

## Efficiency of Spraying Nano-Kaolinite Compare with Chelated Nano Fertilizer in Improving Growth and Yield of Wheat Under Different Levels of Water Stress

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### Abstract

A field experiment was carried in Babylon governorate to study the efficiency of spraying nano-kaolinite compare with chelated nano fertilizer in improving growth and yield of wheat under different levels of water stress and according to RCBD, split-plots arrangement. The treatments included the control (without spray) treatment, spray treatments of normal kaolinite solution (K<sub>1</sub>) and nano (K<sub>2</sub>), and nano chelated fertilizer (S<sub>1</sub>). The experimental units were exposed to four water irrigation treatments i.e. regular irrigation, and three levels of water stress (30, 60 and 90% of water needs) represented by B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub> and B<sub>3</sub>, respectively. Spraying treatment with nano kaolinite solution had the highest value of plant height of (98.31cm) under regular irrigation. The highest value of leaf area was achieved after spraying with nano kaolinite (43.01) under 30% of water deficiency. The treatment B<sub>2</sub>K<sub>2</sub>S<sub>0</sub> gave the highest value of chlorophyll content (66.60 spad). In terms of number of grains in the spike, the treatment B<sub>3</sub>K<sub>2</sub>S<sub>1</sub> under water deficiency of 90%, gave the highest value (46.80 grains/spike). The treatment B<sub>2</sub>K<sub>1</sub>S<sub>0</sub> recorded 51.23 cmol/kg of K, while Ca, Mg, P and S achieved the highest values of 12.47, 11.75, 7.00 and 11.28 cmol/kg of the treatments B<sub>0</sub>K<sub>2</sub>S<sub>0</sub>, B<sub>2</sub>K<sub>1</sub>S<sub>0</sub>, B<sub>2</sub>K<sub>1</sub>S<sub>0</sub> and B<sub>1</sub>K<sub>1</sub>S<sub>0</sub> respectively. Among the micronutrients, Fe had highest value of 2180 mg/kg with the treatment B<sub>2</sub>K<sub>2</sub>S<sub>0</sub>. As for Zn recorded the highest value of 130 mg/kg with the treatment B<sub>1</sub>K<sub>2</sub>S<sub>1</sub>. All high values of Cu, Mn and Mo were achieved 34.41, 250 and 120 mg/kg with the treatment B<sub>1</sub>K<sub>1</sub>S<sub>1</sub>. The role of the spraying treatments in the foliar feeding and the readiness of the elements for the vegetative and fruiting parts did not discourage the plant from absorbing nutrients from soil solution, and transferring them to up take plant parts through root group, and water stress to which plant was exposed, it's never be discouraged biological and physiological functions.

**Key words:** Nano Kaolinite; Wheat; Nano fertilizer; Water stress.

### Introduction:

Nanotechnology is one of the most important advanced sciences and priorities of the modern era that have received attention from the scientific community and to it several definitions, including the ability to build small and large materials and produce them with precision and control of the atom, and nano science studies, the properties of condensed materials and their behavior at the nanoscale and the study *Al-Wotaify and Moshe– Research Journal of Science – RJS 3(2): 34-47 December 2022*

of nano natural phenomena (Mansoori, 2005). In light of this technology, the widespread use of nano materials for reclamation and control of environmental pollutants. In addition, clay minerals are very useful nanotechnologies in soil reclamation and pollutant treatment due to their possession of distinct physicochemical properties, represented by high specific surface area as a result of their geometrical shape, and the fine grain size is less than 2  $\mu\text{m}$  among the soil separators such as sand and silt (AL-Wotaify, 2019). At least one of the dimensions of clay minerals is characterized by the nanoscale dimension, which makes them non-toxic and inexpensive adsorbent materials that are used in a variety of fields, whether industrial, agricultural, engineering and environmental, and are environmentally friendly (Churchman *et al.*, 2006; Zhu and Niuguna, 2014). Iraq is located within arid and semi-arid regions, and is controlled by unstable conditions in terms of the abundance of arable water and various human uses, especially after the severe decrease in the quantities of water and the current water revenues of the Tigris and Euphrates rivers, which are much lower than their natural levels, as a result of unbalanced water strategies and policies. The clear situation with the riparian countries (Al-Shammari, 2012) and when water is not available to the plant in the required quantities, it negatively affects its growth indicators and the components of the yield to include anatomical, morphological, physiological, and biological aspects, which results in reducing the size of the plant and its leaf area, which in turn affects the decrease in the productivity of the crop due to its exposure to water stress. The phenomenon of water shortage in the root zone, and limiting plant absorption to it for a certain period of time, is considered one of the most important types of abiotic environmental stresses affecting the reduction of plant yield. The kaolinite minerals resulting from the weathering of potassium feldspar and mica are high in potassium (Wilson, 2006). Accordingly, it can contribute to controlling the mechanism of opening and closing the stomata, and the ability of the mineral to maintain relative moisture, which contributes to reducing the effort exerted by the plant to absorb water during its scarcity at the root zone and to reduce the effect of the osmotic stress inside the plant, as well as the kaolinite mineral content of other elements in its structural composition, it can be considered a source of nutrients for the plant under the appropriate conditions (Al-Khafaji *et al.*, 2000). In addition, Iraqi soils are rich in potassium and above the critical level at times, but it is not readily available for the plant due to what it suffers from stabilization processes between the inner layers of minerals and the speed of its loss from the soil, so adding a substance or fertilizer containing potassium makes it available to plant (Mengel and Kühlenbecker, 1993). The availability of potassium and some elements have a role in water stress, which is one of the most important causes of the loss in the productive quantity of the crop excelling the loss resulting from other environmental influences, irrigation has priorities in the stages of emergence and formation of plant organs for the vegetative and reproductive parts, and in the advanced stages of the yield components and its quality (Al-Sahuki *et al.*, 2009).

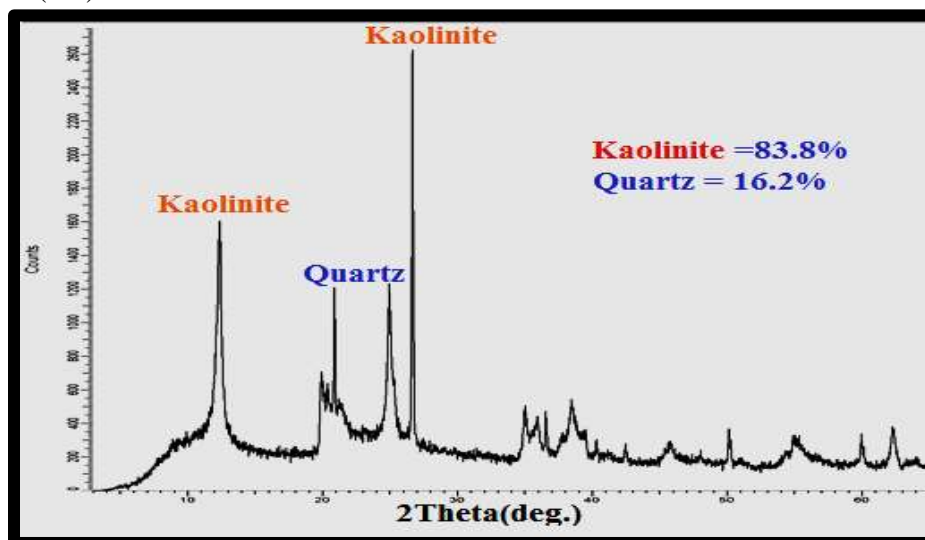
### **Materials and methods:**

#### **Experiment location:**

A field experiment was conducted during the winter season 2019/2020 at a farmer's field, in Babylon, which is 6 km away from the center of Hilla city in the northeast direction. The Babylonians' and Assyrians' interest in digging canals and streams for irrigating crops was one of the factors in forming the soil of this ancient city (Khalaf, 1959).

### Preliminary actions:

A sample of Dawakhlah kaolinite mineral whose formation is in the western desert of Iraq was prepared by the General Company for Geological Survey and Mining in Baghdad. The mill has a granular size of less than 75  $\mu\text{m}$  by the mentioned company. The metal under current study was diagnosed by X-ray diffraction apparatus at College of Science, University of Baghdad through its base distance of 7.31 Ångström, with a percentage of 83.8% (Fig 1), and grinding a portion of the normal kaolinite sample represented by the symbol K1 with the help of a nanoparticle mill. The particle size of the mineral was measured after milling by using the Particle Size Analyzes at the laboratories of Faculty of Materials Engineering, University of Babylon, and at a size of 70 nanometers for a sample of nano-kaolinite (K2).



**Figure 1: X-ray diffraction of Dawakhlah kaolinite from the Western Desert of Iraq**

The total content of the elements in the normal and nano kaolinite samples was estimated based on the number of nanoparticles elements in that compost package (S1) by means of an X-ray fluorescence device (XRF) at the laboratories of the Ministry of Science and Technology, Baghdad, which is shown in Table (1).

**Table (1): The element content of nano and regular kaolinite and nano fertilizer.**

Sample	Total content of macro nutrients (Cmol/kg)					Total content of the micronutrients (Cmol/kg)				
	K	Ca	Mg	P	S	Fe	Zn	Cu	Mn	Mo
<b>K<sub>1</sub></b>	3.94	1.37	3.62	0	0.59	12.35	0	0	0	0
<b>K<sub>2</sub></b>	3.76	7.9	2.75	0.54	1.43	49.74	0.04	0.02	0	0
<b>S<sub>1</sub></b>	4.34	0.25	1.23	0.96	1.87	0.71	40	5	20	1

Solutions from these samples were prepared at a volume of 2 g/L according to the recommendations announced in the instructions leaflet for the package containing a group of nanoparticles in the nano fertilizer.

### Soil preparation:

The soil was prepared with Moldboard plows tillage, then was divided into three replicates according to Complete Randomized Blocks Design. The experimental plot is in an area of 20 m<sup>2</sup>, with dimensions of 4 x 5 m. The distance between rows 35 cm. The main plot included water stress factor (B), and regular irrigation (B0), where the levels of water stress were 30, 60 and 90% represented by B1, B2 and B3

respectively. As for the sub-plot, spraying with S0 and S1 nano fertilizer solution, at a concentration of 0 and 2 g/L. With the same concentration of sub-sub plot included spraying with normal, nano kaolinite solution, and the control sample K1, K2 and K0 respectively. The aforementioned solutions were sprayed during the tillering and booting stages.

#### **Cultivation and fertilization:**

The seeds of wheat, IPA and 99 cultivars were cultivated at the beginning of December of 2019, the distance between lines was 35 cm, as each experimental plot contained 6 lines. DAP fertilizer, which contains 46% nitrogen, was added at once, mixed with soil during cultivation. The field was irrigated with a water pump equipped with a meter to record the amount of water added during regular irrigation, and water stress levels. During vegetative and reproductive stages, the plants were sprayed according to the estimation of water need to reach the mentioned water levels, and based on the following equation described by Shabib *et al.*, (2017).

$$d = A(pw_2 - pw_1) * pb * D * \%w \dots (1).$$

Where: **d**: is the depth of water for the water requirement, **A**: is the area of the experimental plot, **Pw<sub>2</sub>**: is moisture weight, at field capacity, **Pw<sub>1</sub>**: initial (initial) volumetric moisture, **pb**: bulk density, **D**: depth of root zone, and **% W**: stands for percentage specific to each of the levels of water stress.

The requirements for quantities of added water were calculated in liters to maintain specified percentage for each level of water stress throughout the period of time for each of the two stages of tillering and booting. This is done by estimating the soil moisture content using gravimetric method for measuring soil moisture, as well as field capacity at each experimental plot in order to determine the irrigation time. To determine the depth of the added water, samples were taken from the soil before and after each irrigation during the tillering and flowering stages. The moisture content in soil samples was estimated by drying the samples in the microwave oven for a period of fifteen minutes, then dried in the electric oven at 105 ° C for 24 hours. Note that in each stage there must be an estimate of the water need and supply the experimental plots with water to complete the deficiency in each level of water stress. The solutions under the current study are sprayed directly, and at the time of the early hours of the morning. As well as following up the weeding manually. The crop was harvested in May of 2020.

#### **Growth parameters and yield components:**

**-Plant height (cm):** ten plants per plot (cm) were selected to measure their height by using a tape measure from the level of the soil surface to the end of the stem of the main stem kernel, according to Donaldson (1996).

**-The flag leaf area (cm<sup>2</sup>):** was estimated as the average area of ten plants for the main stems, and for each experimental plot (Thomas, 1975), according to the following equation (2):

$$\text{The flag leaf area} = \text{length of the flag leaf} \times \text{width at the center of the leaf} \times 0.95 \dots (2).$$

**-The chlorophyll content (spad):** was done by means of a chlorophyll meter (SPAD-502), at an average of ten readings per experimental plot upon completion of the flowering stage, by placing the upper group of leaves between both ends of the device, according to Reynolds *et al.*, (1998).

**-The number of grains per kernel:** was manually calculated as the average for ten kernels.

#### **Element content of plant parts:**

The leaves after the flowering stage were taken of plants with an area of 1 m<sup>2</sup> and dried, then they were cut into small parts after washing them with a solution containing a detergent at a concentration of 0.2%, then washed in a distilled water to remove the detergent residues. The leaves were dried in an

electric oven at a temperature of 70 ° C for 24 to 48 hours. Then were milled and preserved well according to the method mentioned by Jones and Steyn, (1973) and reported by Al-Sahaf (1989) and it was sent to the Research Center, Department of Science and Technology, Baghdad, for the purpose of assessing its content of the elements mentioned of the spraying treatments with an X-ray fluorescence tool.

#### **Statistical analysis:**

The data was analyzed according to randomized complete block design (RCBD) within the arrangement of split-split plot, and the averages were compared using the lowest significant difference test (LSD) at a level of 0.05 of significance using GenStat software (Narrator and Abdulaziz, 1980).

#### **Results and discussion:**

##### **Plant height (cm):**

Table (2) shows a high value of wheat plant height at water stress levels of 30, 60 and 90%, which sprayed with normal and nano kaolinite solution were noticed. As well as the spray with nanoparticles, where the treatment  $B_0K_2S_0$  reached the highest value (98.31 cm), then the treatment  $B_0K_2S_1$  (95.99 cm), and finally the treatments  $B_1K_2S_0$  and  $B_2K_2S_0$  (96.20 and 94.07 cm) respectively. These results can be due to its fine nanoparticle size which provides a high specific surface area and capacity of ion exchange for its elemental content with the histological composition of the vegetative organs. This is in agreement with Agrawal and Rayhore, (2014) who stated that nano nutrients are characterized by their small particle size with the presence of a large number of atoms on the outer surfaces that increase their chemical reactions, as well as their effective role in the accuracy of the packaging of the vegetative parts, this is to maintain the ionic and water balance inside the plant cell. Then comes the super nano solution, which has an effect on the increase in the average plant height. This enhances the role of nanoparticles in improving the traits of vegetative growth of the plant, as well as the content of the two treatments sprayed with kaolinite and super nanoparticles of nutrients ready for absorption by the vegetative parts (Table 1), especially potassium, iron, copper, zinc and manganese that play a positive role together inactivating enzymes and division with elongation of plant tissue cells (Mohsen and Katami, 2016). Abdul Amir *et al.*, (2016) stated that the nano fertilizers consisting of iron, zinc and copper in certain concentrations contribute to an increase in plant height. The reasons for the high plant average at the level of water stress of 30%, and its decrease at the level of 60 and 90%, may be due to the fact that the moisture content in the soil provided by the level of water stress 30% is appropriate to the requirements of the physiological and biological processes that are practiced by the plant, in contrast to its decrease in the soil at the two levels. This causes a reduction in stem and leaf cell division, and their small size. In addition to the high level of water stress, it works to intercept and convert solar energy into a chemical, and produce the dry matter needed to complete the elongation process (Al-Tabbal *et al.*, 2006). All these indicators are evidence of the role of nano kaolinite in improving plant properties under the current study, and the level of water stress of 30%, which provides soil moisture suitable for plant growth and can be close to that provided by regular irrigation, and when moisture tightening does not cause water stress and this is what Al-Hafozi and Khalaf (2004) stated that a water stress average between 25-50% provides a moisture tension that does not cause stress to the plant, and a quantity of water available for plant growth and the fulfillment of its production requirements.

**Table (2): The effect of spraying treatments with normal and nano kaolinite solution, and nano fertilizer on plant height at different levels of water stress.**

Mean	Nano fertilizer (S)		Kaolinite treatments (K)	Water stress levels (B)
	S <sub>1</sub>	S <sub>0</sub>		
91.77	93.78	89.77	K <sub>0</sub>	B <sub>0</sub>
89.27	90.19	88.34	K <sub>1</sub>	
97.15	95.99	98.31	K <sub>2</sub>	
88.48	90.21	86.74	K <sub>0</sub>	B <sub>1</sub>
86.86	88.23	85.49	K <sub>1</sub>	
94.45	92.69	96.20	K <sub>2</sub>	
88.59	89.98	87.21	K <sub>0</sub>	B <sub>2</sub>
85.84	85.43	86.25	K <sub>1</sub>	
92.70	91.33	94.07	K <sub>2</sub>	
87.23	90.19	84.27	K <sub>0</sub>	B <sub>3</sub>
79.17	82.44	75.90	K <sub>1</sub>	
89.68	90.93	88.43	K <sub>2</sub>	
89.26	90.12	88.41	Mean	
(S)=1.00, (BxK)= 4.05, (BxKxS)=4.6			LSD <sub>0.05</sub>	

#### Flag leaf area (cm<sup>2</sup>):

The results in Table (3) confirmed that the highest value of flag area was (43.01cm<sup>2</sup>) for the treatment B<sub>1</sub>K<sub>2</sub>S<sub>0</sub>, then the treatment B<sub>2</sub>K<sub>2</sub>S<sub>0</sub> (42.25 cm<sup>2</sup>). This enhances the content and nano kaolinite from the nutrients and its direct contact with its strong adhesion, and ease of absorption by the leaves due to its precise nano size. The highest value recorded is (43.01 cm<sup>2</sup>) when spraying with nano kaolinite under a water stress level of 30%, then comes 60% level for the same treatment, at a value of (42.25 cm<sup>2</sup>), as a result of the availability of moisture content in the soil at a level that does not constitute water stress, which makes the plant in a natural state and with sufficient water to carry out its physiological and biological processes. In general, the level of water stress of 60% was similar in its results to the level of water stress of 30%, which was also close in its results to the level of normal irrigation in the spraying treatments and control treatment. The reasons may be due to the water requirement of leaves being less than it is during growth stages, such as the booting, which is sensitive to different types of stresses, and is most affected by lack of irrigation. The aforementioned indicate that there is a clear effect of all treatments on leaf area and that the values of the treatments between them were heterogeneous effect at the least significant difference. This may be due to the adsorption capacity of kaolinite and its specific surface area, which became high due to the fine grain size, and its failure to be in direct contact with the foliar feed, it may be due also to the interaction between the nano kaolinite and the super nanoparticles that formed a particles size that reduced the availability of the nutrients.

**Table (3): The effect of spraying treatments with normal and nano kaolinite solution, and nano fertilizer on flag leaf area at different levels of water stress.**

Mean	Nano fertilizer (S)		Kaolinite treatments (K)	Water stress levels (B)
	S <sub>1</sub>	S <sub>0</sub>		
35.71	37.00	34.43	K <sub>0</sub>	B <sub>0</sub>
33.19	35.63	30.75	K <sub>1</sub>	
38.03	35.45	40.60	K <sub>2</sub>	
34.38	36.74	32.02	K <sub>0</sub>	B <sub>1</sub>
35.16	37.85	32.47	K <sub>1</sub>	
41.38	39.75	43.01	K <sub>2</sub>	
31.74	33.41	30.06	K <sub>0</sub>	B <sub>2</sub>
35.01	34.50	35.51	K <sub>1</sub>	
42.08	41.92	42.25	K <sub>2</sub>	
30.77	32.02	29.52	K <sub>0</sub>	B <sub>3</sub>
30.98	30.81	31.15	K <sub>1</sub>	
34.63	36.52	32.73	K <sub>2</sub>	
35.25	35.97	34.54	Mean	
(S)=1.43, (BxK)=5.76, (BxKxS)=6.60			LSD <sub>0.05</sub>	

#### Chlorophyll content (Spad):

Table (4) shows the chlorophyll content values under the studied treatments. The treatments B<sub>0</sub>K<sub>2</sub>S<sub>0</sub> and B<sub>2</sub>K<sub>2</sub>S<sub>0</sub> recorded the highest values of 66.60 and 61.23, respectively after which the treatments B<sub>0</sub>K<sub>2</sub>S<sub>1</sub> and B<sub>2</sub>K<sub>2</sub>S<sub>1</sub> recorded the values of 60.00 and 56.37, with an average of 63.30 and 58.80 respectively. Where, the triple interaction treatments were recorded at water stress level of 30 and 90%, the lowest values were recorded for the chlorophyll content. These results confirm the importance of the iron kaolinite content, the availability of adequate moisture content from regular irrigation, and the 60% stress level in improving the chlorophyll content of the leaves. As well as the ability of the clay mineral nano to absorb light energy by the leaves, which then turns into chemical energy that activates enzymes and form pigments, including chlorophyll (Akhkha *et al.*, (2011). Also, Abdul Amir *et al.*, (2016) found that when plants were treated with nano fertilizers for iron, zinc and copper, significant differences were recorded in vegetative growth indicators, including the chlorophyll content of leaves. This was shown by Hanifa (2015) who exhibited that water stress caused a decrease in chlorophyll for three cultivars of wheat. In general, the results of the chlorophyll content did not record high differences between the values of water stress levels and the spraying treatments to the extent that the regular irrigation treatments distinguished from others. As well as the ability of the clay mineral to absorb light energy by the leaves, which then turns into chemical energy that activates enzymes and form pigments, including chlorophyll (Akhkha *et al.*, (2011). Also found Abdul Amir *et al.*, (2016) when treating plants with nano fertilizers for each of iron, zinc and copper, significant differences were

recorded in vegetative growth indicators, including the chlorophyll content of leaves. In general, the results of the chlorophyll content did not record high differences between the values of water stress levels and the spraying treatments to the extent that the regular irrigation treatments distinguished from others.

**Table (4): The effect of spraying treatments with normal and nano kaolinite solution, and nano fertilizer on chlorophyll content at different levels of water stress.**

Mean	Nano fertilizer (S)		Kaolinite treatments (K)	Water stress levels (B)
	S <sub>1</sub>	S <sub>0</sub>		
52.80	56.27	49.33	K <sub>0</sub>	B <sub>0</sub>
47.67	49.43	45.90	K <sub>1</sub>	
63.30	60.00	66.60	K <sub>2</sub>	
45.65	47.87	43.43	K <sub>0</sub>	B <sub>1</sub>
44.47	46.40	42.53	K <sub>1</sub>	
53.00	53.10	52.90	K <sub>2</sub>	
47.32	49.37	45.27	K <sub>0</sub>	B <sub>2</sub>
47.75	49.53	45.97	K <sub>1</sub>	
58.80	56.37	61.23	K <sub>2</sub>	
43.17	44.83	41.50	K <sub>0</sub>	B <sub>3</sub>
44.23	44.50	43.97	K <sub>1</sub>	
51.23	52.23	50.23	K <sub>2</sub>	
<b>49.94</b>	<b>50.83</b>	<b>49.07</b>	<b>Mean</b>	
<b>(S)= 1.20, (BxK)=6.18, (BxKxS)=N.S.</b>			<b>LSD<sub>0.05</sub></b>	

**Number of grains per kernel (grain/kernel):**

Table (5) shows the results of the number of grain per spike, under the studied treatments. The treatment B<sub>0</sub>K<sub>2</sub>S<sub>0</sub> had more grains than B<sub>0</sub>K<sub>2</sub>S<sub>1</sub>, and also when the B<sub>2</sub>K<sub>2</sub>S<sub>0</sub> treatment gave more number than the treatment B<sub>2</sub>K<sub>2</sub>S<sub>1</sub>, indicating the superiority of the treatment of nano kaolinite alone, compared with the interaction of kaolinite and nano fertilizer that affected the number of grains, perhaps to increase its content of calcium and iron. On the contrary, the treatment B<sub>3</sub>K<sub>2</sub>S<sub>0</sub> gave the lowest number of grains (39.51) compared to the treatment B<sub>3</sub>K<sub>2</sub>S<sub>1</sub>, which was (46.80). As, it was contrary to the lengths of the kernels in these two treatments. The reason may be due to the presence of some important elements in chelated fertilizer that increase the plant's resistance to water stress, especially potassium, which was characterized by its high content in nanocomposites and its content can be increased in a combined manner when both nanoparticles stimulate the plant to exercise its natural role in carrying out its biological and physiological activities all so the results of regular irrigation, and the level of stress of 60%, came with higher values, as a result of the availability of adequate moisture content for balanced absorption of the elements, and the degree of fullness of the grain. This is what Mirbahar *et al.*, (2009) indicated that inappropriate water stress levels in the provision of moisture

content affect the number of grains and yield, as a result of plant cell reductions, reduced formation of compounds and an increase in carbon dioxide formation, in comparison with other compounds inside the plant cell. Thus, they reduce dry matter, cell division, and chlorophyll content when studying wheat yield. As well as other elements that play an important role in the osmotic regulation process, such as manganese, which may be due to its participation in the nitrate reduction processes within the plant (Abduahi and Al-Younes, 1988). Al-Oqaili *et al.*, (2011) stated that adding levels of magnesium and potassium increased dry matter and grains, as well as zinc, iron and copper, increased the number of grains and other yield components.

**Table (5): The effect of spraying treatments with normal and nano kaolinite solution, and nano fertilizer on grains per kernel at different levels of water stress.**

Mean	Nano fertilizer (S)		Kaolinite treatments (K)	Water stress levels (B)
	S <sub>1</sub>	S <sub>0</sub>		
57.68	61.18	54.19	K <sub>0</sub>	B <sub>0</sub>
41.98	47.66	36.30	K <sub>1</sub>	
74.05	69.88	78.21	K <sub>2</sub>	
33.52	40.41	26.62	K <sub>0</sub>	B <sub>1</sub>
33.64	37.35	29.92	K <sub>1</sub>	
48.35	48.61	48.10	K <sub>2</sub>	
32.81	36.46	29.16	K <sub>0</sub>	B <sub>2</sub>
33.22	36.24	30.21	K <sub>1</sub>	
66.63	65.30	67.95	K <sub>2</sub>	
28.89	31.99	25.79	K <sub>0</sub>	B <sub>3</sub>
30.61	32.15	29.07	K <sub>1</sub>	
43.16	46.80	39.51	K <sub>2</sub>	
43.71	46.17	41.25	Mean	
(S)=1.40, (BxK)=7.36, (BxKxS)=7.99			LSD <sub>0.05</sub>	

#### Leaves content of nutrients:

Table (6) indicates the total content of the elements in the dry matter of the leaves of the wheat plant under the current study, which was estimated according to the total content of these elements in the nano fertilizer and the mineral kaolinite (Table 1). The potassium content ranged between 28.28-43.71 cmol/kg for the spraying treatments when using regular irrigation, and the treatment B<sub>0</sub>K<sub>2</sub>S<sub>0</sub> recorded the lowest values, and the highest was recorded for the treatment B<sub>0</sub>K<sub>1</sub>S<sub>1</sub>. At the 30% stress level, it ranged between 37.53-40.38 cmol/kg. Treatment B<sub>1</sub>K<sub>1</sub>S<sub>1</sub> recorded the lowest values, while treatment B<sub>1</sub>K<sub>2</sub>S<sub>0</sub> was the highest. The potassium content reached the highest values between 29.51-51.23 cmol/kg at a water stress level of 60%, and the lowest value was for treatment B<sub>2</sub>K<sub>0</sub>S<sub>0</sub>, and the highest was for treatment B<sub>2</sub>K<sub>1</sub>S<sub>0</sub>. The approximation for the lowest value was in the treatment B<sub>2</sub>K<sub>2</sub>S<sub>0</sub> (30.76), and for the highest value was for the treatment B<sub>2</sub>K<sub>1</sub>S<sub>1</sub> (43.43). The results show that phosphorous in *Al-Wotaiify and Moshe– Research Journal of Science – RJS 3(2): 34-47 December 2022*

leaf dry matter at regular irrigation recorded the lowest value of (3.29 cmol/kg) for treatment B<sub>0</sub>K<sub>0</sub>S<sub>0</sub>, as well as for treatment B<sub>0</sub>K<sub>2</sub>S<sub>1</sub> with a value of 3.70 and 3.93 cmol/kg for the treatment B<sub>0</sub>K<sub>2</sub>S<sub>0</sub>. The sulfur content ranged between 8.00-10.37 cmol/kg in the regular irrigation treatments, and the highest value was recorded by the treatment B<sub>0</sub>K<sub>0</sub>S<sub>1</sub>. At the 30% water stress level, the lowest value of 8.59 and 8.62 cmol/kg was recorded by treatments B<sub>1</sub>K<sub>0</sub>S<sub>0</sub> and B<sub>1</sub>K<sub>2</sub>S<sub>1</sub> respectively, and the highest value of 11.28 cmol/kg was that of treatment B<sub>0</sub>K<sub>1</sub>S<sub>1</sub>. While at a water stress level of 60%, the treatments gave the lowest values between 8.28-8.81 cmol/kg. According to the results, it can be said that the spraying treatments with nanoscale kaolinite were not unique in recording the highest values, except for the calcium content in the treatment B<sub>0</sub>K<sub>2</sub>S<sub>0</sub>. In contrast to the kaolinite treatment, which assumed the highest role in most of the values at the water stress levels under study. It is evident from this that the contribution of nano that gain density of kaolinite from negative charges because the main source of them in this mineral are the processes of grinding and breaking of crystalline edges (Eggleton and Aspandiar, 2007). The smaller the granular size, the higher the specific surface area (AL-Wotaiyf, 2019). Thus, the adhesion and interaction of the clay mineral with the plant parts increases, which can be invested in the opportunity to absorb the elements in the mineral composition, as well as the mechanism of resisting water stress that can stimulate the plant to absorb the elements, especially that relates to the mechanism of counteracting the craving through what the nanoparticles have facilitated in the speed of response. As a result, the propulsion and transfer of nutrients from the vegetative parts to the reproductive became used in the building processes, and the energy needed in more biological and physiological processes. To agree with what was shown by Muhammad (2002) that most of the absorbed elements turn into non-free organic compounds, as a result of the increase in metabolic processes in plants, and their investment in the structural construction of the components of the kernels. Calcium is by nature known to slow movement inside the plant, so its content in the dry matter of the leaves became high in spite of the clay mineral nanoparticles. What confirms the properties acquired by kaolinite due to its nano scale, it is the accumulation of the remaining macronutrients in the dry matter of the leaves at the kaolinite treatments under the percentage of the three levels of water stress, especially sulfur, which gave the highest values among the macronutrients at the water stress level of 90%, especially when in the treatment B<sub>3</sub>K<sub>1</sub>S<sub>1</sub>. The dry matter content of leaves may play a role in regular water stress, but the lack of water at the aforementioned level has led to its failure to be pushed from storage sites to energy production sources. The severity of plant exposure to water stress can confuse the activity of the biological and physiological activities that the plant exercises, and disturb the process of optimal utilization of this nutrient in the construction and composition of what is related

to the compounds of metabolism. This coincided with the weakening of the usual role of kaolinite, and the decrease in the significance of the vegetative and reproductive parts in connection to their functions normally. As for the high potassium content, perhaps because it does not enter cellular compounds and plant tissues, but is responsible for transporting nutrients from outside and into cells, and distributing them among plant tissues. According to Jablonska (1990), the absorbed phosphorus is transformed into organic phosphorous for building cellular and kernel tissues. The dry matter content of the leaves of the macronutrients and micronutrients were within the limits or levels that were added to the plant except for iron was higher than these limits. Likewise, the toxicity limit is greater than 500 mg/kg mentioned by Ryan *et al.*, (2013), as a result of the high iron content of the nano-kaolinite treatment.

**Table (6): The effect of spraying treatments with normal and nano kaolinite solution, and nano fertilizer on Leaves content of nutrients at different levels of water stress.**

Treatments	Macronutrients (Cnimol/kg)				Micronutrients (mg/kg)					
	Ca	S	P	Mg	Ca	Mo	Mn	Cu	Zn	Fe
B <sub>0</sub> K <sub>0</sub> S <sub>0</sub>	9.42	8.03	3.29	5.50	9.42	0.00	000	33.62	38.32	430
B <sub>0</sub> K <sub>0</sub> S <sub>1</sub>	10.62	10.37	4.70	7.95	10.62	0.00	210	23.98	68.26	640
B <sub>0</sub> K <sub>1</sub> S <sub>0</sub>	11.40	8.00	5.51	8.16	11.40	0.00	140	29.59	48.78	920
B <sub>0</sub> K <sub>1</sub> S <sub>1</sub>	7.92	8.65	5.48	6.25	7.92	0.00	130	0.00	45.60	610
B <sub>0</sub> K <sub>2</sub> S <sub>0</sub>	12.47	8.31	3.93	10.91	12.47	0.00	180	0.00	36.09	2180
B <sub>0</sub> K <sub>2</sub> S <sub>1</sub>	12.35	9.50	3.70	10.29	12.35	0.00	240	0.00	73.59	910
B <sub>1</sub> K <sub>0</sub> S <sub>0</sub>	10.10	8.59	3.48	9.75	10.10	74.77	200	0.00	0.00	970
B <sub>1</sub> K <sub>0</sub> S <sub>1</sub>	10.55	10.06	5.67	8.62	10.55	0.00	170	0.00	49.34	590
B <sub>1</sub> K <sub>1</sub> S <sub>0</sub>	10.60	11.28	3.32	8.12	10.60	0.00	170	0.00	37.99	670
B <sub>1</sub> K <sub>1</sub> S <sub>1</sub>	12.40	10.09	4.09	11.75	12.40	120.00	250	34.41	92.34	820
B <sub>1</sub> K <sub>2</sub> S <sub>0</sub>	10.4	9.62	3.77	8.54	10.4	0.00	160	23.98	0.00	570
B <sub>1</sub> K <sub>2</sub> S <sub>1</sub>	9.85	8.62	3.45	7.66	9.85	0.00	210	28.00	130.00	1240
B <sub>2</sub> K <sub>0</sub> S <sub>0</sub>	10.77	9.93	4.67	10.25	10.77	0.00	180	0.00	40.48	820
B <sub>2</sub> K <sub>0</sub> S <sub>1</sub>	7.95	8.28	5.35	6.83	7.95	80.97	140	0.00	80.96	460
B <sub>2</sub> K <sub>1</sub> S <sub>0</sub>	9.10	10.65	7.00	9.41	9.10	90.53	200	0.00	56.89	720
B <sub>2</sub> K <sub>1</sub> S <sub>1</sub>	7.20	8.81	4.58	7.29	7.20	0.00	170	0.00	48.37	670
B <sub>2</sub> K <sub>2</sub> S <sub>0</sub>	9.47	8.78	2.96	8.29	9.47	0.00	170	0.00	0.00	2080
B <sub>2</sub> K <sub>2</sub> S <sub>1</sub>	8.85	8.81	3.96	6.79	8.85	0.00	150	0.00	75.57	490
B <sub>3</sub> K <sub>0</sub> S <sub>0</sub>	11.97	9.93	3.22	10.50	11.97	0.00	190	0.00	38.42	790
B <sub>3</sub> K <sub>0</sub> S <sub>1</sub>	1.10	8.50	5.16	8.87	1.10	0.00	170	0.00	0.00	930
B <sub>3</sub> K <sub>1</sub> S <sub>0</sub>	9.97	9.31	4.38	8.04	9.97	0.00	160	0.00	0.00	640
B <sub>3</sub> K <sub>1</sub> S <sub>1</sub>	7.92	12.00	5.12	7.791	7.92	99.97	140	0.00	51.88	720
B <sub>3</sub> K <sub>2</sub> S <sub>0</sub>	7.80	7.28	4.38	6.37	7.80	0.00	140	34.19	0.00	700
B <sub>3</sub> K <sub>2</sub> S <sub>1</sub>	9.52	5.09	5.25	8.91	9.52	0.00	130	0.00	37.15	1860

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