, 2021 for all treatments at the Ranya location, and on September 27, 2021 for all treatments at the Qaladza facility. Five plants were randomly tagged in each plot for nondestructive growth analysis (Figure 5).

Figure 5. Growth parameters measuring.

2.10.1Root length (cm)
Root length was calculated as the average length of roots in centimeters.

2.10.2Fresh and dry root weight (g)
The average weight of fresh roots dried to a constant weight inside a perforated paper bag at 68°C, stated in grams.

2.10.3Stem diameter (mm)
The stem diameter was determined at the midpoint of the plant's length using a vernier caliper and expressed in millimeters (mm).

2.10.4Plant height (cm)
The plant height was determined in centimeters using a linear meter scale from the base of the stem to the point of stem insertion with a head.

2.10.5Fresh and dry stem weight (g)
A fresh stem of the plant was cut in half, weighted, and then placed in the perforated paper bag. The bag was then dried to a constant weight in a hot air oven set to 68°C.

2.10.6Leaf area (cm^2)
The leaf area as determined by (Schneiter, 1978) **Error! Reference source not found.**:

LA = {(the leaf's maximum length X the leaf's maximum breadth) X 0.6683} – 2.45 **(Equation 2)**

2.10.7Fresh and dry leaf weight (g)
Weighing the total weight of fresh leaves and drying them to a constant weight within a perforated paper bag in a hot air oven set at 68°C.

2.10.8Head diameter (cm)
In each treatment, the diameter of the adult head was measured in centimeters using a meter tape across the head's center.

2.10.9Fresh and dry head weight (g)
Each treatment's head weight (g) was recorded and then placed in a perforated paper bag and dried to a constant weight in a hot air oven set at 68°C.

2.11Statistical Analysis
The parameters were examined statistically used the variance analysis (ANOVA), an approach to split-plot in randomized complete block design (RCBD) according to the IBM SPSS Statistics program (26); the mean comparison was performed using Duncan's multiple range test at a significance threshold of 0.05.

3.RESULTS AND DISCUSSION

3.1Effect of irrigation treatment on some growth characters at both locationss
The data in Table 5 demonstrates the effect of irrigation treatment on a variety of growth characteristics at both locations. All growth characters (root deep, fresh root weight, dry root weight, stem diameter, plant height, fresh stem

weight, dry stem weight, one leaf area, fresh leaf weight, dry leaf weight, head diameter, fresh head weight and dry head weight) were significant responses to irrigation at both locations. As indicated in Table 5, the maximum values for all characters were obtained with I_4 complete irrigation treatment except root deep, which was obtained with I_1 skipping irrigation during the vegetative stage at both locations.

Skipping irrigation during the vegetative stage resulted in a maximum root depth of 45.667 and 48.003 cm for both locations, while the minimum value for this attribute was 39.000 and 39.983 cm for both locations when full irrigation was used. At both locations, I1 and I_2 predominated I3 and I_4, while no significant differences were noticed between I_1 and I_2, also between I_3 and I_4. In particular soils, the number of roots are crucial for efficient water intake and increased crop output under drought stress. Therefore, the plant roots are the most vital part that gets. As a result, the most critical component of the plant that gets water availability is limited. Leaf growth is reduced, resulting in a fall in relative dry matter portioning. Because of larger root depth, sunflower genotypes obtain moisture and nutrients from deeper layers of soil which they are more tolerant of drought stress conditions (Angadi and Entz, 2002).

The I_4 treatment achieved a maximum fresh root weight of 85.150 and 64.767g at both locations. However, I_1 achieved a minimum weight of 42.383 and 41.698 g at both locations. At Ranya and Qaladza locations, I4 predominated I1, I2, and I_3 significantly, also significant differences were recorded between I_1 and I_2; I_3 and between I_2 and I_3 in this treat. The dry root weight under I_4 recorded the highest value for this feature, 36.240 and 27.565 g for both locations, respectively, while I1 recorded the lowest values, 18.038 and 17.747 g for both locations. The comparison result of this treat at both locations had the same result of fresh root weight. Previously, it was established that when drought stress increases the mean values of fresh plant weight and plant dry weight decrease (Qamar *et al*., 2018).

The stem diameter also increased due to the increase in water level. The values of this were ranged between 11.433 and 19.767; 12.050 and 16.083 mm for I_1 and I_4, respectively, at both locations. At the first location (Ranya City), the I_3 and I_4 predominated I_1 and I_2, and there were not significantly different under I_1 and I_2; I_3 and I_4, while at the second location (Qaladza City), the I_4 exceeded I1, I_2, and I_3 significantly, also I_3 predominated I_1 and were not significantly different under I_1 and I_2; I_2 and I_3. These findings corroborate those of Mirshekari *et al*. (2012), who observed that increased water amount enhanced stem diameter substantially.

The plant height values were between 163.333 and 173.500; 138.333 and 156.000 cm for I_1 and I_4 at both locations. The I_4 values were exceeded significantly each of I_1, I2, and I_3. Moreover, there were significant differences between other treatments (I_1, I2, and I_3) for this character at both locations. These findings corroborate Ashraf and O'Leary (1996), who concluded that the lower values could be a result of water stress, which slows cell growth and so shortens stems by reducing internodal elongation. Unger (1986), who discovered that when all other parameters were equal, the availability of water from emergence to anthesis had a significant effect on plant height.

As shown in Table 5, the fresh stem weight had the highest value under the effect of I_4, which was 324.333 and 239.333 g for both locations, respectively, while the lower value was obtained under I_1; 254.333 and 192.333 g for both locations respectively. At both locations, the fresh stem weights were significant different under all treatments (I_1, I_2, I_3, and I_4). The highest dry stem weights were 59.288 and 43.750 g under I_4 at both locations, respectively, while the lowest values were 46.492 and 35.159 g under I_1 for both locations respectively. The I_4 values exceeded significantly each of I_1, I_2, I_3 at both locations (significant differences between all treatments). These changes could be the result of fewer cell divisions occurring as a result of the decreased amount of soil water (Farahvash *et al*., 2011).

The leaf area under I_4 recorded the highest value for this trait, which was 85.532 and 80.781 cm^2 for both locations respectively, but the lowest value was 73.959 and 72.038 cm^2 recorded by the I_1 for both locations respectively. At the first location, I3 and I_4 predominated I_1 and I_2, while no significant differences were noticed between I_1, I_2, and also between I_3 and I_4. However, at the second location, the I_4 values were exceeded significantly, each of I_1, I_2, I_3, and there were significant differences between all treatments. Previous research has established that leaf area is critical in calculating the growth index of sunflower, the plant with the highest sensitivity to water deprivation. According to the findings of Soriano *et al*. (2004), sunflower can reach its maximum leaf area when fully irrigated in relation to water scarcity. Then, the primary indicator of water stress in the sunflower vegetative phase is a reduction in the size of the leaves (Shiranirad, 2000).

In regard to fresh leaf weight in Table 5, under I_4, the height values were 234.173 and 198.293 g for both locations, respectively. While the lowest values under I_1 were 149.760 and 132.080 g for both locations, respectively. The I_4 values exceeded significantly each of I_1, I_2, and I_3, and there were significant differences between all treatments at both locations. The dry leaf weights highest values under I_4 at both locations were 48.287 and 40.888 g, respectively, while the lowest values were 30.881 and 27.235 g recorded under I_1 for both locations respectively. Significant difference were noticed between all treated for this character. These discrepancies in dry weight may be due to a lack of available water during the sunflower's growth stages (Farahvash *et al*., 2011).

The highest values of head diameter at both locations were 15.567 and 13.550 cm recorded by I_4. The lowest values of this trait were 12.767 and 12.150 cm recorded by I_2 at both locations. At the first location, I_3 and I_4 predominated I_1 and I_2 significantly, while no significant differences were present between I_1 and I_2 and between I_3 and I_4. However, at the second location, there were no significant differences between I_1 and I_2, but I_4 exceeded I_1, I_2, and I_3 significantly, and also I_3 exceeded I_1 and I_2 significantly. Increased watering frequency resulted in an increase in head diameter (Shafi *et al*., 2013). This decrease was most likely caused by a lack of turgor required for cell expansion and a lack of photosynthesis available to meet sink demand (Hussain *et al*., 2010). Gholinezhad *et al*. (2009) discovered that drought stress has a constant detrimental influence on head diameter. Soil water deficiency significantly reduced head diameter, and the decreases were greater during flowering than during bud initiation.

The highest values of fresh head weight at both locations were 45.167 and 44.312 g recorded by I_4. The lowest values of this trait were 33.650 and 30.337 g recorded by I_2 at both locations. At the first location, I4 predominated I1, I2, and I_3, and also I_1 and I_3 predominated I2 significantly, while no significant differences were present between I_1 and I_3. However, at the second location, there were no significant differences between I_1, I2, and I3, but I_4 exceeded I1, I2, and I_3 significantly. The highest values of dry head weight at both locations were 16.368 and 16.059 g recorded by I_4. The lowest values of this trait were 12.195 and 10.994 g recorded by I_2 at both locations. The comparison result of this treat had the same result of fresh head weight at both locations.

Ali and Noorka (2013) discovered that water stress during vegetative growth reduces dry matter as a result of a drop in leaf water potential caused by decreased water updating in response to increased atmospheric demand, which has a significant effect on leaf expansion. These findings are in agreement with Ardakani *et al*., (2005), who found that water scarcity during the vegetative or early flowering stages of sunflower resulted in decreased dry matter output. However, Cox and Jolliff (1986) discovered that well-irrigated treatments produced significantly more dry matter than deficiency and dry land treatments.

3.2Effect of salicylic acid on some growth characters at both locations

The data in Table 6 demonstrate the effect of salicylic acid on several growth characteristics at both sites. Most of the growth characters had respond significantly to salicylic acid effect, while no significant differences were noticed among root deep, fresh leaf weight, dry leaf weight, head diameter, fresh head weight, and dry head weight at the first location and among root deep and head diameter at the second location. As shown in Table 6, it was noticed that the highest values for all characters produced by S_1 salicylic acid applied treatments except root deep, which recorded the highest value at S_0 non-salicylic acid at both locations.

In detail, the fresh root weight, dry root weight, stem diameter, plant height, fresh stem weight, dry stem weight, one leaf area, fresh leaf weight, dry leaf weight, head diameter, fresh head weight and dry head weight under S_1 recorded the highest values, which were 63.925g, 27.2065g, 16.6917mm, 169.3333cm, 300.6667g, 54.9619g, 81.146cm^2, 189.15g, 39.0027g, 14.3083cm, 38.9333g and 14.1094g at first location respectively, and 54.2008g, 23.0679g, 14.5667mm, 151.1667cm, 236.25g, 43.1865g, 77.3283cm^2, 168.48g, 34.7406g, , 12.825cm, 35.9192g and 13.0171g at second location respectively, but the lowest value recorded by the S_0 were 61.1833g, 26.0396g, 14.7917mm, 168.3333cm, 283.75g, 51.8695g, 78.2389cm^2, 182.4767g, 37.6267g, 13.8667cm, 37.6917g and

13.6595g at first location respectively, and 48.8158g, 20.776g, 12.7083mm, 141.4167cm, 197.8333g, 36.1639g, 75.2176cm^2, 155.0467g, 31.9706g, 12.675cm, 33.7842g, and 12.2434g at second location respectively. While, the root deep under S_0 recorded the highest values which were 42.8333 and 44 cm, but the lowest values recorded by S1 which were 42.0417 and 43.9967 cm for both locations respectively. Salicylic acid, according to Noreen *et al*. (2009), stimulates development in sunflower lines. Salicylic acid increases the antioxidant capacity of the leaf, resulting in an increase in leaf peroxidase activity. In sunflower lines with root fresh weight and a CO2 exchange system, a positive connection between leaf peroxidase and super oxide dismutase activity was reported. Furthermore, the increase in sunflower growth caused by exogenous salicylic acid may have been related to alterations in photosynthesis. For example, El-Tayeb (2005) found that salicylic acid-induced growth enhancement could be a result of increased antioxidant activity that protects plants from oxidative damage. Therefore, photosynthesis, a critical element in determining plant development and yield (Natr & Lawlor, 2005), may have been suppressed as a result of salicylic acid administration. This increase in photosynthetic rate as a result of exogenous salicylic acid application was consistent with previous research indicating that exogenous salicylic acid boosted the photosynthetic rates in a variety of crops. e.g., maize (Khodary, 2004), soybean (Khan *et al*., 2003), and wheat (Singh & Usha, 2003). In comparison, Nemeth *et al*. (2002) discovered that exogenously given salicylic acid through the rooting media inhibited growth in maize. Salicylic acid increased the amount of anthocyanin and chlorophyll in Spirodella polyrriza, Popova *et al*. (1997) reported salicylic acid is a water-soluble antioxidant that can also act as a growth regulator in plants. Salicylic acid treatment of rapeseed enhanced the amount of glucosinolate in the leaves. It is a thio-glucoside discovered in the Brassicaceae family of plants.

3.3Interactive effect of salicylic acid and irrigation treatments on some growth characters at both locations

The data in Table 7 demonstrate the effect of irrigation treatments and salicylic acid on several growth characteristics (root deep, fresh root weight, dry root weight, stem diameter, plant height, fresh stem weight, dry stem weight, one leaf area, fresh leaf weight, dry leaf weight, head diameter, fresh head weight and dry head weight). The results show that all studied characters significantly responded to the interaction effect at both locations.

Regarding to the first location, the interaction effect (irrigation and salicylic acid) was nonsignificant between the achene formation stage and nonskipping irrigation for root deep stem diameter and head diameter. And between the vegetative stage and the flowering stage for one leaf area and head diameter; also between the vegetative stage and the achene formation stage for fresh head weight and dry head weight. For the second location, the interaction effect recorded no significant differences between the vegetative stage and the flowering stage for root deep stem diameter and head diameter, and between the flowering stage and the achene formation stage for stem diameter, head diameter and dry head weight; also between the vegetative stage and the achene formation stage for head diameter, fresh head weight and dry head weight; and between the vegetative stage, achene formation stage and non-skipping irrigation for head diameter. While the data analysis showed that the remaining parameters were recorded significantly.

The highest values for the characters fresh root weight, dry root weight, stem diameter, plant height, fresh stem weight, dry stem weight, one leaf area, fresh leaf weight, dry leaf weight, head diameter, fresh head weight and dry head weight were 87.000g, 37.027g, 21.133mm, 175.333cm, 332.667g, 60.811g, 87.548cm^2, 243.533g, 50.217g, 16.100cm, 46.867g and 16.984g at first location, and 69.450g, 29.558g, 18.100mm, 158.000cm, 271.333g, 49.600, 81.477g, 208.867cm^2, 43.068g, 13.600g, 44.360gm and 16.076g at second location recorded by the interaction between I_4 with salicylic acid applied (S_1) respectively, but for root deep, which recorded the highest value at the interaction between I_1 skipping irrigation at the vegetative stage with non-salicylic acid applied (S_0) was 46.333 cm at first location, and was 48.573 cm by interaction I_1 with S_1 at second location. At the first location, the lowest values of fresh root weight, dry root weight, stem diameter, plant height, fresh stem weight, dry stem weight, and one leaf area, recorded by the interaction of I_1 with non-salicylic acid applied (S_0) were 41.433g, 17.634g, 11.067mm, 162.333cm, 248.667g, 45.456g and 72.767cm^2 respectively but for fresh leaf weight and dry leaf weight recorded by the interaction of I_1 with S_1 were 148.893g and 30.702g. While for the character root deep, the lowest values were 38.667cm and 39.167cm recorded by the interaction between I_4 and S1, but for head diameter, the fresh head weight and dry head weight characters were 12.733mm; 33.233g; 12.044g and 12.067mm; 28.170g; 10.209g, recorded by the interaction between I_2 and S_0 at both locations respectively. However, the lowest values of fresh root weight, dry root weight, stem diameter, plant height, fresh stem weight, dry stem weight, one leaf area, fresh leaf weight, and dry leaf weight were recorded by the interaction of I_1 with non-salicylic acid applied (S_0), which were 40.590g; 17.275g; 11.067mm; 133.333cm; 188.333g; 34.427g; 70.840cm^2; 124.107g and 25.591g respectively at second location. Geetha *et al*. (2012) demonstrated that, regardless of the genotype examined, water deficiency during the bud initiation stage resulted in a significant reduction in dry matter when compared to full irrigation. Salicylic acid raises abscissic acid (ABA) levels in stressed plants, preserves the plant's resistance to stress, and stimulates plant regrowth (Ianovici, 2011). Salicylic acid's ameliorative effect on crop plant growth under abiotic stress conditions may be owing to its role in stomatal control, growth and photosynthesis (Arfan *et al*., 2007). Salicylic acid functions as a messenger and growth regulator in the induction of resistance to biotic and abiotic conditions like such as drought (Senaratna, 2003). Salicylic acid plays a crucial role in abiotic stress tolerance in wheat, namely, drought tolerance (Singh & Usha, 2003), and wheat salt tolerance (Sakhabutdinova *et al*., 2003; Shakirova *et al*., 2003). Salicylic acid's ameliorative effect on crop plant growth under abiotic stress conditions may be owing to its role in water interactions (Barkosky & Einhelling 1993), and nutrient absorption (Glass 1974).

3.4Effect of geographical location on growth characters

The data in Figure 6 illustrate the effect locations on growth characteristics. This effect was significant for plant height, fresh stem weight, dry stem weight, and head diameter, but it is not significant for root length, fresh root weight, dry root weight, stem diameter, leaf area, fresh leaf weight, dry leaf weight, fresh head weight and dry head weight.

It was confirmed that fresh root weight, dry root weight, stem diameter, leaf area, fresh leaf weight, dry leaf weight, fresh head weight, and dry head weight showed the best value at the first location (Ranya location), they were predominated by 9.68, 9.68, 7.16, 7.15, 14.76, 14.76, 2.19, 6.91, 6.91, 4.98, 4.73 and 4.73 %,espectively, while root length exhibited the best value at the second location (Qaladza location) and it predominated by 1.80 %. These results support the suitability of the Ranya location for the growth of this crop compared to the Qaladza location.

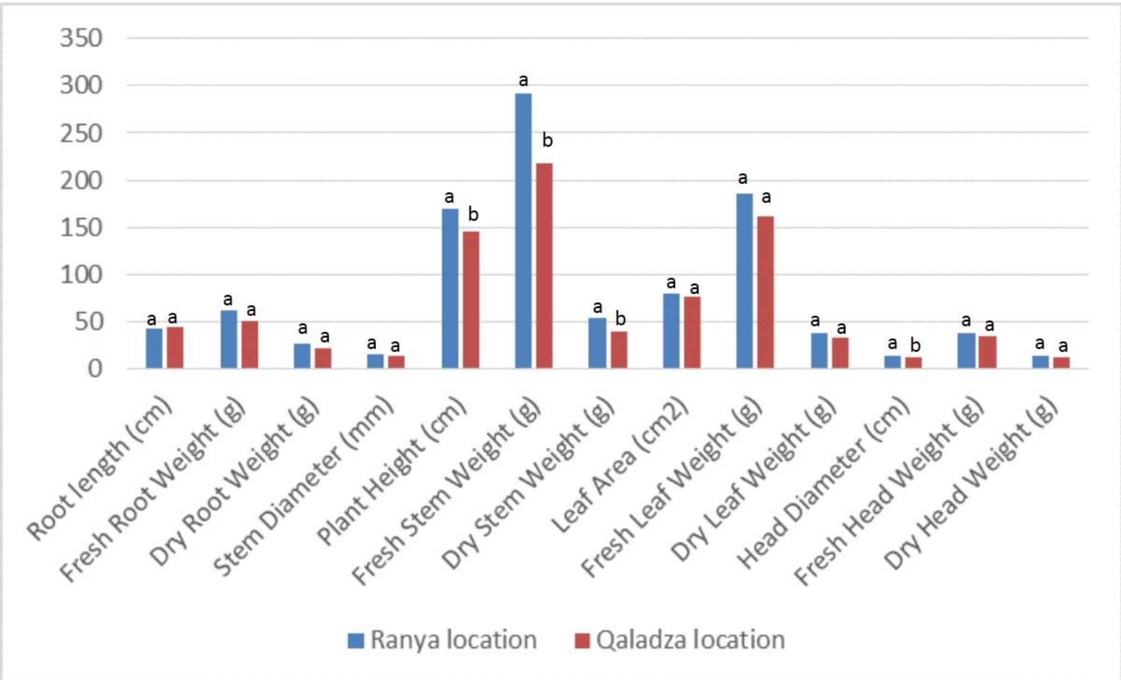

Figure 6. Effect of geographical location on growth characters.

4.CONCLUSION

Sunflower is an excellent candidate for deficit irrigation administered throughout the growing season or at specific growth phases. A significant amount of water can be conserved with deficit irrigation, and bigger regions can be served with the available water. Plants can respond strongly and fairly to water shortages, but the recorded growth reductions are frequently within permissible levels.

The experiment findings indicated that the maximum sunflower growth may be reached by not skipping irrigation with salicylic acid applied. In the case of more restricted irrigation, it is best to avoid restricting irrigation water during the flowering time. Water scarcity results in substantial growth losses. When salicylic acid is employed at a limiting concentration, it has a significant effect on growth.

As a result, limiting irrigation during the flowering stage should be avoided, although deficit irrigation during the achene development stage is acceptable when irrigation water is scarce. Thus, the results indicate that salicylic acid could be utilized as a mild antistress agent.

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Table 5. Effect of irrigation treatments on some growth characters at both locations

Irrigation Treatments	Root length (cm)	Fresh Root Weight (g)	Dry Root Weight (g)	Stem Diameter (mm)	Plant Height (cm)	Fresh Stem Weight (g)	Dry Stem Weight (g)	One Leaf Area (cm^2)	Fresh Leaf Weight (g)	Dry Leaf Weight (g)	Head Diameter (cm)	Fresh Head Weight (g)	Dry Head Weight (g)
Ranya location													
I_1	45.667a	42.383d	18.038d	11.433b	163.333d	254.333d	46.492d	73.959b	149.760d	30.881d	12.867b	37.583b	13.620b
I_2	44.083a	50.067c	21.308c	13.300b	167.000c	285.500c	52.189c	75.017b	162.283c	33.463c	12.767b	33.650c	12.195c
I_3	41.000b	72.617b	30.906b	18.467a	171.500b	304.667b	55.693b	84.262a	197.037b	40.629b	15.150a	36.850b	13.354b
I_4	39.000b	85.150a	36.240a	19.767a	173.500a	324.333a	59.288a	85.532a	234.173a	48.287a	15.567a	45.167a	16.368a
Qaladza location													
I_1	48.003a	41.698d	17.747d	12.050c	138.333d	192.333d	35.159d	72.038d	132.080d	27.235d	12.317c	33.343b	12.084b
I_2	46.800a	45.802c	19.493c	12.717bc	143.000c	204.000c	37.291c	74.460c	149.370c	30.800c	12.150c	30.337b	10.994b
I_3	41.207b	53.767b	22.883b	13.700b	147.833b	232.500b	42.501b	77.813b	167.310b	34.499b	12.983b	31.415b	11.385b
I_4	39.983b	64.767a	27.565a	16.083a	156.000a	239.333a	43.750a	80.781a	198.293a	40.888a	13.550a	44.312a	16.059a

Table 6. Effect of salicylic acid on some growth characters at both location

Salicylic acid Treatments	Root length (cm)	Fresh Root Weight (g)	Dry Root Weight (g)	Stem Diameter (mm)	Plant Height (cm)	Fresh Stem Weight (g)	Dry Stem Weight (g)	One Leaf Area (cm^2)	Fresh Leaf Weight (g)	Dry Leaf Weight (g)	Head Diameter (cm)	Fresh Head Weight (g)	Dry Head Weight (g)
Ranya location													
S_0	42.8333a	61.1833b	26.0396b	14.7917b	168.3333b	283.75b	51.8695b	78.2389b	182.4767a	37.6267a	13.8667a	37.6917a	13.6595a
S_1	42.0417a	63.925a	27.2065a	16.6917a	169.3333a	300.6667a	54.9619a	81.146a	189.15a	39.0027a	14.3083a	38.9333a	14.1094a

Qaladza location													
S_0	44a	48.8158b	20.776b	12.7083b	141.4167b	197.8333b	36.1639b	75.2176b	155.0467b	31.9706b	12.675a	33.7842b	12.2434b
S_1	43.9967a	54.2008a	23.0679a	14.5667a	151.1667a	236.25a	43.1865a	77.3283a	168.48a	34.7406a	12.825a	35.9192a	13.0171a

Table 7. Interactive effect of salicylic acid and irrigation treatments on some growth characters at both locations**.**

Irrigation and Salicylic acid Treatments		**Root length (cm)**	**Fresh Root Weight (g)**	**Dry Root Weight (g)**	**Stem Diameter (mm)**	**Plant Height (cm)**	**Fresh Stem Weight (g)**	**Dry Stem Weight (g)**	**Leaf Area (cm^2)**	**Fresh Leaf Weight (g)**	**Dry Leaf Weight (g)**	**Head Diameter (cm)**	**Fresh Head Weight (g)**	**Dry Head Weight (g)**
Ranya location														
I_1	**S_0**	46.333a	41.433e	17.634e	11.067d	162.333f	248.667d	45.456d	72.767c	150.627e	31.059e	12.800b	37.367c	13.542c
	S_1	45.000ab	43.333de	18.443de	11.800cd	164.333e	260.000cd	47.528cd	75.151c	148.893e	30.702e	12.933b	37.800c	13.699c
I_2	**S_0**	44.667ab	48.133cd	20.486cd	11.800d	169.333d	271.333c	49.600c	74.739c	160.333de	33.061de	12.733b	33.233e	12.044e
	S_1	43.500bc	52.000c	22.131c	14.800bc	164.667e	299.667b	54.779b	75.296c	164.233d	33.865d	12.800b	34.067de	12.346de
I_3	**S_0**	41.000cd	71.867b	30.586b	17.900ab	170.000cd	299.000b	54.657b	81.934b	194.133c	40.030c	14.900a	36.700cd	13.300cd
	S_1	41.000cd	73.367b	31.225b	19.033a	173.000b	310.333b	56.729b	86.590a	199.940c	41.228c	15.400a	37.000cd	13.409cd
I_4	**S_0**	39.333d	83.300a	35.452a	18.400a	171.667bc	316.000ab	57.765ab	83.516b	224.813b	46.357b	15.033a	43.467b	15.752b
	S_1	38.667d	87.000a	37.027a	21.133a	175.333a	332.667a	60.811a	87.548a	243.533a	50.217a	16.100a	46.867a	16.984a
Qaladza location														
I_1	**S_0**	47.433a	40.590g	17.275g	11.067c	133.333d	188.333e	34.427e	70.840f	124.107f	25.591f	12.300abc	33.160bc	12.017bc
	S_1	48.573a	42.807fg	18.219fg	13.033bc	143.333c	196.333cde	35.890cde	73.235e	140.053ef	28.879ef	12.333abc	33.527b	12.150b
I_2	**S_0**	46.667a	44.643f	19.000f	12.367bc	136.333d	191.667de	35.037de	73.068e	146.293de	30.166de	12.067c	28.170c	10.209c
	S_1	46.933a	46.960e	19.986e	13.067bc	149.667b	216.333b	39.546b	75.852d	152.447de	31.435de	12.233bc	32.503bc	11.779bc
I_3	**S_0**	41.100bc	49.947d	21.257d	13.333bc	142.000c	204.000bcd	37.291bcd	76.877cd	162.067cd	33.418cd	12.833abc	29.543bc	10.707bc
	S_1	41.313b	57.587c	24.509c	14.067b	153.667ab	261.000a	47.711a	78.748bc	172.553bc	35.580bc	13.133abc	33.287b	12.063bc
I_4	**S_0**	40.800bc	60.083b	25.571b	14.067b	154.000ab	207.333bc	37.901bc	80.085ab	187.720b	38.708b	13.500ab	44.263a	16.041a
	S_1	39.167c	69.450a	29.558a	18.100a	158.000a	271.333a	49.600a	81.477a	208.867a	43.068a	13.600a	44.360a	16.076a