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Research Article

Effect of spraying with Nano nitrogen and potassium on some Morphological Characteristics of Calendula officinalis L. plant under water stress conditions

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Abstract:

An experiment was carried out in plastic pots in the College of Agriculture , University of Kerbala, to investigate the effect of foliar spraying with Nano nitrogen and potassium on some phenotypic characters of *Calendula officinalis* L. under the water stress condition in sandy loam soil in winter growing season (2023-2024). Factorial experiment in a CRD with 3 replications was used for the study. The experiment consisted of three factors with three replicates. The first factor consisted of two levels of irrigation water levels (50% and 100% of soil field capacity) denoted as S_1 and S_2 (Table 1). The second factor was foliar application using three levels of liquid Nano nitrogen fertilizer (0, 2 and 4 ml) L^{-1}, denoted as N0, N1, and N_2 respectively. The third factor was foliar application of the complex Nano-potassium fertilizer at three concentrations, 0, 2, and 4 g L^{-1}, designated K_0, K_1, and K_2, respectively. These levels were randomly assigned to all experimental units. The design involved 54 experimental units. Data were subjected to statistical analysis as per the design adopted and means were compared at 5% level of probability. The results indicated a significant impact of the factors examined in this study, as well as their interactions, on various phenotypic traits, including plant height, stem diameter, number of leaves, and number of flowers. The average values of these traits decreased under conditions of water stress when irrigation was applied at 50% of the soil field capacity. Additionally, the values further declined with lower concentrations of foliar spray containing Nano nitrogen and potassium.

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INTRODUCTION

As a serious problem of widespread existence, water shortage becomes the challenge of human beings. Drought is one of the most significant factors restricting and constraining plant production growth in Iraq in particular. For this reason, it is necessary to study the ability and capacity of plants to withstand water stress as one of the significant factors limiting the productivity of field crops in general, and of medicinal plants in special, leading also to unfavorable effects on productive capacity of field crops and plants. According to (IPCC), a large probability of reduction of rainfall until these times (rainfall deficit) and higher evaporation rates have been observed: increased drought periods (e.g., decrease in soil moisture) are expected to occur in the future. Crop drought will be more severe in the face of rising temperature [25].

Water stress refers to a situation in which there is insufficient water. This issue has become an increasingly challenging global problem in food production, which is diminishing for many reasons, particularly climate change, over-cultivation and pollution, which is capable of affecting crops as well as the human populace. Climate change also induces a number of biotic and abiotic effects on plants in altered abiotic stress scenarios. The plants are severely affected by environmental stresses such as drought, temperature extremes, cold, metal toxicity, and high salinity, which have a direct bearing on food security. Water stress is one of these consequences [19]. Water stress of less than 30% of maximum field capacity, as well as cereal competition for soil moisture and other resources, potentially compromise or inhibit the germination, plant growth and seed yield [38]. [28] Reported the effect of water stress on the morphological traits of the plants where there was a significant reduction of leaf area index, plant height, chlorophyll content, gas exchange, and photosynthetic efficiency due to the water stress at the 50% of the field capacity value.

Promising technologies have also been utilized to enhance plant tolerance to these stresses, including the use of nanoparticles, which are believed to improve plant performance under stressful conditions. Drought can be mitigated by using anti-transpiration compounds, which are bioactive and capable of reducing water vapor loss through transpiration when applied to plant leaves (foliar feeding). This is considered one of the most effective approaches to minimize water stress and has been established with the use of compounds of bio-stimulatory character, as in the case of nanoparticles which are able to stimulate cell division and growth and reduce transpiration [37].[3],[35] Nano-nitrogen and Nano-potassium spraying showed considerable positive effects on growth parameters of *C. officinalis* both in normal and water stress conditions. They are increased the vegetative and flowering characters in the plant and they have minimized the hazards of water stress. Water stress reduced plant height, stem diameter, number of leaves and number of flowers; however, foliar spraying of Nano nitrogen and potassium alleviated the adverse effect of water stress relative to the control treatment. Based on the above, in addition to the increasing production of this plant because of its medical importance, this study was designed to determine the impact of spraying with Nano nitrogen and potassium on some phenotypic traits in *C. officinalis* under various water stress conditions for the following purposes: studying the effect of the interactions between the study factors to reach the optimal criteria for productivity of *C. officinalis* plants obtained under different irrigation quantities, determining the response of *C. officinalis* plants to spraying with Nano nitrogen and potassium and its impact on some phenotypic traits.

Materials and Methods

The experiment was conducted in plastic pots at the College of Agriculture, University of Kerbala. A plastic cover (2 mm thick agricultural nylon) was placed on the iron frames constructed for this purpose at a height of 2 m to protect the treatments from rain, while leaving the sides open for ventilation. A sandy, unaffected by salinity (1.28 ds m^{-1}) was used in the experiment. The soil was filled into plastic pots 40 cm long and 40 cm in diameter, perforated at the bottom, with (25) kg of soil per pot. A sample of the soil was taken before planting to measure some of its physical and chemical properties in the central laboratory of the College of Agricultural Engineering Sciences, University of Baghdad Table (1).

This experiment was designed as a factorial experiment with three factors in a completely randomized design (CRD) with three replicates. The first factor represented irrigation with river water at 50% of the soil content at field capacity as the first level and irrigation with river water at 100% of the soil content at field capacity as the second level. The second factor represented three different levels of liquid Nano nitrogen fertilizer (0, 2, 4) ml L^{-1}, and the third factor represented three different levels of complex Nano potassium fertilizer (0, 2, 4) g L^{-1}. Therefore, the total experimental units used in this study are 54 experimental units. *C.officinalis* seeds were planted during October (1-10-2023). The experiment continued until the end of the winter season of (2024), at a rate of 10 seeds in one pot containing 25 kg of sandy soil mixture and then thinned to three plants after 15 days of seedling emergence and at equal distances of approximately (5) cm between one seed and another.

The first irrigation was given, and the irrigation process was according to the water need of the plant and the weight method was adopted to control the moisture content of the soil within the limits of the required field capacity under study. One month and ten days after planting, and after ensuring the emergence of full leaves on the plant, the first foliar spray of the two concentrations of Nano nitrogen fertilizer was given, and the first batch of the two concentrations of Nano potassium fertilizer was added the next day as a vegetative spray. The same concentrations were continued for four sprays (one spray every 4 weeks, starting at the 4-6 leaf stage), until flowering was 100% complete [8]. A drop of Al-Zahi solution (cleaning solution) was used to reduce the surface tension of water, ensure complete wetting of the leaves, and increase the efficiency of the spray solution. The pots were well watered before spraying to increase the plants' efficiency in absorbing the sprayed material, as humidity plays a role in the process of cell swelling and stomata opening. In addition, watering before spraying reduces the concentration of solutes in the leaf cells, which increases the penetration of the spray solution ions into the leaf cells [11]. The control treatment was sprayed with distilled water only, and the second, third, and fourth batches of Nano-concentrations of nitrogen and potassium were added one month after each addition and in the same way. All agricultural operations followed in the production of this plant were carried out, including fertilizing with basic nutrients at an amount of 50 (kg ha^{-1}) phosphorus from a calcium superphosphate fertilizer source before planting [6]. Plant height was measured using a Metric Tape Measure in each experimental unit for each replicate from the soil surface to the top of the plant, and then the average plant height was extracted. The diameter of the main stem was measured in each experimental unit at a distance of 2 cm from the soil surface using a Venire Caliper Digital, and then the average diameter of the plant stem was calculated. The leaves and flowers of the three plants from each treatment for each replicate were manually counted and the number was divided by three, and then the average number of leaves and flowers per plant was extracted.

RESULTS AND DISCUSSION

1. Plant Height (cm)

The data presented in Table (2) demonstrate that the effect of Nano nitrogen (N) sprayed on *C. officinalis* concerning plant height is highly significant, There was remarkable increase in plant height with the increase in applied levels of nitrogen up to the highest value with N_2 (4 ml L^{-1}) treatment of 33.27 cm, which was 40.97% more than control treatment N_0 (without Nano nitrogen), which was recorded 23.60 cm.

The increase of plant height could be referee to that nitrogen is one from vital nutrients for the plant as it serves as one of the doses of macronutrients that play imperative function in controlling the act of some plant hormones as (auxins and cytokinines) that result for elongation of internodes and rise the plant height [20]. [33] Application of nitrogen at 120 kg ha^{-1} had a marked effect on vegetative growth attributes of *C. officinalis* and resulted in the tallest height of the studied plant of (47.42 cm). The results presented here are in close comparison with those found by [32] for rosemary plants *Rosmainus officinalis* L., who indicated that high nitrogen concentrations (6 g L^{-1}) had positive and significant effects on increasing plant height (as vegetative growth indicator), which underscores the vital influence of nitrogen on the growth of plants.

According to the results in the above table the effect of spraying with Nano potassium on this characteristic was significant and due to gradually increase in the amount of spraying with Nano potassium, plant height was increased. The longest plant height was found in the K_2 (4 g L^{-1}) (32.12 cm) which was 22.27% higher than comparison treatment (the only sprayed with distal water) 26.27 (cm). This because potassium is involved in the control of many processes such as metabolism, growth, development and photosynthesis of the plant, having action on the process of cell division, expansion and elongation, that determine the optimal expansion of the cell wall which is necessary for the growth of plant. It is connected also with the protein synthesis and it blocks in the activation of a dozens of enzymes that are involved in the further enhancements of the plant growth, including the growth in the height of the plant [27]. This finding is in line with that of [35] who reported that spraying with Nano potassium resulted in a significant effect on the growth parameters of *C. officinalis*, also the findings of [5], [1], and [31] who reported that increasing level of potassium fertilization led to a significant increase in plant height.

The results as presented in the above mentioned table revealed that the level of irrigation water had led to reduction in plant height as it reached 26.55 cm when adding irrigation water at S_1 compared with the comparison treatment (irrigation at S_2) which record 32.14 cm (a reduction rate of 17.39%). It can be concluded from the obtained results that there are obvious positive effects by increasing the studies character values case of plant height after the water stress reduce due to the increasing of the irrigation levels from S_1 to S_2. This could be due to the influence of water stress on negative effects of vegetative growth parameters in plants, which stimulate the production of ROS in plant cells causing water scarcity and oxidative stress, influencing plant height. [29]. Also, irrigation at S_1 resulted in a reduction in plant height in response to absence of (cell division, expansion, and elongation) which were influenced by absence of soil water supply especially under sandy soils. This results in smaller leaf areas and less light reaching the leaves, and therefore the efficiency of converting light energy of the physical nature into the chemical energy required for the formation of dry matter involved in elongation decreases [16]; [9]. The trait of reduced plant height due to water stress was also found by [12] and [10].

Bilateral interrelations between the jeu-study factors exerted a marked effect on this characteristic, Demanding interactions of the two factors of Nano - spraying nitrogen and potassium spraying were significant, when, the highest plant height was obtained for N_2K_2 that was 36.55 cm and its lowest was observed for N_0K_0 that was 20.10 cm.

The effect of the interaction of the two levels of Nano nitrogen spraying and two levels of additional irrigation water was significant for this characteristic, wherein the highest value (35.95 cm) of plant height was recorded from treatment N_2K_2 and the lowest value of plant height (21.03 cm) was recorded from the treatment N0K0. The interaction of irrigation water and Nano potassium spray treatment had a significant effect on plant height, where the highest value of plant height was recorded with N_2 K_2 and was 35.14 cm and lowest value was with N_0 K_0 and was 23.25 cm.

There turned out to be a large interaction between our study factors in this characteristic. Plants height the highest value of plant height was recorded in treatment $N_2K_2S_2$ (39.10 cm) with an increment value of 139.44% as compared with the lowest value recorded in treatment $N_0K_0S_1$ (16.33 cm).

The greatest response in the phenotypic trait (plant height) was recorded in the N_2K_2 treatment in Table (2). The variation in the response is likely related to the intensity of joint influence of plants and different types and amounts of added fertilizers. It is observed that expression of the vegetative and root growth parameters increases with increasing concentration up to a certain concentration (which vary with the specific growth and yield parameter), this may be in equilibrium by providing the doses of nitrogen and potassium, which is actually needed for the plants at cellular elongation and cell expansion stage.

2. Stem Diameter (mm)

The individual effect of each Nano nitrogen and potassium on significant increase of *C. officinalis* stem diameter was revealed from Table (3). The concentration (2 and 4 ml L^{-1}) of Nano nitrogen showed the highest significant increase in plant stem diameter (6.27 and 6.74 mm, respectively), with increasing rates of (18.08 and 26.93%) as compared to the control treatment, which gave rise to weak-stemmed plants (5.31 mm). The same for Nano potassium due to concentration 2 and 4 g L^{-1} the statistically significant increase in plant stem diameter by the mean of (6.10 and 6.48) mm respectively, and the increase rate reached (6.09 and 12.70%) respectively were the highest values, as compared with control treatment yielded weak stems plant with mean (5.75) mm. Results of irrigation at the two levels showed that Irrigation used to have a marked effect on stem diameter, where irrigation at 100% field capacity resulted in plants for a large stem diameter, estimated by 6.46 mm in comparison to water stress treatment (irrigation at 50% of field capacity) that led to stem diameter of 5.76 mm. The water is known as the vehicle for the transportation of nutrients from soil into the plant and plant lacking soil water shows a reduced growth and productivity. [38] Figured out that water stress (below 30% field capacity) as well as crop competition for soil moisture and other resources influence plant growth. With the aggravation of water stress, the water content in the cell of plant tissue decreased accordingly, which plays a key role in cell expansion, as well as other organs in the plant, if there is any defect in the cell expansion, it can lead to all plant organ cell growth. In light of these studies, also [13], these results are in line with those of many studies.

It is worthy to mention from the data of the two-way interaction between the factors of studying, that we got lowest diameter of the plant stems linking the plant treatment compounded with S_2 through spraying with of 4 ml L^{-1} of Nano nitrogen treatment, where it gave a mean average value 7.20 mm, and highest increase of plant diameter was at with the treatment of (irrigated at S_1 with spraying at of 0 ml L^{-1}) of Nano nitrogen treatment, gave a mean average 5.19 mm.

It is clear from the results presented in the mentioned table that (irrigating plants with S_2 with the treatment of spraying plants with Nano potassium) gave the highest values in the studied trait with an average of 6.78 (concentration of 4 g L^{-1}), while the interaction treatment between irrigation water (added with S_1 with spraying with a concentration of 0 g L^{-1} of Nano potassium) recorded the lowest value in the average stem diameter of 5.37(mm).

The interaction between the two bio nutrients, Nano nitrogen and potassium reflected a remarkable increase in plant stem diameters in the treatment with *C. officinalis* leaf spraying with a concentration of 4 in (ml L^{-1}, g L^{-1}) of Nano nitrogen and potassium together, plant average 7.37 mm, an increase rate reached 45.08% comparing to the control treatment that resulted in plants with a small stem diameter average 5.08 mm.

The results showed that there were significant differences between the studied results of the factors for the triple interaction, where it became clear the triple interaction of irrigating water levels (50 and 100%) with concentration of 4 (ml L^{-1}, g L^{-1}) of Nano nitrogen and potassium together were significantly higher than the average diameter of the studied property with an average (7.01 and 7.74 mm) respectively in comparison to a triple interaction between the ratio of the water stress S_1 of the concentration of 0 (ml L^{-1}, g L^{-1}) of Nano nitrogen and potassium ,the lowest diameter of plant stem with an average area (4.83 mm).

This can be attributed to the fact that direct foliar application of Nano fertilizers to the plant body, even at low concentration, significantly adds to the enhanced transport rates of substances responsible for raising the stem diameter and amount of vessels [23]. This is consistent with the report of [17] who observed that the estimates of all the values of the various plant growth variables when Nano NPK was applied were high.

[30] reported that the cause is because of the foliar application of nanoparticles where they are characterized by their chemical and physical properties such as their easy penetration into plants and quick spreading and as a result of that, this would increase the speed of their intake and their high solubility, as a result they would give positive results that are reflected in the enhancing growth in plants. These findings are in agreement with [7] on plant growth rate of vegetative and root diameter growth of Lalanki *citrus reticulate* L. by using foliar application Nano fertilizers. The increase in stem diameter when sprayed with Nano nitrogen and potassium (N_2K_2) under irrigation water S_2 is due to the positive role of this Nano treatment, thus the maximum investment of these elements in the vital processes in their struggle for existent and their effect in increasing the stem diameter growth.

3. Number of leaves (Leaf Plant^{-1})

Average number of plant leaves as presented in Table (4), irrigation at S_2 resulted in a significantly higher average meaning number of leaves as compared to S_1, it is a mean difference of 22.42 leaf plant^{-1} to the lowest mean number of leaves of 47.11 leaf plant^{-1}. The effects of the other two individual effects of the nitrogen and potassium nanoparticles, at the concentrations used (2 and 4 ml L^{-1}, 2 and 4 g L^{-1}) respectively, were that there was a significant increase in this trait, where the higher concentration (4 ml L^{-1}) achieved the highest increase in the number of leaves that reached an average (66.22 and 62.44) leaf plant^{-1} for each of the two nutrients compared to control treatment which had average number of

leaves which was lower (36.38 and 40.11) leaf plant^{-1} respectively.
From the table above, we can deduce the result of two-way interaction for the studied factors and the best plants in terms of the increase in (number of their leaves were in case when used S_2 for irrigation and 4 ml L^{-1} of Nano nitrogen with the highest average of 73.66 leaf plant^{-1} and growth rate 118.84% compared to the number of leaves from the plants irrigated with irrigation water of S_1 0 ml L^{-1} of Nano nitrogen with an average of 33.66 leaf plant^{-1}.
It is reported that in plants sprayed with Nano potassium at 4 g L^{-1} and irrigated in S_2 (crop leaf area) showed highest mean value of the studied trait (71.22) leaf plant^{-1} respectively, while the interaction between the irrigation level S_1 with a level of 0 g L^{-1} of the Nano potassium resulted in the lowest average of 37.77 leaf plant^{-1} equal 88.56% more as compared to control.
It can be seen from the table that the joint application of nitrogen and potassium nanoparticles spraying the two factors at a concentration of 4 (ml L^{-1}, g L^{-1}), were double factors causing an increase of chrysanthemum leaves, by 75.33 leaf plant^{-1} at an increase rate in the number of chrysanthemum leaves by 220.55%, when compared to the comparison treatment, with the number of leaves being 23.50 leaf plant^{-1}.
The results of three-way interaction of the studied factors indicated that the level of irrigation S_2 and the concentration of 4 ml L^{-1} of Nano nitrogen and 4 g L^{-1} of Nano potassium had the most positive effect on this characteristic and with an average of 85.66 leaf plant^{-1} was obtained. Than the irrigation treatment (S_1 and 0 ml L^{-1} of Nano nitrogen of Nano potassium 0 g L^{-1}),with number of leaves of 21.33 leaf plant^{-1} which is equivalent to a rise of 301.59 %.
This explains that the use of Nano nitrogen and potassium spraying transfer the efficiency of the plant uptake of water and nutrients to plants, and the macro nutrient have effective role in different of the plant-metabolic processes consequently increase the growth, which positively affect in the increasing the characteristics of the vegetative group as a result of the expansions of cell due to growth stimulating hormones. This explains why number of leaves also increases and it has some implication for other results. These findings concur with the proposition of [30]. This result agrees with that obtained by [24], while working on fertilization of *Mentha spicata* (mint) and squash *Mentha longifolia* (longifolia) plants; he observed that nitrogen fertilization resulted in an increase in the height of plants in relation to unfertilized ones.
Results are consistent with the findings of [41] and [18] who reported that Nano elements could stimulate the vegetative cells to divide and elongate by directly affecting the leaf forming regions and increasing the divisions number and also via affecting hormones concerned in the process of leaf formation and increasing its numbers. Nitrogen also induced increase in emergence to one or more leaves and a synergy of the elements, nitrogen - with others absorbed from the soil by the plant, as a brick in several building tissues of plant growth. [26] Showed an elevated number of leaves when treated with 50 µg ml of CNT in tomato.
As reported by [21], the inhibition of ethylene activity decreased abscission and [36] reported the same. An increase in leaf number had also been reported as a response to the inhibition of ethylene action. [14].

4. Number of flowers (flower plant^{-1})

The statistical analysis results presented in (Table 5) showed that Nano nitrogen concentration has a highly significant effect on the number of flowers per plant. As the Nano nitrogen concentration rose from 0 ml L^{-1} to 4 ml L^{-1}, plant averaged number of flowers per plant was increased from 4.22 flowers to 9.16 flowers, respectively, with 117.0 % increase. Regarding the influence of Nano potassium, Table shows its notable effect on the average number of flowers per plant. The average flower number of plants treated with Nano potassium spraying was increased to 5.22 flowers plant to 7.94 flowers plant with average of 52.11% as compared to the control. The same table indicates that there are statistical differences when a reduction in the intensity of water stress during the S_2 irrigation with respect to number of flowers trait in *C. officinalis* plants (on average 7, 96) flower Plant^{-1} with plants irrigated with high irrigation water by S1 with the Lowest mean of 5.70 flower plant^{-1}.

According to the table of bilateral relations of the studied factors, bilateral interaction When water stress and spraying Nano nitrogen has the greatest impact on this trait that the plants irrigated with added irrigation water at a level of S_2 and irrigation water plus Nano nitrogen spraying with concentration of 4 ml L^{-1} has increased number of flowers to an average of 10.77 flowers plant^{-1} as compared to its minimum number of flowers (3.22) flowers plant^{-1} in plants irrigated with irrigation water at S_1 and S_0 concentrations of 0 ml L^{-1} of Nano nitrogen. The water supply with Nano potassium interaction also had influence on the characteristic studied and the maximum number of flowers was observed in the plants that received the supply S_2 and 4 g L^{-1} of Nano potassium, with an average of 9.33 flowers plant^{-1} compared to the lowest of 4.44 flowers plant^{-1} interaction of irrigation with water at S_1 and 0 g L^{-1} of Nano potassium. Interaction effect when Nano nitrogen and Nano potassium were included in the model was significant by influencing the average of this trait, as control treatment (0 Nano nitrogen + 0 Nano potassium) exhibited the lowest average of 3.33 flowers plant^{-1} and the highest was 10.83 flowers plant^{-1} following 4 ml L^{-1} treatment. 4 ml L^{-1} for Nano nitrogen and Nano potassium, respectively) as the increase rate reached 225.23% compared to control treatment, which did not significantly from the treatment (4 ml L^{-1} N and 2 g L^{-1} K).

The triple interaction of experimental factors also significantly influenced the mean of this trait, as water stress treatment without adding any combination of the Nano nitrogen and potassium performed the least with a mean of 2.66 flowers plant^{-1}, the highest being 13.00 flowers plant^{-1} was derived from the plants that were not given stress water (irrigation of S_1) and spraying (4 ml L^{-1} Nano nitrogen + 4 g L^{-1} Nano potassium) having an increase of 388.72% over the control (minimum value).

The result in Table (5) indicated that spraying Nano NPK had a positive effect on earliness of flowering in *C. officinalis* plants, and this might be due to that auxins can mediate response pathways of each other reciprocally and act to the same end but separately [39, 40]; it could be as an outcome of more accumulation of IAA and rapid transportation of sugars to the reproductive parts of the plant.

The foliar spray by macronutrients (Nano nitrogen and potassium) led to increase in the number of leaves and chlorophyll of leaves which promoted more efficient capacity of photosynthesis, carbohydrate production and its transportation towards storage parts (flowers) extending the growth and developmental stage. This is the same as the value that our study had estimated Table (5) [2].

The reason for the raise in the characteristics of the floral growth may be attributed to potassium with indicated two important functions in the promoting cell division with meristematic tissue growth [4] and in the regulation of the osmotic potential of the cells by regulating the opening and closing of the stomata, making it possible to boost the number of flowers [11], as well as in the transport of formed carbohydrates from the production

areas (leaves) and their accumulation within the flowers [15].
In the experimental conditions, maximum Nano N_2, K_2 and S_2 irrigation water values caused the greatest chlorophyll contents compared with control treatment. This finding may partially account for the promoted growth and flowering.
The data shown in (Table 5) indicated that addition of Nano elements under irrigation level of S_2 increased the average number of flowers, i.e. the maximum number of flowers were given with $N_2K_2S_2$ treatment; and the minimum was recorded with $N_0K_0S_1$ where both [26] and [22] explained the increasing of flower and fruit yield on treating the *C. officinalis* plants with Nano particles.

Table (1): Some physical and chemical characteristics of soil sample used in this study.

Adjective		Value	Unit
pH		7.9	-
Electrical conductivity (EC)		1.28	$ds.m^{-1}$
Organic matter		8.62	$gm. Kg^{-1}$
Soluble cations	Ca^{2+}	5.5	$C mol.Kg^{-1}$ Soil
	Mg^{2+}	3.8	$C mol.Kg^{-1}$ Soil
	Na^{1+}	2.7	$C mol.Kg^{-1}$ Soil
	K^{+}	0.41	$C mol.Kg^{-1}$ Soil
Soluble anions	SO_4^{2-}	6.6	$C mol.Kg^{-1}$ Soil
	HCO_3^{1-}	2.4	$C mol.Kg^{-1}$ Soil
	CO_3^{2-}	Nil	$C mol.Kg^{-1}$ Soil
	Cl^{-}	3.3	$C mol.Kg^{-1}$ Soil
Available N		14	$gm. Kg^{-1}$
Available P		13.6	$gm. Kg^{-1}$
Available K		85.4	$gm. Kg^{-1}$
Soil separators	Sand	846	$gm. Kg^{-1}$
	Silt	83	$gm. Kg^{-1}$
	Clay	71	$gm. Kg^{-1}$
Texture Sandy loam			

*Analyzes in soil analysis laboratories at the Faculty of Agriculture - University of Baghdad

Table (2) : The effect of spraying with Nano nitrogen and potassium on the height of the *C. officinalis* plant (cm) growing under two different irrigation water levels.

Nano nitrogen spraying (ml.L-1) N	Nano potassium spraying (g.L-1) K	Irrigation levels (from field capacity value) S %50 S_1			% 100 S_2			N*K
0	0	16.33			23.88			20.10
	2	22.55			24.10			23.32
	4	24.22			30.55			27.38
2	0	26.22			31.66			28.94
	2	28.77			35.44			32.10
	4	29.10			35.77			32.44
4	0	27.21			32.33			29.77
	2	30.55			36.44			33.49
	4	33.99			39.10			36.55
S		26.55			32.14			
								N
N*S	0	21.03			26.18			23.60
	2	28.03			34.29			31.16
	4	30.58			35.95			33.27
								K
K*S	0	23.25			29.29			26.27
	2	27.29			31.99			29.64
	4	29.10			35.14			32.12
L.S.D at 0.05		N	K	S	K * N	S * N	S * K	* K * N S
		0.86	0.86	0.7022	1.72	1.5722	1.5722	2.3422

Table (3): The effect of spraying with Nano nitrogen and potassium on the diameter of the *C. officinalis* stem (mm) growing under two different irrigation water levels.

Nano nitrogen spraying (ml.L^{-1}) N	**Nano potassium spraying (g.L^{-1}) K**	**Irrigation levels (from field capacity value) S** %50 S_1	% 100 S_2	**N*K**
0	0	4.83	5.34	5.08
	2	5.27	5.38	5.33
	4	5.48	5.58	5.53
2	0	5.54	6.35	5.94
	2	5.84	6.85	6.34
	4	6.06	7.01	6.54
4	0	5.73	6.73	6.23
	2	6.11	7.14	6.63
	4	7.01	7.74	7.37
S		5.76	6.46	
				N
N*S	0	5.19	5.43	5.31
	2	5.81	6.73	6.27
	4	6.28	7.20	6.74
				K
K*S	0	5.37	6.14	5.75
	2	5.74	6.46	6.10
	4	6.18	6.78	6.48

	N	**K**	**S**	**K * N**	**S * N**	**S * K**	*** K * N S**
L.S.D at 0.05	0.1218	0.1218	0.0994	0.2436	0.2212	0.2212	0.343

Table (4): The effect of spraying with Nano nitrogen and potassium on the number of leaves of the *C. officinalis* plant (leaf $plant^{-1}$) growing under two different irrigation water levels.

Nano nitrogen spraying ($ml.L^{-1}$) N	Nano potassium spraying ($g.L^{-1}$) K	Irrigation levels (from field capacity value) S %50 S_1			% 100 S_2			N*K
0	0	21.33			25.66			23.50
	2	38.00			42.66			40.33
	4	41.66			49.00			45.33
2	0	44.33			49.66			47.00
	2	48.00			69.66			58.83
	4	54.33			79.00			66.66
4	0	47.66			56.00			51.83
	2	63.66			79.33			71.50
	4	65.00			85.66			75.33
S		47.11			59.62			
								N
N*S	0	33.66			39.11			36.38
	2	48.88			66.11			57.50
	4	58.77			73.66			66.22
								K
K*S	0	37.77			43.77			40.77
	2	49.88			63.88			56.88
	4	53.66			71.22			62.44
L.S.D at 0.05		N	K	S	K * N	S * N	S * K	* K * N S
		1.3799	1.3799	1.1267	2.7598	2.5066	2.5066	3.8865

Table (5): The effect of spraying with Nano nitrogen and potassium on the number of flowers of the *C. officinalis* plant (flower plant^{-1}) growing under two different irrigation water levels.

Nano nitrogen spraying (ml.L^{-1}) N	**Nano potassium spraying (g.L^{-1}) K**	**Irrigation levels (from field capacity value) S** %50 S_1	% 100 S_2	**N*K**
0	0	2.66	4.00	3.33
	2	3.33	5.66	4.50
	4	3.66	6.00	4.83
2	0	5.00	6.66	5.83
	2	6.66	8.00	7.33
	4	7.33	9.00	8.16
4	0	5.66	7.33	6.50
	2	8.33	12.00	10.16
	4	8.66	13.00	10.83
S		5.70	7.96	
				N
N*S	0	3.22	5.22	4.22
	2	6.33	7.88	7.11
	4	7.55	10.77	9.16
				K
K*S	0	4.44	6.00	5.22
	2	6.11	8.55	7.33
	4	6.55	9.33	7.94

L.S.D at 0.05	**N**	**K**	**S**	**K * N**	**S * N**	**S * K**	**S * K * N**
	0.5891	0.5891	0.481	1.1782	1.0701	1.0701	1.6592

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