ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI: http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

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

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ABSTRACT:

This experiment was conducted on NS Leviathan hybrids during the summer season under the semiarid region. It was designed as a split plot factorial arrangement using randomized complete block design (RCBD) with three replications. 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 the yield at three growth stages (vegetative, flowering, and achene-forming stages), and compared to the effects of full irrigation I_4. Complete irrigation with salicylic acid applied resulted in the best production, while the lowest yield 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 flowering stage and increasing yield 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 have a better seed production.

KEY WORDS: Drought stress; Deficit irrigation; Salicylic acid; Sunflower yield
DOI: http://dx.doi.org/10.21271/ZJPAS.34.4.6
ZJPAS (2022) , 34(4);53-66 .

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). According to Salunkhe (1992), Helianthus is made up of 37 different species, 17 of them are cultivated for their aesthetic value. Helianthus derives from the Greek words, “helios” which means sun and “anthos” which means flower. Sunflowers are thought to have originated in Mexico and the southwest United States, where they were used as a food source by indigenous peoples (EA, 2000). According to archeological evidence, it has been grown in New Mexico and Arizona for near (5,000) years. According to Semelczi-Kovacs (1975), it was used by American Indians (Putt, 1997). Sunflower was the primary source of food for North American Natives from the Tropics to the Arctic Circle, and from the Pacific Ocean to the Missouri River (Harvard, 1895).

Sunflower is the fourth largest vegetable oil sources 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 can be around 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 which is 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). Because it has zero cholesterol level and high amount of unsaturated fatty acids, sunflower is one vital oilseed crops that is consumed worldwide (Alberio, 2014). Oilseeds are a vital part of modern agriculture since they provide nutritious food for both humans and animals that

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Article History:
Received: 20/04/2022
Accepted: 29/05/2022
Published: 15/08 /2022

is conveniently accessible. The world's second most valuable traded commodity is oil and its byproducts (Anderson and Beardall, 1999).

Water scarcity is a major constraint on plant species global spread and growth, adaptation to water scarcity has a significant impact on plant evolution (Kursar *et al*., 2009). Water supply is dwindling because of dwindling natural rainfall, overextraction of groundwater, increasing population, and rising agricultural water usage (Asraf and Ali, 2015). Increasing water production necessitates the use of effective water management systems (Mancosu *et al*., 2015).

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). In addition to its great yield, sunflower has a remarkable ability to new environments adaptation because of its high oil content which plays a vital role in crop rotation as well as having more drought resistant than most other oil crops (Oraki and Aghaalikhana, 2012). The yield and oil content of sunflower could be reduced if water stress occurs during their key growing and flowering phases. However, sunflower achene and oil yield are strongly influenced by water quantity and distribution (Iqbal *et al*., 2005); this has been established in several studies. A worldwide decline in sunflower yields has been linked to drought (Dragovi and Maksimovi, 1995). It is widely believed that water stress is the most significant factor limiting crop yields in 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). Reduced yields are more common in treatments where the crop has more difficulty accessing water (Silva *et al*., 2011). Excessive usage of water should be avoided because it reduces the yield of crops (Loose, 2013). 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. A water lack during seed development and growth can have a significant impact on its oil content composition (Flagella *et al*., 2002). During the germination, seedling, and flowering phases, plants are particularly vulnerable to drought (Ashraf and Mehmood, 1990). In the flowering stage, stress results in ovarian and embryonic abortions, pollen sterility, and a reduction in leaf area index. Vegetative phase with stress 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) have an important role in the development of tolerance under abiotic and biotic stresses (El-Tayeb, 2005), like drought (Sedghi, 2003). According to (Hussein *et al*., 2007), SA has significant effects on enzymes such as catalase and peroxidase, as well as osmotic regulators like as glycine, proline, ameliorates and betaine on the effects of water stress, cold, heat and heavy metals on maize and tomato plants. Noreen *et al*. (2009) found that SA stimulates sunflower line growth. Leaf peroxidase activity has enhanced because of SA increased capacity antioxidant. 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). Plant physiological functions are regulated by salicylic acid (SA), a phenolic molecule having antioxidant capabilities (Mehrabian *et al*., 2011). Hydrolysis of glucosinolates that are produced by rapeseed rose releases various chemicals that protect plants against infections and pests when tissues are injured, according to Popova *et al*. (1997). It has been shown that salicylic acid can boost the enzymes activity such as ascorbate peroxidase and glutathione reductase 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 quality seed, such as antioxidant enzyme production, seed primary metabolism, and protein biosynthesis (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). Grain yield and several physical seed properties were most affected by environmental conditions (Nel *et al*., 2000).

The main objective of this study was to investigate how salicylic acids skipping irrigation at different growth stages affects sunflower yield**.**

2.METHODS AND MATERIALS

2.1The Experimental Site Location

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

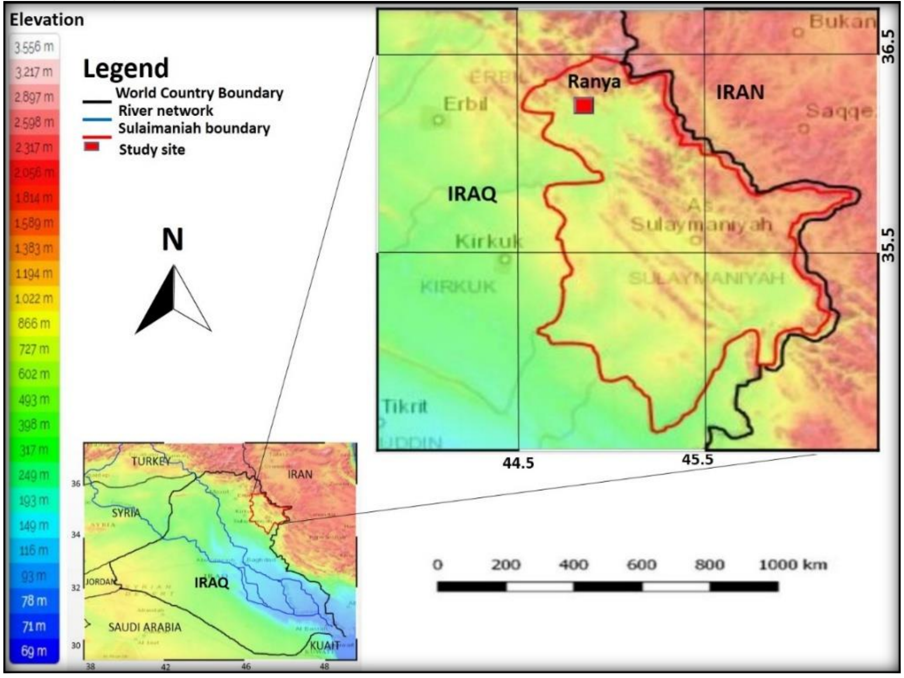

Figure 1. The study location**.**

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 Ranya

Month	Temperature °C		Humidity (%)	Wind speed (ms^{-1})	Precipitation
	Minimum	**Maximum**			
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

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).

2.3.1 Irrigation Treatments

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

Table 2. Details of irrigation treatment

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)

2.3.2 Salicylic Acid Treatment

The salicylic acid treatments consist 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 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. Salicylic acid applied

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).

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 placed with a plant spacing of 0.30 m, which result 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.

2.6Sowing Date

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

2.7Watering 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. Dripper points of the selected plots due to skip irrigation were closed at deferent growth stages (Praveen, 2021).

2.8Analytical Methods and Laboratory Analysis

2.8.1Soil 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 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 wet oxidation following Walkley Black method. $CaCO_3$ 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 are summarized during (Table **4**).

Equation 1. Soil moisture content %

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

Table 4. Soil 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

2.8.2Extraction of Seed Oil

After thoroughly cleaning the harvested seeds to remove any pollutants that might interfere with subsequent processes, the sample was taken from every treatment and mechanically pulverized using Electric Blender. Petrol Ether was used to dissolve the seed samples, and then ether was evaporated in the Soxhlet apparatus. The leftovers were composed of crude fat. A Soxtherm S306 A, manufactured by Gerhardt GmbH in Germany, were utilized (Instruction Manual Soxtherm S306 A. 2000), (Undersander *et al*., 1993; Cunniff, 1995)

The oil content was determined using (Equation 2).

Equation 2. Oil percentage

$$\text{Oil \%} = \frac{\text{the flask's weight and the amount of oil extracted - Empty flask weight}}{\text{the sample's weight}} \text{ X 100}$$

2.9Yield and Yield Attributes

For every subplot, five plants were selected randomly with three replications at the full maturity stage. Means of five plants were used to estimate yield.

2.9.1Oil Yield

The oil yield was calculated by the seed yield (kg ha^{-1}) multiplying in oil percent by one hundred (Al-Jubouri, 1997), as illustrated in (Equation 3).

Equation 3. Oil yield kilo grams per hector

$$\text{Oil yield} = \frac{\text{Seed yield X oil (\%)}}{100}$$

2.9.2Seed Yield

Five representative plant seed weights were added to the seed weights of the net plots, and then the average seed production was calculated in kg ha^{-1}.

2.9.3Biological Yield

Biological-yield was calculated as above ground biomass $plant^{-1}$ by weighing whole plant, including stalks and seeds, then changed to kilograms/hector, using plant samples gathered at full maturity stage.

2.9.4Harvest Index

The harvest index was calculated using the seed yield to biological yield ratio (Singh and Stoskopf, 1971). (**Equation 4**).

Equation 4. Harvest index

$$\text{HI \%} = \frac{\text{Seed yield}}{\text{Biological yield}} \text{ X 100}$$

2.10Statistical 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.

3RESULTS AND DISCUSSION

3.1 Irrigation Effect on Yield

Table 5 illustrates the irrigation treatment effect on yield and its mean components. The analysis variance confirmed that the irrigation treatments significantly influenced all characters.

Full irrigation I_4 produced the maximum number of oil yield, seed yield, biological yield, and harvest index which reached 1217.538 kg ha^{-1}, 3865.961kg ha^{-1}, 7205.283kg ha^{-1} and 53.692 % respectively. On the other hand, skipping irrigation at flowering stage I_2 produced the minimum number of oil yield and seed yield as reached 631.158 and 2451.013 kg ha^{-1} respectively. Hoverver, the number of empty seeds and yield reduction, which recorded the lowest values at vegititve stage irrigation skipping I_1 was 5287.082 kg ha^{-1}, while harvest index recorded 44.640 under effect I_3. These results confirm that the most sensitive stage for water deficit is the second stage (skipping irrigation at the flowering stage).

The I_4 predominated I_1, I_2 and I_2, also I_1 and I_3 predominated I_2, there were no significant difference under I_1 and I_3, oil yield and seed yield characters. These findings revealed that as available water increased, oil yield increased as well. Similarly, Mahmood *et al.* (2019) found that seed oil content increased as irrigation levels increased. Baba *et al.* (2016) showed that sunflower oil content rose when irrigation water application increased, and irrigation deficits had a major effect on seed production. According to Shafi *et al.* (2013), during the seed filling and flowering stages, water stress significantly reduces sunflower seed output. Water deficits should be avoided throughout the flowering stage, but its allowed during seed production, and increasing the watering interval lowers oilseed content, as Mobasser and Tavassoli (2013) concluded. The greatest oil content was determined when irrigation was complete. However, irrigation deficiency has less influence on sunflower output at late growth stages than it does at early growth stages (Kaya and Kolsarici, 2011). Sezen *et al.* (2011) reported that deficiency irrigation drastically lowered oil content. This resulted in a lower yield via a lower oil ratio in deficit irrigation. Water stress during the pre-anthesis via anthesis stage, sunflower production was reduced (Dar *et al*., 2009). Kazemeini *et al*. (2009) showed that the sunflower's oil content was the most sensitive parameter for water deficiency during the blooming and reproductive formation stages. Demir *et al*. (2006) reported the maximum oil yield from completely watered plots, 1780 kg ha^{-1}. When irrigation intervals increased, oil output decreased (Roshdi *et al*., 2006). According to Ardakani *et al*. (2005) water stress treatment and nonirrigation at any stage resulted in a decrease in oil yield. Water quantity and distribution have a considerable effect on oil yield (Iqbal *et al*., 2005). Drought stress, which occurs throughout the sunflower flowering stage and seed filling, can degrade oil content (Hammadeh *et al*., 2005). According to Roshdi and Rezadoost (2005), a soil moisture shortage during flowering reduces seed output. These discrepancies could be a result of impaired photosynthate transfer to reproductive organs (achenes) caused by drought stress (Asch *et al*., 2005). These discrepancies could be explained by drought stress during the flowering stage, which reduced full grains by destroying reproductive structures, yet water scarcity during the grain filling stage resulted in insufficient grain assimilation, as described by (Khomri, 2004). Khot and Patil (2002) concluded that irrigation had no meaningful effect on the weight of 100 seeds. Water scarcity at all phases of growth via development is one of the variables limiting seed growth which can affect oil composition (Flagella *et al*., 2002). Seed output rose as irrigation water was administered in greater volumes. Drought stress at various growth phases, particularly during the reproductive stage, reduces seed output by lowering the mobilization of assimilates to seeds, the length of photosynthesis, and the contribution of stem reserves to seed remobilization (Kang *et al*., 2002). Kakar and Soomro (2001) demonstrated that varying irrigation frequency had a substantial effect on the oil concentration.

The I_4 predominated I_1, I_2 via I_3, and also I_3 predominated I_1 and I_2, and there were not significant difference under I_1 and I_2, for biological yield character. Drought stress significantly lowers the plant's growth and biomass (Vassilevska-Ivanova *et al*., 2016) as a result of decreased cell elongation and division (Anjum *et al*., 2011). Bajehbaj (2010) discovered that when drought stress increases, biological yield declines. These findings corroborate those of Rodriguez *et al*. (2002), who similarly demonstrated a decline in biological yield in response to drought stress.

The I_1 and I_4 predominated I_2 and I_3, and there were not significant difference under I_1 and I_4 and between I_2 and I_3 for harvest index character. In tests conducted by Soriano *et al*. (2004), a drop in the harvest index was documented as a result of water deficiency tension, they believed that under dry situations, the harvest index is determined by the water amount absorbed following pollination. The water stress presence during anthesis in physiological maturity circumstances had a substantial effect on the harvest index of sunflower (Chimenti *et al*., 2002; Dogara et al, 2022).

Table 5. Irrigation Treatment Effect on Yield

Irrigation Treatments	Oil Yield (kg/ha)	Seed Yield (kg/ha)	Biological Yield (kg/ha)	Harvest Index
I_1	788.717b	2800.639b	5287.082c	53.004a
I_2	631.158c	2451.013c	5442.202c	45.043b
I_3	801.921b	2715.899b	6081.482b	44.640b
I_4	1217.538a	3865.961a	7205.283a	53.692a

3.2 Salicylic Acid Effect on Yield

The methods for obtaining salicylic-acid are listed in **Table 6**. The data illustrate the SA effect on yield and its mean components. All characters responded significantly to salicylic acid applied (S_1), except the harvest indices were noticed no significant differences.

As illuted in **Table 6**, it was noticed that the highest-values for all characters produced by S_1

salicylic acid applied treatments, except the harvest index, which recorded the highest value for S_0 non-salicylic acid, and the highest values for all traits were 899.231, 3012.674, 6136.013 kg ha^{-1}, and 49.2133 % respectively, but the lowest value were recorded 820.436, 2904.082, 5872.011 kg ha^{-1} and 48.9764 % respectively.

Salicylic acid treatment boosted the several enzymes activity, including peroxidase, catalase, ascorbate peroxidase, superoxide dismutase and glutathione reductase (Manochehrifar, 2010; Sedghi *et al.*, 2010). Salicylic acid influenced seed quality activities such as seed primary metabolism, protein biosynthesis, seed storage, protein transport, and antioxidant enzyme production, resulting in improved seed yield (Rajjou *et al.*, 2006). Salicylic acid protects against oxidative damage by preserving superoxide dismutase activity for O_2 elimination (Rao *et al.*, 1997). Leon *et al*. (1995) revealed that H_2O_2 inhibited free benzoic acid and SA accumulation in tobacco leaves. They hypothesized that H_2O_2 initiates the manufacture of salicylic acid.

Table 6. Effect of salicylic acid on sunflower yield

Salicylic Acid Treatments	Oil Yield (kg/ha)	Seed Yield (kg/ha)	Biological Yield (kg/ha)	Harvest Index
S0	820.436b	2904.082b	5872.011b	49.2133a
S1	899.231a	3012.674a	6136.013a	48.9764a

3.3Interactive Effect of Salicylic Acid with Irrigation Treatment on Yield

The Figures below illustrate the interaction effect between irrigation via salicylic acid treatments on sunflower oil yield(Figure 3), seed yield (Figure 4), biological yield(Figure 5) and harvest index (Figure 6).All studied characters significantly responded to the interaction effect. However, nonsignificant difference was recorded between flowering stage and achene formation stage. Moreover there was no significant record between vegetative stage and nonskipping irrigation for harvest index.

The interaction between full irrigation and salicylic acid applied (I_4S_1) produced the highest value for the characters oil yield, seed yield, and biological yield which were 1264.981, 3888.109 and 7394.988 kg ha^{-1}, respectively. While, the highest value of the character harvest index was 54.806 recorded by I_4S_0.

The interaction between skipping irrigation at flowering stage with non-salicylic acid applied (I_2S_0) produced the lowest value for the character oil yield and seed yield (611.828 and 2399.976 kg ha^{-1} respectively). However, the minimum reduction of biological yield was 5232.708 kg ha^{-1} recorded by I_1S_0. While, the lowest value for the character harvest index was 43.688 recorded by I_3S_0.

The study shows that sunflower yield significantly increased concerning full and deficit irrigation treatments. It has been found that sunflower yields can be increased significantly and even improved with the use of full irrigation with salicylic acid. These findings revealed that the most sensitive parameters to the interaction between water deficit and salicylic acid throughout the flowering and reproduction formation stages are water deficit and salicylic acid concentration. It was confirmed that salicylic acid application enhanced sunflower seed yield per unit of available water. Similarly, the foliar spray of SA increased the biological production of wheat during periods of water scarcity (Singh & Usha, 2003). A rise in sunflower seed output was dependent on irrigation regimes (Ashoub *et al*., 2003; Abdel-Hafez *et al*., 2002). Salicylic acid inhibits peroxidase and catalase enzymes via osmotic regulators such as betaine, proline, and glycine in maize via tomatoes and mitigates the effects of drought stress, heavy metals, heat, cold, and salinity (Sedghi, 2002; Hamad, 2021). Popova *et al.* (1997) demonstrated that transgenic Arabidopsis plants (NahG) produce salicylate hydroxylate, which converts salicylic acid to catechol (resulting in a lower concentration of endogenous salicylic acid in transgenic plants than in wild plants), were more resistant to oxidative stress induced by salt and osmotic stress than wild type plants. When tissues are injured, glucosinolates are hydrolyzed, releasing a variety of chemicals that defend plants from infections and pests. Fereres *et al*. (1986) demonstrated that water stress resulted in a decrease in sunflower harvest index. According to Rawson and Turner (1983), regular irrigation resulted in the highest yield.

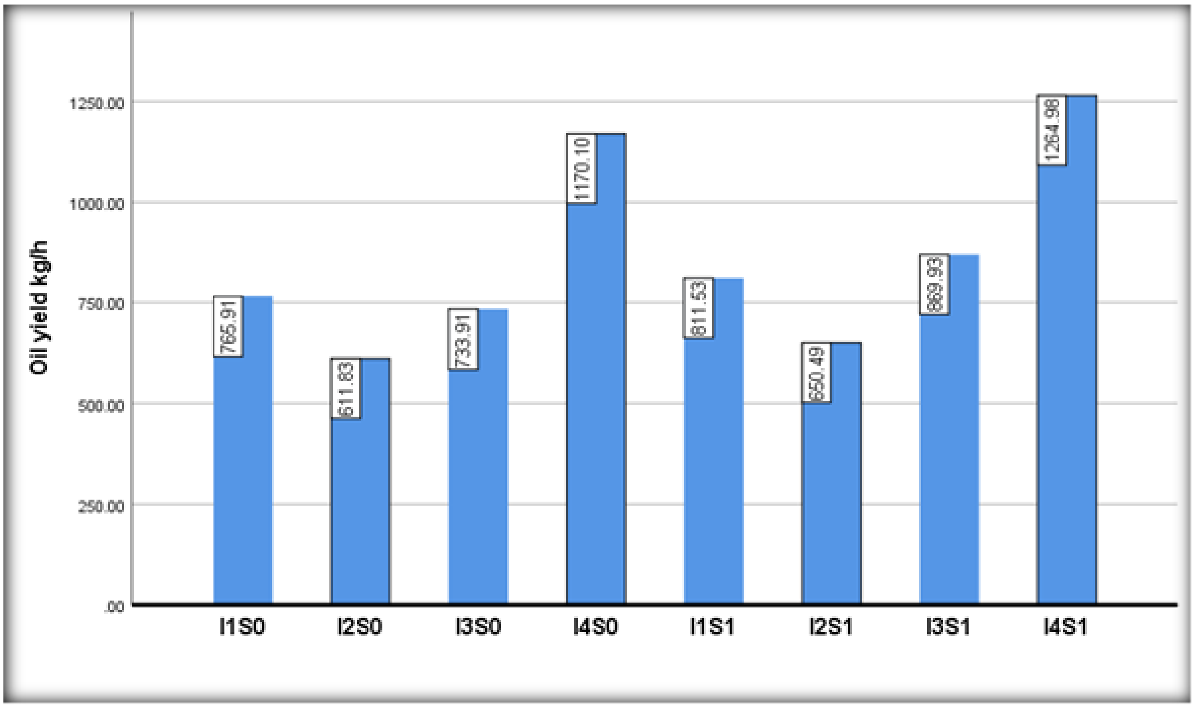

Figure 3. Interactive effect of salicylic-acid via irrigation treatments on oil yield.
While, I1= Vegitive stage skipping irrigatin, I2 = Flowering stage skipping irrigatin, I3 = Seed formatoin stage skipping irrigatin,I4 = Full irrigation, S0 = Non-applied salicylic acid and S1= Apllied salicylic-acid.

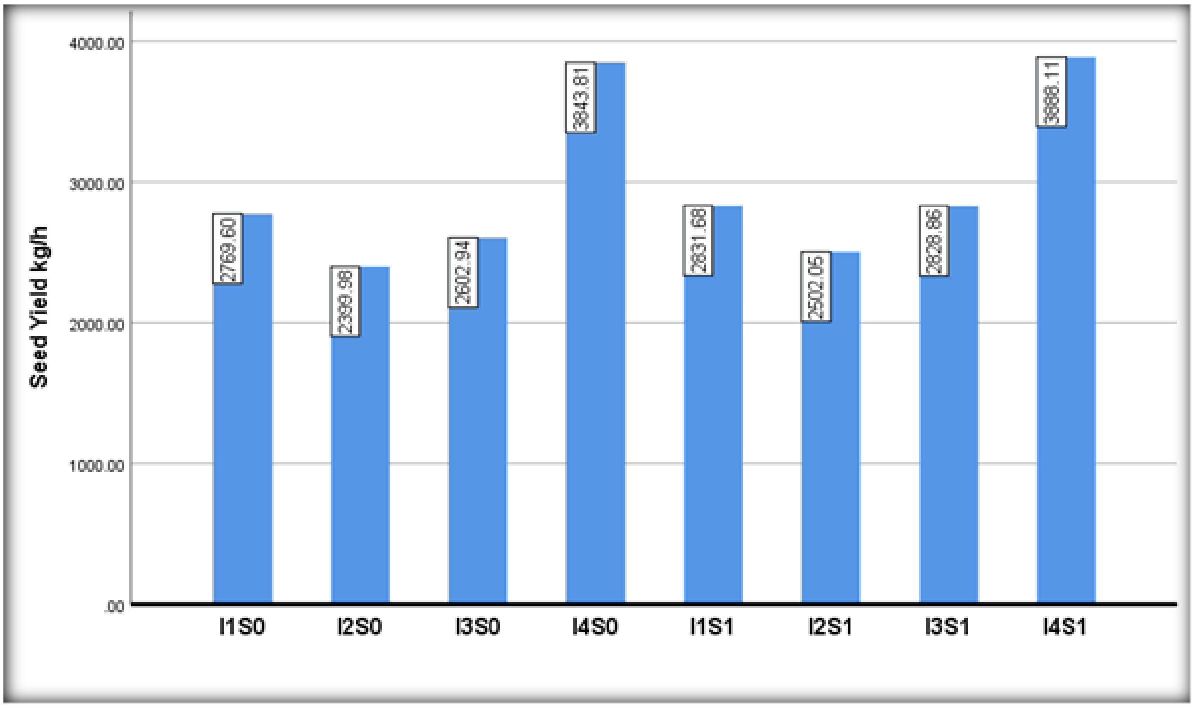

Figure 4. Interactive effect of salicylic-acid and irrigation treatments on seed yield.
While, I1= Vegitive stage skipping irrigatin, I2 = Flowering stage skipping irrigatin, I3 = Seed formatoin stage skipping irrigatin,I4 = Full irrigation, S0 = Non-applied salicylic acid and S1= Apllied salicylic-acid.

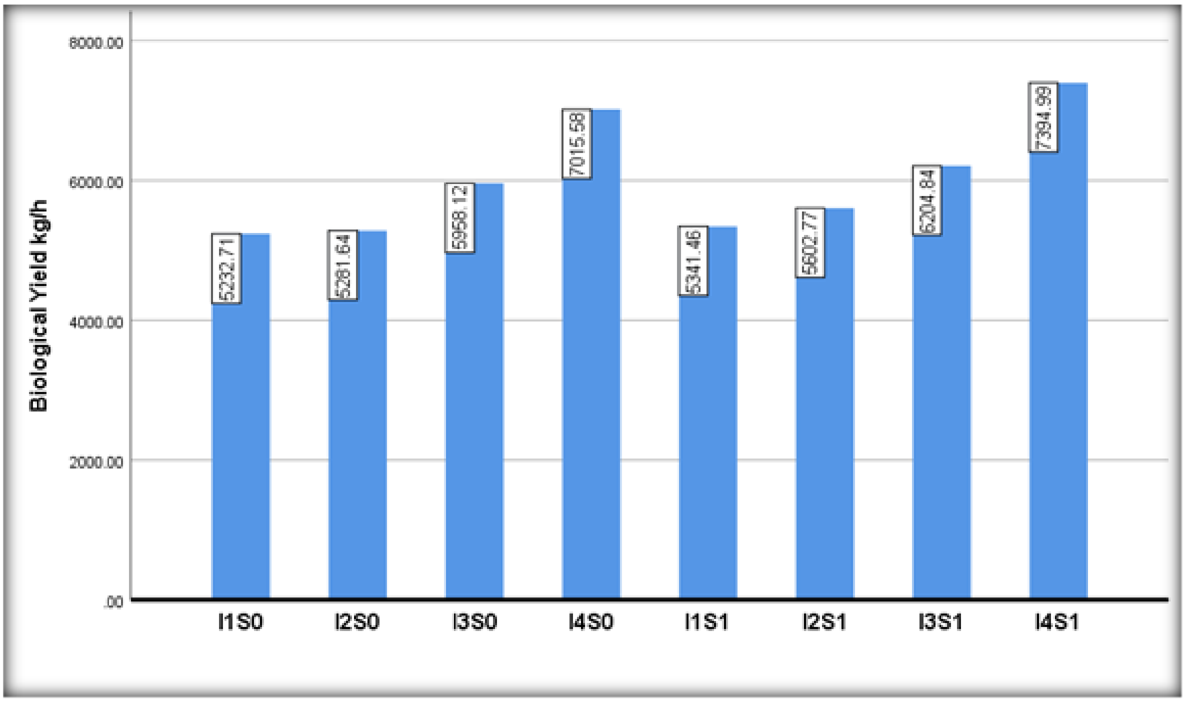

Figure 5. Interactive effect of salicylic-acid and irrigation treatments on biological yield.
While, I1= Vegitive stage skipping irrigatin, I2 = Flowering stage skipping irrigatin, I3 = Seed formatoin stage skipping irrigatin,I4 = Full irrigation, S0 = Non-applied salicylic acid and S1= Apllied salicylic-acid.

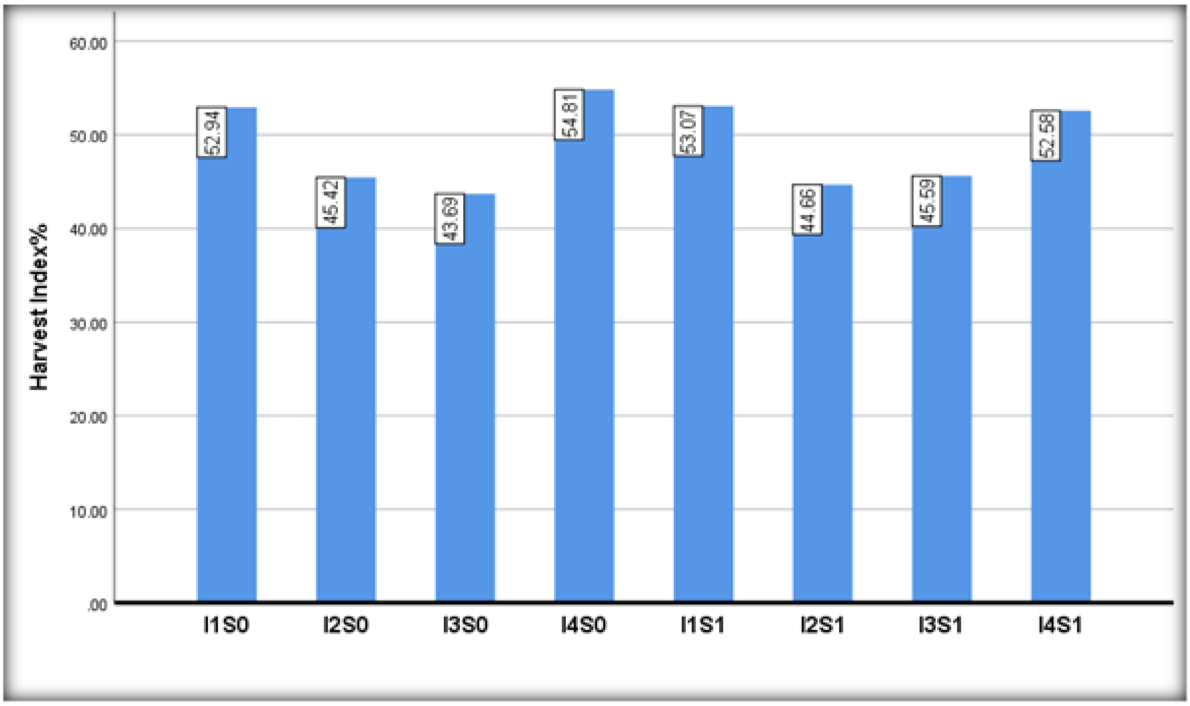

Figure 6. Interactive effect of salicylic-acid and irrigation treatments on Harvest Index.
While, I1= Vegitive stage skipping irrigatin, I2 = Flowering stage skipping irrigatin, I3 = Seed formatoin stage skipping irrigatin,I4 = Full irrigation, S0 = Non-applied salicylic acid and S1= Apllied salicylic-acid.

4.CONCLUSION

Sunflower is an excellent candidate for deficit irrigation administered throughout the growing season or at specific growth phases. The observed results indicate that deficit irrigation may be considered as a viable method in places with scarce water resources. 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 yield reductions are frequently within permissible levels. The statistical analysis revealed significant yield variations across treatments.

The findings of this study established a feasible irrigation method, thereby making a significant contribution to food security in a semiarid region. The experiment findings indicated that the maximum sunflower yields 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 yield losses. When salicylic acid is employed at a limiting concentration, it has a significant effect on seed via oil yields.

Finally, this study's findings indicated that flowering is the most vulnerable stage of the plant to water stress caused by deficit irrigation. 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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