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The allelopathic effect of sunflower residues on the growth of salt-stressed wheat plants

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Abstract:

A plastic pot experiment was done in a private nursery in Baquba, the center of Diyala Governorate, during the 2024-2025 growing season. Using three replicates and two variables in a randomized complete block design (RCBD), the experiment aimed to determine the effect of sunflower residues from three parts (roots, stems, and leaves) on the germination and growth characteristics of wheat seedlings under salt stress. Concentrations of 0, 6, 9, and 12 dS/m^{-1} of NaCl were used. The results showed a significant decrease in the average values of the studied traits with increasing concentrations of NaCl, particularly at 12 dS/m^{-1}. This concentration led to a decrease in germination percentage (46.2%), plant height (53.2%), and the number of branches per plant (19.6%), as well as in the other studied traits. The results indicated that adding sunflower residues to the soil yielded the best results for the studied traits, especially the leaf residues, as they showed the greatest increase in germination percentage and number of branches per plant. Branching in the plant is 8.8% and 37%, respectively.

Keywords: *Allelopathic effect, sunflower residues, salt stress, wheat plant.*

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تأثير مخلفات زهرة الشمس على الصفات الأنباتية والنمو لنبات الحنطة المجهد ملحياً

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الخلاصة

أجريت تجربة اصص بلاستيكية في احد المشاتل الاهلية في بعقوبة - مركز محافظة ديالى للموسم الزراعي 2024- 2025 ، باستخدام ثلاثة مكررات ومتغيرين بتصميم القطاعات العشوائية الكاملة RCBD لمعرفة تأثير مخلفات ثلاثة أجزاء من زهرة الشمس (الجذور، والسيقان، والأوراق) على الصفات الانباتية والنمو لبادرات الحنطة تحت الاجهاد الملحي، إذ تم أخذ التراكيز 0،6،9،12 ديسي سيمنز م -1من NaCl ، أظهرت نتائج التجربة انخفاضاً معنوياً في متوسطات الصفات المدروسة عند الري بالتراكيز المتزايدة من NaCl ولاسيما عند التركيز 12 ديسي سيمنز م -1 إذ أدى الى انخفاض في نسبة الانبات وبلغ 46.2% وارتفاع النبات بنسبة 53.2% وعدد التفرعات في النبات بنسبة 19.6% وكذلك بقية الصفات المدروسة،

وتبين نتائج التجربة ان أضافة مخلفات زهرة الشمس الى التربة أعطت افضل النتائج على الصفات المدروسة ولاسيما مخلفات الأوراق، إذ كانت الزيادة في نسبة الانبات وعدد التفرعات في النبات 8.8, 37% على الترتيب.

الكلمات المفتاحية: *التأثير الاليلوباثي ، مخلفات نبات زهرة الشمس، الاجهاد الملحي، نبات الحنطة.*

1. Introduction

Allelopathic influence is the interaction between neighboring plants that leads to the stimulation or inhibition of growth through allelopathic chemicals released through volatilization or decomposition of plant or root secretions during growth (Zhang et al., 2021). These chemicals are found in many parts of the plant, such as seeds, roots, stems, leaves, and other parts (Respatie et al., 2019). Allelopathic influence is an interspecies interaction in which one species releases chemical compounds into the environment that act as toxins to other species. It is a fundamental scientific concept in chemosynthesis, referring to the effect of plants or microbial chemicals on the growth, production, and dispersal of plants and soil microorganisms in natural communities or agricultural systems. It is characterized by a combination of biotic and abiotic stresses exerted by donor plants on recipient plants (de Albuquerque et al., 2011; Yang et al., 2011).

The sunflower is one of the most important agricultural crops due to its numerous uses in seed and oil production, and it is one of the most consumed vegetable oils worldwide(Alwan & Dawood, 2025) Sunflowers thrive in various soil conditions, allowing them to compete successfully with other cereal crops. Furthermore, the plant can survive drought stress conditions due to its deep root system (Hussain et al., 2018). The presence of crop residues on the soil surface can inhibit weed growth and affect the germination of the subsequent crop to be planted (Das et al., 2021). Wheat (*Triticum aestivum* L.) is a cereal crop belonging to the Poaceae family (Paniagua-Zambrana et al., 2020). Wheat is a good source of dietary fiber, phenolic acids, starch, and antioxidant compounds. These substances provide wheat with a variety of medicinal properties, such as anticancer, antidiabetic, and antimicrobial effects (Moshawih et al., 2022). Wheat is a moderately salt-tolerant crop, as its production is affected by irrigation water salinity and environmental factors, especially alkalinity (Ghogdi et al., 2012). The suitable conditions for its cultivation are sunny locations and moderate to dry conditions (Hilty et al., 2019). It has a wide ability to adapt to surrounding conditions and tolerate various stresses (Gupta et al., 2020). Therefore, the aim of study was to determine the effect of sunflower residues from three parts (roots, stems, and leaves) on the germination and growth characteristics of wheat seedlings under salt stress.

2. Materials and Methods

2.1 Soil Preparation:

Slightly saline soil was used and mixed with sunflower waste. Part of the soil was mixed with root waste, part with stem waste, and part with leaf waste, with 12 pots prepared with each mixture. The remaining soil was left without waste.

2.2 Design and Implementation of the Experiment:

The experiment was conducted in a nursery in Baquba during the 2024-2025 growing season. Planting took place on December 21, 2024, using a completely randomized (CRD) design with three replications. Dry crop residues were used and directly applied to the soil at a concentration of 2% per 400 g (Qasem & Issa, 2005) in pots 16 cm in diameter and 15 cm high, each containing 2 kg of soil. Wheat seeds were then sown in these pots. The pots were divided into four groups of 12 pots each, with 25 seeds sown in each pot at equal spacing. All pots were watered with regular water (germination irrigation) for one month, followed by watering with different salt concentrations (6, 9, and 12 dS/mL), in addition to a control treatment. These salt concentrations were prepared by adding sodium chloride to salt-free water.

2.3 Studied Characteristics:

Measurements were taken after full growth and included:

Germination Percentage (%): Calculated using the following equation (Kandil et al., 2012):

$$Germination\ Percentage = Number\ of\ Germinated\ Seeds / Total\ Number\ of\ Seeds \times 100$$

2.3.1 Plant Height (cm):

Measured from the soil surface to the top of the spike (excluding the awns) during the flowering stage using a measuring tape.

2.3.2 Number of Branches:

Counted the number of branches for each plant from the crown area and for all pots at the end of the flowering stage.

2.3.3 Number of Leaves on the Main Branch:

Counted the leaves on the main branch for all potted plants at the flowering stage.

2.3.4. Main Stem Diameter:

The stem diameter was measured for three plants from each pot, and then the average was calculated using a Vernier Caliper during the flowering stage.

2.3.5 Flag leaf area (cm^2):

The flag leaf area during the flowering stage was calculated using the following equation (Thomas, 1975):

$$Leaf\ area\ (cm^2) = Leaf\ length\ (cm) \times Leaf\ width\ at\ midpoint\ (cm) \times 0.95$$

2.4 Statistical analysis:

The data were analyzed according to a randomized complete block design (RCBD) using the SPSS statistical software version 22, and the means were compared using Duncan's multiple range test at a probability level of 0.05 (Al-Tamimi et al., 2015).

3. Results and Discussion

3.1 Germination Rate (%)

Table (1) shows significant differences in the average germination rate of wheat seedlings with the addition of sunflower residues. Planting in leaf residue soil recorded the highest average at 78.75%, while planting in regular soil recorded the lowest average at 72.33%. The increase in germination rate was 8.8%, which may be attributed to the sunflower residues contributing to increased soil organic matter, thus becoming an organic fertilizer that provides the soil with essential elements without the need for chemical fertilizers (Flayyih & Almarie, 2017)

The results shows significant differences in NaCl concentrations. Irrigation with 0 dS/m¹ resulted in the highest germination rate of 93.92%, while irrigation with 12 dS/m¹ resulted in the lowest average germination rate of 50.50%. The percentage decrease with increasing NaCl concentration was 46.2%. This may be due to the fact that salt in the external environment reduces osmotic potential, making water absorption by the seed difficult, thus causing the seed to fail to swell or delaying the swelling process (Farooq et al., 2024). Table 1 also shows significant differences in the interaction between adding plant residues to pots and irrigating with different NaCl concentrations. The interaction between leaf residues and irrigation with 0 dS/m¹ resulted in the highest germination rate of 96.33%, while the interaction between normal soil and irrigation with 9 dS/m¹ resulted in the lowest average germination rate of 45.33%.

Table 1: Effect of sunflower residues and irrigation with different salt concentrations on the average germination rate of wheat seeds (%)

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	89.33 bcd	94.00 ab	96.00a	96.33a	93.92A
6	84.00d	84.67cd	90.00bc	86.67cd	86.33B
9	70.67f	70.00f	72.00 ef	76.67e	72.33C
12	45.33i	52.67gh	48.67hi	55.33g	50.50D
Average	72.33C	75.33B	76.67AB	78.75A	

3.2 Plant Height (cm)

There is a significant difference in plant part residues between the averages for this trait. Root residues gave the highest value at 31.50 cm, while stem residues gave the lowest value at 25.17 cm, with an increase of 25.14% (Table 2). The same table also shows significant differences in NaCl salt concentrations. Irrigation with a concentration of 0 dS/m-1 resulted in the highest average height at 39.25 cm, while irrigation with a concentration of 12 dS/m^{-1} resulted in the lowest average height at 18.33 cm, with a decrease of 53.2% with increasing NaCl concentrations. This may be because when salinity is high, the plant absorbs less water from the soil, leading to a decrease in cell pressure and consequently reduced growth (Saddiq et al., 2021). Table (2) shows the significant differences in the interaction between plant residues and irrigation with different NaCl concentrations. The interaction between root residues and irrigation with 1 dS/m² resulted in the highest average height, reaching 42.33 cm, while the interaction between stem residues and irrigation with 9 dS/m² resulted in the lowest average height, reaching 12.00 cm.

Table 2: Effect of sunflower residues and irrigation with different salt concentrations on the average height of wheat plants (cm)

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	36.33b	42.33a	36.33b	42.00a	39.25A
6	31.67c	31.67c	29.33c	32.00c	31.17B
9	24.67d	30.00c	23.00de	22.67de	25.08C
12	20.00e	22.00de	12.00f	19.33e	18.33D
Average	28.17B	31.50A	25.17C	29.00B	

3.3 Number of Branches in the Plant:

The results shows significant differences in the average number of branches with the addition of plant residues. Leaf residues resulted in the highest number of branches, reaching 6.08, while normal soil resulted in the lowest average, reaching 3.83 branches, representing a 37% increase. Significant differences were also observed with regard to NaCl salt concentrations. Irrigation with a concentration of 0 dS/m¹ resulted in the highest average, reaching 5.50 branches, while irrigation with a concentration of 12 dS/m¹ resulted in the highest average, reaching 4.42 branches, representing a 19.6% decrease (Table 3).

There are significant differences in the interaction between plant residues and irrigation with different NaCl concentrations. The interaction between leaf residues and irrigation with a concentration of 0 dS/m¹ resulted in the highest average number of branches, reaching 7.00, while the interaction between leaf residues and irrigation with a concentration of 12 dS/m¹ resulted in the lowest average. M-1 had the lowest average number of branches, at 2.33.

Table 3: Effect of sunflower residues and irrigation with different salt concentrations on the average number of branches in wheat plants

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	5.67abc	4.67bcd	4.67bcd	7.00a	5.50A
6	4.67bcd	5.00bcd	4.00de	5.33bcd	4.75B
9	2.00f	4.33cde	6.33ab	6.00abc	4.67B
12	3.00ef	2.33f	6.33ab	6.00abc	4.42B
Average	3.83C	4.08C	5.33B	6.08A	

3.4 Number of leaves on the main branch:

Table (4) shows no significant differences in the average values for this trait, as the percentages were similar across the different averages. The same table also indicates no significant differences when irrigated with different concentrations of NaCl. Further reveals no significant interaction between sunflower plant residues and irrigation with different concentrations of NaCl. This lack of significant interaction could be attributed to the absence of differences in the direction or magnitude of the response, or to the trait's response at different levels of one factor not changing with the other.

Table 4: Effect of sunflower residues and irrigation with different concentrations of NaCl on the average number of leaves on the main branch of wheat

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	4.33a	5.00a	5.00a	4.67a	4.75 A
6	4.67a	4.67a	5.00 a	4.67a	4.75A
9	5.00 a	5.00a	4.33a	4.67a	4.75A
12	4.33 a	4.67 a	4.67a	4.67a	4.58A
Average	4.58A	4.83A	4.75A	4.67A	

3.5 Main Stem Diameter:

Table (5) shows no significant differences between the average plant residues for main stem diameter. Similarly, no significant differences were observed when irrigating with different NaCl concentrations, as the average values were similar. The results also indicate no interaction between sunflower residues and irrigation with different salt concentrations of NaCl.

Table 5: Effect of Sunflower Residues and Irrigation with Different Salt Concentrations on the Average Main Stem Diameter of Wheat

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	0.13667	0.14333	0.18000	0.13667	0.14917
6	0.11667	0.08667	0.16000	0.13667	0.12500
9	0.09667	0.17000	0.13333	0.12667	0.13167
12	0.13667	0.14667	0.12000	0.14333	0.13667
Average	0.12167	0.13667	0.14833	0.13583	

Combined (NS.), Concentrations (NS.), Extracts (NS.)

3.6 Flag leaf area (cm²):

Table (6) shows significant differences between the mean values for sunflower residue treatments. Soil without residue resulted in the highest mean flag leaf area at 6.075 cm², while leaf residue resulted in the lowest mean at 3.850 cm², representing a 36.6% increase. The same table also shows significant differences when irrigating with different NaCl salt concentrations. Irrigation with 0 dS/m¹ resulted in the highest value at 6.267 cm², while irrigation with 12 dS/m¹ resulted in the lowest area at 3.892 cm². Table 6 also shows a significant interaction between plant residues and irrigation with different salt concentrations of NaCl. The interaction between soil without residues and irrigation with a concentration of 9 dS/m^{-1} resulted in the highest average area, reaching 8.267 cm², while the interaction between leaf residues and irrigation with a concentration of 12 dS/m^{-1} resulted in the lowest average area, reaching 2.900 cm².

Table 6: Effect of sunflower residues and irrigation with different salt concentrations on the average flag leaf area of wheat

Concentrations in dS/m¹	sunflower residues				
	Ordinary soil	root residues	stem residues	leaf residues	Average
0	6.367bc	7.467ab	6.233abc	5.000abc	6.267A
6	5.267abc	6.433abc	3.900 bc	3.567c	4.792AB
9	8.267a	5.400abc	4.467bc	3.933bc	5.517AB
12	4.400bc	4.200bc	4.067bc	2.900c	3.892B
Average	6.075A	5.875A	4.667AB	3.850B	

4. Conclusion

The study concludes that adding sunflower residues to the soil resulted in better outcomes compared to soil without residues. It led to an increase in germination rate, plant height, number of branches, and flag leaf area in wheat plants. This may be because the residues improved the soil when added in small concentrations. If added in larger quantities, they may have damaged the plants due to the release of inhibitory substances. Furthermore, applying NaCl at a concentration of 12 dS/m² led to a decrease in the studied traits, as it affected germination rate, plant height, and flag leaf area. The best interaction between residues and NaCl concentrations was between leaf residues and irrigation at a concentration of 0 dS/m². We suggest future research on the effect of residues in large quantities on wheat plants.

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