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Test of Nano-Fertilizer and Different Irrigation Intervals on Growth and Yield of Maize *Zea mays* L.

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Abstract. The experiment was conducted in the autumn season (2020 AD) using the (RCBD) design and with three replications, in which the first factor tested the NPK nano fertilizer neutral consisting of four levels (N1, N2, N3, N4) (0,75,150,225) PPM sequentially, the NPK was equidistant, added twice the first with The seeds when planting. The second sprayed after a month of planting. The second factor uses different irrigation intervals consisting of three (F1, F2, F3) (4,6,8) days. The results of the experiment showed that the nano-fertilizer was significantly superior to Treatment N3 in all studied growth traits and yield, to give it the highest rate of traits: plant height, number of leaves, chlorophyll content, number of rows/horn, the weight of 500 grains, total dry matter yield, total grain yield per unit area, which amounted to (212.48 cm) , (14.04), (51.11), (13.51 row/cob), (136.83 g), (10.32 tons/ha) and (22.92 tons/ha) according to the order. As for the irrigation intervals, the irrigation interval was distinguished (F1) and was significantly superior to the other irrigation intervals, except for the irrigation interval F2, which was distinguished in the height of the plant to give it the highest rate (203.95 cm). The interaction was significant for nano fertilizer and irrigation intervals, where the two combinations of N3F1, N3F2 recorded the highest values for plant height (234.14, 234.23 cm), number of leaves (15.13, 15.00 leaves/plant), chlorophyll content (55.31, 55.99 cci), number of rows on the cob (14.26, 14). 13. row/cob), weight of 500 grains (143.62, 143.60 g), total grain yield (11.85, 11.79 ton/ha) and dry matter yield (25.76, 25.63 ton/ha) in order and without significant difference between them for the above traits.

Keywords: nano-fertilizer, irrigation separators, nutrients, maize.

Introduction

Maize (*Zea mays* L), which belongs to the grass family (Stuessy, 2009), has high production capabilities and is one of the crops with high productivity and has significant economic importance. The efficiency of crops in absorbing production sources of light, nutrients, and water (Awika, 2011) and its leaves contribute to the manufacture of paper and extract the best types of oil and starch from its grain, as the vegetative parts and seeds are used as concentrated feed because they contain 2% ash, 4.6% oils, 10.6% proteins, 81% carbohydrates, and vitamins B1, F and B2 (Al-Nasrawi, 2015). Its productivity for 2019 in Iraq is estimated at 473.1 thousand tons / ha, with a cultivated area of 515.2 thousand acres (Central Statistics Organization, 2020). In general, agriculture in the world, and Iraq in particular, faces many challenges, including water scarcity and climate change. Everyone must manage or schedule irrigation, understand the water balance of the soil, and estimate the amount present in the root zone at any given time. Agriculture in the world in general and in Iraq in particular faces many challenges, including water scarcity and climate change. Everyone must manage or schedule irrigation, understand the water balance of the soil, and estimate the amount actually present in the root zone at any given time. Crop production decreases in arid and semi-arid areas and the reason is Water deficiency at all stages of plant growth (Harrison *et al*., 2014), one of the challenges is to increase consumption of agricultural products by increasing the world's population in 2050 to reach 9 billion people (FAO, 2012). This requires the advancement of agricultural development to achieve the best economic and agricultural stability. Hence, it is necessary to face these challenges. In recent years,

scientists have invented nanotechnology fertilizer, the science of atoms and molecules, applying theoretical concepts, and studying nanoparticles. There is much research on using this modern technology in the agricultural field under the name of Agro-nanotechnology to treat plant problems and improve its qualities (Abo batta, 2016). Nano is used to feed and transport compounds to all places needed by the plant. This increases the activity of the photosynthesis process by increasing the percentage of leaf chlorophyll (Lin *et al*., 2014). Among the countries that have employed nanotechnology in agriculture, manufacturing and processing food products, America, Japan, and China are the world's largest leaders (Mongillo, 2007). Due to the lack of scientific research on nano-fertilizer and irrigation separators on maize, this research was applied, which aims to:

1- Rationing irrigation water based on increasing irrigation intervals and their effect on maize and the efficiency of its use.

2- Knowing the effect of modern technology (Nanotechnology NPK) on the characteristics of yellow corn.

3-Studying the interaction between irrigation intervals and NPK nano fertilizer and its effect on the yield.

Materials and Methods

This research was applied in the fall season (2020 AD). In Salah Al-Din Governorate/Al-Sharqat District/Al-Hakna Village, the left coast of Al-Sharqat, the American variety 5060 DKC was used in this research. First, the fallow land was ploughed perpendicularly with the inverted plough. Next, the land was smoothed and broken up and levelled with the rivet, then the milling according to the distance (0.75) m between one farm and another, and the land was cultivated on 7/18/2020. This study was applied using the two-factor design (RCBD) with two factors. The first factor, four levels of nano NPK fertilizer (N1, N2, N3, N4). The following concentrations were used (0, 75 PPM, 150 PPM and 225 PPM) In order, the NPK ratio was equal, the fertilizer was used twice, the first being treated with seeds when planting and the second spray (one month after the planting date). In the early morning to increase absorption efficiency and avoid extreme heat. As for the second factor, there are three levels of irrigation intervals, F1, F2, F3 (4 days, six days and eight days) in order, and with three replications, each iterator contains 12 harmonic factor treatments. The experimental unit contained (4) spikes with a length of (3) m, and the distance between the spikes and units was (0.75) m, and between replicates (2) m and (9) m^2, the area of the experimental units was planted, (3) seeds were planted. For each hole and the distance between plants (20) cm. The data of growth characteristics and yield components were recorded to take ten plants as a sample randomly from the middle roses to study the following traits:

1- Plant height (cm).

2- Number of leaves/plant.

3- Chlorophyll content CCI: measured by Opti-science device.

4- Number of rows/cob.

5- Weighing 500 grains/gm: 500 grains were taken randomly from ten plants per experimental unit, and their weight was measured with a sensitive scale at 15.5% humidity (Al-Sahuki, 1990).

6-Grain yield per unit area (tons/ha): the harvest of the middle roses of the experimental unit and then discarding its grains, adding to it the grains of the ten plants that were previously taken, then calculating the yield for all plants and converting it to tons/ha at a humidity of 15.5% (Al-Sahuki, 1990).

7- Dry yield (tons/ha): Calculated for all the weights of the dry yield, stalks, leaves, and stems.

Table 1. shows the analysis of variance for the studied traits.

		Mean squares of deviations (MS)						
Sources of difference	Df	plant height	number of leaves	Chlorophyll content	Number of cob/rows	Weight 500 grain	grain yield	Dry yield
Replicators	2	9.532	**0.563	**7.206	**0.217	**5.732	0.371	**0.127
Nano Fertilizer-A	3	**2785.467	**7.974	**328.174	**2.176	223.564	**12.231	**36.199
Irrigation dividers-B	2	**5392.791	**21.260	**421.211	**15.267	950.617	**45.534	**114.35
Overlap AB	6	**631.220	**1.085	**16.396	**0.364	27.47	**1.188	**6.958
Error	22	26.411	0.212	6.533	0.151	8.275	0.770	0.193
Total	35							

**Moral at 1%

Results and discussion

1- Plant height (cm): The results of Table (2) indicated that there was a significant difference in the height of the plant when the nano fertilizer, as

the level N3 was distinguished over the rest of the levels by giving it an average of (212.48 cm) and the plant rose by (25.31%) compared to N1, which is the lowest height of the plant It reached (169.55 cm), and the results indicate that the F2 level of the irrigation intervals was significantly distinguished over the rest of the other irrigation intervals by giving it the highest height (203.95 cm) and an increase of (22.80%) compared to the average F3 level, which is the lowest height of (166.07 cm). The frequent excess irrigation leads to the decomposition and removal of nutrients in the rhizosphere and ultimately weakening soil fertility (Karajeh *et al.,* 2000). The table shows the significant interaction between the nano fertilizer and the combinations of irrigation spacers. As the two combinations, N3F1 and N3F2, were characterized by giving them the highest height (234.14 and 223.23 cm) and an increase of (43.83 and 43.89%) according to the order compared to the combination N1F3 (162.78 cm). This is the lowest height for the trait. This is due to this nano-fertilizer that provides friendly nutrients to the crop throughout its growth period and increases growth. This nano-fertilizer prevents the plant stem cell from biotic and abiotic stresses. Hence, photosynthesis activity increases and its products flow towards the stem cell, leading to division and elongation and positively reflecting on the stem. These results are consistent with (Al-Quraishi, 2017) when nano fertilizer is applied to maize.

Table 2. Effect of nano fertilizer and irrigation intervals and their interaction on plant height (cm).

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	175.20 e	170.66 F	162.78 h	169.55 d
N2	188.65 d	209.45 B	166.81 g	188.30 c
N3	234.14 a	234.23 A	169.07 f	212.48 a
N4	208.07 b	201.46 C	165.64 g	191.72 b
Irrigation breaks	201.51 b	203.95 A	166.07 c	190.51

Similar numbers do not have a significant difference between them at 5%

2- Number of leaves/plant: It was clear from Table (3) that the N3 level of nano fertilizer with significant superiority recorded the highest value of (14.04) and with a leaf increase rate of (19.38%) compared to the N1 level, which recorded the number of leaves at a low level of (11.76), and in In the same table, the irrigation interval F1 was significantly superior to F2, F3 by giving an average of leaves of (13.95) and an increase of (22.26%) of leaves compared to F3, as its average of leaves was (11.41), while the interaction was significant for nano fertilizer and irrigation intervals in the characteristic of the number of leaves The two combinations N3F1 and N3F2 were distinguished by giving them an average of (15.13 and 15.00) and an increase of (37.45 and 36.36%) of leaves, respectively, compared to the combination N2F3 (10.93), which is the lowest average of leaves. The reason is the direct role of nano-nutrients (NPK) in stimulating growth buds, then revealing and dividing the leaf cell, expanding and prolonging the duration of its stay green, which increased the leaf area and thus activated the net representation (NAR) and the speed of the flow of its products, which prompted the stem cell to divide and elongate to get the highest stem. Table (2) All this was reflected positively by the increase in the number of papers. Here, nanotechnology lies in the slower nitrogen decomposition process, i.e. slow decomposition, which lasts for a longer period (Ali and Al-Gawthry, 2019).

Table 3. Effect of nano fertilizer and irrigation intervals and their interaction on the number of leaves/plant.

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	12.33 e	11.96 f	11.00 h	11.76 d
N2	13.73 c	13.60 c	10.93 h	12.75 c
N3	15.13 a	15.00 a	12.00 F	14.04 a
N4	14.60 b	13.00 d	11.73 G	13.11 b
Irrigation breaks	13.95 a	13.39 b	11.41 C	12.91

Similar numbers do not have a significant difference between them at 5%

3- Chlorophyll content CCI: The results shown in Table (4) showed that the nano fertilizer had a significant difference in the chlorophyll content, as the N3 level was distinguished by giving it the highest content of 51.11 and an increase of (37.65%) compared to the N1 level, which recorded a low level of chlorophyll content amounted to (37.13), the levels of irrigation intervals significantly affected the increase of chlorophyll, as the level F1 was significantly distinguished over the rest of the other irrigation intervals by giving it the highest chlorophyll (49.32) and an increase of (28.97%) of leaf chlorophyll compared to F3. As for the interaction, it was significant for nano fertilizer and irrigation intervals for chlorophyll, where the two combinations N3F1 and N3F2 were characterized by giving them an average of (55.31 and 55.99) and an increase of (72.01 and 69.92%) of the

chlorophyll content, respectively, compared to the combination N1F3 by giving it the lowest chlorophyll amounted to (32.55). The main reason for the increase in chlorophyll is the increase in leaves (Table 3). In addition to the increase of nutrients by the nano fertilizer, especially nitrogen in the leaves, this is essential for forming chlorophyll pigments, which was reported (Lee and Tollenaar, 2007). The nitrogen will go to young leaves quickly because it is a mobile element and thus increases the chlorophyll content; the chlorophyll of leaves decreases when the concentration of nitrogen decreases. This leads to the destruction and ageing of the leaves (Thomas and Smart, 1993).

Table 4. Effect of nano fertilizer and irrigation intervals and the interaction between them on the CCI content of chlorophyll.

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	42.15 e	37.23 g	32.55 H	37.13 d
N2	46.29 d	45.82 d	39.32 C	43.81 c
N3	55.31 a	55.99 a	42.04 E	51.11 a
N4	53.54 b	50.66 c	39.61 F	47.94 b
Irrigation breaks	49.32 a	47.42 b	38.24 C	44.99

Similar numbers do not have a significant difference between them at 5%

4-Number of ear rows: The results of Table (5) indicate that the fertilization was significant at the N3 level and outperformed all levels and gave the highest The value of (13.51 row/cob) with an increased rate of (9.21%) compared to N1 of non-fertilization, which gave the lowest rate (12.37 row/cob), and it is noted from the table that there is a significant effect of the levels of irrigation intervals, as F1 outperformed the rest of the levels to give it the highest rate (13.58). row/cob), and the trait increased (17.98%) compared to F3. While the interaction was significant between the mixtures of irrigation spacers and nano fertilizer in the same trait, two combinations of N3F2 and N3F1 that do not differ significantly between each other achieved the average (14.26 and 14.13 rows/cob) in order and significantly outperformed the other combinations. This is because the nano fertilizer and irrigation intervals (4 and 6) days encouraged the plant to absorb the nutrients and water it needs ultimately, thus improving the growth stages. Its output is to places of decay, development, and the emergence of parts, which is reflected positively to increase the consistent characteristic (Al-Jubouri, 2010). Moreover, the results of irrigation intervals every six days are consistent with the results obtained by researchers when regulating the amount of irrigation given to the crop, i.e. reducing the number of irrigations; this leads to an increase in the efficiency of water use by the crop (Al Dulaimi *et al.,* 2015).

Table 5. Effect of nano fertilizer and irrigation intervals and their interaction on the number of rows/cob characteristics.

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	12.86 d	12.60 E	11.66 G	12.37 d
N2	13.66 b	13.33 C	11.26 H	12.75 b
N3	14.26 a	14.13 A	12.13 F	13.51 a
N4	13.53 b	13.26 C	11.00 I	12.60 c
Irrigation breaks	13.58 a	13.33 B	11.51 c	12.8

Similar numbers do not have a significant difference between them at 5%

5-Weight of 500 grams of grain: This characteristic is one of the main yield components of yellow corn, as it indicates the dry matter in the grain, which reflects the efficiency of Source and Sink and is closely related to photosynthesis, and the fullness of its seeds is also related to the leaf area, which pushed the weight of the grain to depend on the growth inputs, The reason for this is because the grain weights are the result of the influences of genetics with the environment (Al-Alousi , Al-Sahuki, 2007). Table (6) shows a significant difference in the levels of nano fertilizer among them, as N3 achieved the highest rate (136.83 gm) for the weight of 500 grains, with an increase of (9.39%) compared to the comparison N1 with an average of (124.67 gm). The irrigation intervals achieved in the above characteristic Significant differences, as F1 gave the highest rate of (136.71 gm) and an increase of (13.17%) compared to F3. This comparison gave the lowest value (120.80 gm). The interaction of nano fertilizer and irrigation intervals showed a significant difference in the characteristic of 500 grains. We note that the two interference combinations N3F2 and N3F1 were significantly superior to the other combinations. There was no significant difference between them to give them the highest rate (143.62 and 143.60 gm). The trait increased (20.49% and 20.47%) according to the order compared to the comparison combination N1F3, which gave the lowest value (119.19 gm). This is due to the increase in Table (4) and the

combined effect of irrigation intervals and nano-fertilizer in activating the photosynthesis process in the stage of grain emergence and fullness. This was positively reflected in the increase in the flow of photosynthetic products to the downstream (seeds); this was confirmed by (Joseph, Morrisson, 2006). The plant absorbs nutrients with high efficiency whenever its small size is much less than a hundred nanometers, and these fertilizers the smaller their size. The more effective they are in water solubility and thus activate photosynthesis and increase its products, the results were similar to the results (Kumar *et al*., 2014; Jhanzab *et al*., 2015; Auwal *et al*. 2017).

Table 6. The effect of nano-fertilizer and irrigation intervals and their interaction on the characteristic of 500 grains (gm).

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	128.86 d	125.95 e	119.19 h	124.67 c
N2	137.19 b	137.03 cb	120.67 g	131.63 b
N3	143.62 a	143.60 a	123.27 f	136.83 a
N4	137.20 b	136.10 c	120.08 hg	131.13 b
Irrigation breaks	136.71 a	135.67 b	120.80 c	131.06

Similar numbers do not have a significant difference between them at 5%

6-Grain yield per unit area (tons/ha): As shown in Table (7) that nano fertilizer had a significant effect on grain yield, as the N3 level achieved the highest rate of (10.32 tons/ha) with an increase rate of (35.43%) compared to At the N1 level, which gave the lowest rate (7.62 tons / ha), and it was shown from the table that the irrigation intervals had a significant difference between them, as the F1 level recorded the highest rate of (9.94 tons / ha) and an increase in the characteristic of the yield amounted to (55.07%) compared to the F3 level, where it gave The lowest value (6.53 tons/ha), and it is noted from the table that there is a significant agreement between nano fertilizer and irrigation separators, as the two interference combinations N3F1 and N3F2 were significantly superior to the other combinations and there was no significant difference between them to give them the highest rate (11.85 and 11.79 tons/ha) with a percentage An increase of (89.90% and 88.94%), respectively, compared to the mixture N1F3, which gave the lowest yield of (6.24 tons/ha). The increase in yield is mainly due to the increase in the weight of 500 grains. Table (6) and the weight of the seeds thus indicate the activity of photosynthesis and the flow of its products to fill (downstream) the developing seeds instead of turning them into elongation and division of stem cells (Sahuki, 2006).

Table 7. The effect of nano fertilizer and irrigation intervals and their interaction on the total grain yield per unit area (tons/ha) characteristic.

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	8.36 e	8.27 e	6.24 g	7.62 c
N2	9.50 c	9.24 cd	6.28 g	8.34 b
N3	11.85 a	11.79 a	7.34 f	10.32 a
N4	10.04 b	9.09 d	6.30 g	8.47 b
Irrigation breaks	9.94 a	9.59 b	6.53 c	8.68

Similar numbers do not have a significant difference between them at 5%

7- Dry yield ton/ha: The results of Table (8) indicated that nano fertilizer had a significant effect on this trait. Where the N3 level gave the highest rate of (22.92 tons/ha) and an increase of (27.12%) compared to the N1 level, which gave the lowest rate (18.03 tons/ha), the results of the table indicate a significant effect of the levels of irrigation intervals in the above characteristic, as F1 gave the highest rate of (22.88 tons/ha) and an increase of (33.80%) compared to the comparison F3, which gave the lowest value (17.10 tons/ha). It is noted from the results. There is a significant agreement between the nano fertilizer and the irrigation separators, as the interaction combinations, N3F1 and N3F2, were significantly superior to the other combinations. There was no significant difference between them to give them the highest rate (25.76 and 25.63 tons/ha) with an increased rate of (55.27% and 54.44%) respectively, compared to with the combination N1F3, which gave the lowest yield of (16.59 tons/ha). The nano-fertilizer and irrigation intervals (4 and 6) encouraged the plant to fully absorb the nutrients and water it needs, thus improving the growth stages. Its outputs are in places of decay, development and emergence of leaves and stem in Tables (2 and 3). This is reflected positively to increase the character and is consistent with (Al-Jubouri, 2010). The lack of yield at the F3 irrigation interval led to an increase in the spacing between the irrigations. Thus, the depletion of soil moisture permanently, which exposed the crop to water tension. This is reflected in the process of cell division and expansion. Indeed, the expansion and elongation

of the leaves would decrease, and then the area of photosynthesis and the flow of its products between the parts of the crop. The water is later than the date of male and female flowering due to the death or lack of vitality of pollen grains, which affected the process of pollination and fertilization and the reduction of rows and length of the ear, which reduced the number of grains and decreased yield. This was confirmed by (Al-Mu'ini, Nahba, 2007) that the lack of water in the vegetative stage reduces the yield from 15-25%, but in the early reproductive stage (before the appearance of the silken) it may reduce the yield by 50%, and the lack of water after setting the grains, i.e. the late reproductive stage, will be reduced by 50%. 25% of the grain yield. The researchers' studies also indicate that water stress significantly reduced the yield of maize grains (Song *et al*. 2019), and therefore the management of plant nutrients under drought stress conditions is one of the important issues in increasing plant production (Mohommadkhani, Roozbehani, 2015).

Table 8. Effect of nano fertilizer and irrigation intervals and the interaction between them on the characteristic of the total yield of dry matter (tons/ha).

Treatment	Overlap of nano fertilizer and irrigation separators			Effect nano Fertilizer
	F1	F2	F3	
N1	19.83 d	17.67 e	16.59 h	18.03 d
N2	22.83 b	22.22 c	17.12 g	20.72 c
N3	25.76 a	25.63 a	17.38 f	22.92 a
N4	22.92 b	22.29 c	17.30 f	20.84 b
Irrigation breaks	22.88 a	21.90 b	17.10 c	20.63

Similar numbers do not have a significant difference betweenthemat5%

Conclusions

1- Spraying the maize crop with NPK nano fertilizer at a concentration of 150 ppm improved the growth and yield characteristics.
2- Maize bears stress conditions for a period of 6 days when sprayed with a concentration of 150 ppm neutral nano fertilizer.
3- The combinations of N3F1, N3F2 gave the best result for all study characteristics.

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