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Spraying with nano-moringa leaf extract affects growth and yields four maize varieties

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Abstract

A field experiment was carried out in the spring agricultural season of 2023 at Ibn Al-Bitar Vocational Preparatory School in the Al-Husseiniyah area in the Holy Karbala Governorate, to study the effect of spraying nano-moringa leaf extract on the growth characteristics and yield of four maize varieties. The split-block experiment was carried out in a randomized complete block design (RCBD) with three replications. The main plots included of four concentrations of nano-moringa leaf extract (0, 200, 400, and 600 mg L^{-1}) sprayed every two weeks until physiological maturity. The subplots included four varieties of maize (NadH9055, NadH362, NadH386, and NadH315). The results showed that spraying with nano Moringa leaf extract at a concentration of 400 and 600 mg L^{-1} caused a significant increase in the number of days up to 50% tasseling, number of days up to 50% silking, leaf area, leaf area index, number of grains per row, weight of 500 grains, and grain yield, which gave averages of (74.08 and 74.08 day), (80.42 and 80.75 day), (4643.42 and 4662.81 cm^2), (2.48 and 2.49), (28.02 and 30.15 grains row^{-1}), (117.17 and 117.58 g), (5.06 and 5.41 Mg ha^{-1}). The results also showed the superiority of the NadH9055and NadH362 varieties in the number of days up to 50% tasseling, number of days until 50% silking, and number of grains per row gave averages of (66.33 and 67.00 days), (68.75 and 70.50 days), and (31.02 and 32.31 grains per row^{-1}) compared to the rest of the varieties. As for grain yield, the NadH362 variety excelled with an average of (6.39 Mg ha^{-1}) for the rest of the varieties. While the NadH315 variety outperformed in leaf area, leaf area index, and weight of 500 grains, , it gave averages of (5409.08 cm^2), (2.88), and (136.42 g) In light of the results presented, it is clear the importance of spraying nano-moringa leaf extract in improving the growth characteristics of maize, which was reflected positively in increasing the yield of four varieties of maize.

Keywords: Grain Yield, Plant Extract, Nano, Maize.

Introduction

Maize is one of the basic cereal crops due to its multiple uses in the field of human and animal nutrition, as it comes after wheat and rice in terms of area and production [1] The economic importance of the Maize crop can be attributed to the fact that its grains contain high percentages of carbohydrates (81%), protein (10.6%), oil (4.6%), and ash (2%), as well as vitamins B1, B2, and E [2,3] However, farmers in Iraq suffer from a decline in Maize productivity compared to other countries of the world, as it is 40% lower than in developed countries. This decline comes from the lack of screening of good genetic compositions, in addition to the lack of interest in spraying nutrients. The interest in foliar nutrition through environmentally friendly compounds, such as moringa leaf extract, is characterized by containing the nutrients that the plant needs, such as N, P, K, and many other elements and growth regulators that work to increase Maize yield [4,5]. [6] showed that spraying the Maize crop every two weeks with moringa leaf extract caused a significant increase in leaf area (526.49 cm^2) and plant height (122.28 cm), superior to the water spraying treatment, which gave averages of 458.34 cm^2. and 119.44 cm, respectively, while spraying with moringa leaf extract had no significant effect on the number of leaves in the plant and the concentration of chlorophyll b, while spraying with moringa leaf extract caused a significant decrease in the content of chlorophyll a and the concentration of carotenoids in the leaves, with a decrease rate of 14.22% and 16.18%, respectively. About the comparative treatment. The results of several studies have shown that moringa extract has a role in improving yield and its components. The results of the study by [7] showed that spraying with moringa leaf extract (80% ethanol) every two weeks (from germination until physiological maturity) caused a significant increase in Maize yield, as it gave an average of 12.8 tons ha^{-1}, superior to the spraying treatment with water only. Which gave an average of 5.6 tons ha^{-1}. [8]showed that spraying the Maize crop with moringa leaf extract (at the silk emergence stage and the seed filling stage) caused a significant increase in the number of grains in the row (41.33 grains row^{-1}), the weight of 1000 grains (280.27 g), and the grain yield (6.21 tons ha^{-1}) and the biological yield (14.61 tons ha^{-1}), superior to the water-only spraying treatment, which gave averages of the number of grains per row (34.60 grains row^{-1}), the weight of 1000 grains (264.34 g), and the grain yield (4.82 tons ha^{-1}) and the biological yield (12.75 tons ha^{-1}). The period of vegetative growth is often reflected positively in increasing the yield per unit area. A high grain yield is the goal that the producer wants to achieve, and this yield is the result of a number of components that interact with each other to produce the yield, and that these components differ depending on the varieties, [9] after applying a field experiment on the Maize plant, which included the use of five genotypes: Ghouta 82, Ghouta 26, Salmonella, and Research 9106 and 5018, genotype gave Ghouta 82 the highest number of grains in rows of 16 rows cob^{-1}, while Ghouta 82 outperformed it by giving The highest number of grains in the grade was 45.08 grains row^{-1}, while the genotype 5018 recorded the lowest number of

grains (25.73 grains row^{-1}), the salmonid genotype excelled by giving it the highest weight of 1000 grains and grain yield with averages of 318 g and 11 tons ha^{-1}, respectively, while genotype 5018 achieved the lowest grain weight of 266 g, while genotype Ghouta 82 gave the lowest grain yield with an average of 6 tons ha^{-1}. Therefore, the study aimed to determine the effect of different concentrations of nano Moringa leaf extract on some growth characteristics and yield of four Maize varieties.

Materials and Methods

A field experiment was carried out in the spring agricultural season 2023 on 17/3/2023 in Ibn Al-Bitar Vocational Preparatory School in the Al-Husseiniyah area in the Holy Karbala Governorate, within longitude 32 and latitude 44. The area of the experimental unit was 3 m^2, leaving 1m^2 of space between the replicates and leaving 1m^2 between the experimental units. The plant density reached 53,333 plants he^{-1}. to study the effect of spraying nano-mortaring moringa leaf extract on some growth characteristics and yield of four varieties of Maize. The split-block experiment was carried out in a randomized complete block design (RCBD) with three replications. The main plots included four concentrations of nano-moringa leaf extract (0, 200, 400, and 600 mg L^{-1}) sprayed every two weeks until physiological maturity, During this time, the nano Moringa leaf extract was prepared following the following steps described previously [10]. The subplots included four varieties of maize (NadH9055, NadH362, NadH386, and NadH315).

Understudied traits

Days from planting to 50% tasseling (Day): The duration from planting (first watering) to 50% tasseling was determined.

Days from planting to 50% silking (Day): The duration from planting (first watering) to 50% silking was determined.

Leaf area (cm^2): It was calculated from the average of five plants according to the following equation:

$$Leaf\ area = Leaf\ length\ below\ ear\ (squared)\ \times 0.75$$

Leaf area index: It was calculated according to the following equation:

$$\textbf{Leaf area index} = \frac{\boldsymbol{Leaf\ area}}{Area\ per\ plant} \times 100$$

Number of grains per row (grain row^{-1}): anually count the number of grains in the row

Weight of 500 tablets (g): 500 seeds were counted from each sample taken from five plants harvested from each experimental unit and weighed with a sensitive balance.

Grain yield (Mg ha^{-1}): The total grain yield was calculated from the average weight of the yield of one plant, taken as an average of five plants harvested from each experimental unit, multiplied by the plant density.

statistical analysis

The data were analyzed statistically for all studied traits, according to the least significant difference (LSD) test, at a probability level of 0.05. The Gene Stat statistical program was used to conduct the statistical analysis.

Results and Discussion

Days to 50% tasselling (Day)

The results of Table 1 showed that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in the number of days from planting up to 50% tasseling, as they gave averages of 74.08 and 74.08 days, respectively, compared to the spraying treatment with water only, which gave 68.00 days, which did not differ significantly from the concentration of 200 mg L^{-1}. Due to the plant's low water content, high temperatures, and low relative humidity, the number of cultivation days was reduced by up to 50% at concentrations of Moringa nano extract 0 and 200 mg L^{-1}. These factors all contributed to the plant's early flowering, or its capacity to complete its life cycle by accelerating essential processes within the plant [11].

The results of Table 1 showed that Maize varieties differ significantly in the number of days until 50% tasseling, as the two varieties NadH386 and NadH315 gave the highest averages for the number of days from planting until 50% tasseling, as they reached 75.50 and 76.83 days, respectively, while the two grades NadH9055 and NadH362 gave the lowest averages. 66.33 and 67.00 days, respectively. The duration of the plant's development period, which is determined by the Stay Green genes, is one of the numerous reasons that may be blamed for this variation in growth period, along with genetics and other factors. Consequently, these genes' expression and function vary depending on the genetic architecture and other parameters that were examined [12].

As for the interaction between the two study factors for this characteristic, the results indicated that there was a significant interaction between the spraying treatments with the extract and the variants, as the concentration of 600 mg L^{-1} with the variety NadH315 gave a higher average in the number of days until 50% tasseling reached 81 days. While the comparison treatment with the NadH9055 variety gave a lower average for this trait, amounting to 63.67 days.

Table (1): effect of nano-moringa leaf extract on four maize varieties' planting to 50% tasseling days.

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	63.67	64.33	72.00	72.00	68.00
200	64.33	65.67	74.00	74.00	69.50

400	**69.67**	**68.33**	**78.00**	**80.33**	**74.08**
600	**67.67**	**69.67**	**78.00**	**81.00**	**74.08**
L.S.D	**2.111**				**1.422**
Average	**66.33**	**67.00**	**75.50**	**76.83**	
L.S.D	**1.013**				

Days to 50% silking (Day)

The results of Table 2 showed that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in the number of days from planting up to 50% silking, as they gave averages of 80.42 and 80.75 days, respectively, compared to the spraying treatment with water only, which gave 68.00. days, which did not differ significantly from the concentration of 200 mg L^{-1}. Increasing the number of days of planting up to 50% silking can be attributed to the availability of sufficient nutrients, which caused the plant's vital processes to slow down and thus increase the duration of its growth and development [13]. This result is consistent with the results of [11].

The results of the same table are shown that Maize varieties differ significantly in the number of days until 50% tasseling, as the NadH315 variety gave the highest average number of days from planting to 50% silking, reaching 88.58 days, while NadH9055, NadH362, and NadH386 gave averages of 68.75, 70.50, and 83. 75 days. The difference between varieties in their growth period may be due to their difference in their ability to effectively manage enzymes and provide the necessary energy in the form of ATP to continue the photosynthesis process, grow leaves, and reduce their aging [14].

The results of Table 2 showed that there was a significant interaction between the spray treatments with Moringa nano extract and Maize varieties in the number of days from planting up to 50% silking. The spray treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1}, when interacted with the NadH315 variety, gave the highest average for this trait. It reached 93.67 days, while the comparison treatment with the NadH9055 variety gave a lower average of 65.67.

Table (2): effect of nano-moringa leaf extract on four maize varieties' planting to 50% silking days.

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	65.67	68.00	81.00	86.00	75.71
200	67.33	68.33	81.00	84.33	75.25
400	72.33	73.33	85.67	90.33	80.42
600	69.67	72.33	87.33	93.67	80.75
L.S.D	2.694				2.091
Average	68.75	70.50	83.75	88.58	
L.S.D	1.169				

Leaf area (cm^2)

The results are shown in Table 3 that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in leaf area, as they gave averages of 4643.81 and 4662.81 cm^2, respectively, compared to the spraying treatment with water only, which gave 4116.91 cm^2. Concentration of 200 mg L^{-1} recorded an average of 4329.41 cm^2. The increase in leaf area when increasing the concentration of Moringa nano extract can be attributed to the role of Moringa extract in promoting growth [15].

The results of Table 3 showed that the Maize varieties differ significantly in leaf area, as the NadH315 variety gave the highest average leaf area per plant, reaching 5409.08 cm^2, while the NadH9055, NadH362, and NadH386 varieties gave averages of 3574.84, 4035.90, and 4732.72 cm^2, respectively. This difference in leaf area is due to genetic factors, as well as to the difference in growth period.

It is evident from the results of Table 3 that there was a significant interaction between spraying treatments with Moringa nano extract and Maize varieties in the leaf area. The spraying treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1} when mixed with the variety NadH315 gave the highest average for this trait, amounting to 5851.20 cm^2. While the comparison treatment with the NadH9055 variety gave a lower average for the same trait, amounting to 3472.60 cm^2.

Table(3):effect of nano-moringa leaf extract on four maize varieties' leaf area (cm^2).

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	3472.60	3647.70	4067.75	5279.60	4116.91
200	3603.83	4049.55	4691.20	4973.04	4329.41
400	3601.79	4401.65	5037.75	5532.50	4643.42
600	3612.15	4044.70	5134.20	5851.20	4662.81
L.S.D	438.158				145.593
Average	3574.84	4035.90	4732.72	5409.08	
L.S.D	244.575				

leaf area index

The results of Table 4 showed that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in the leaf area index, as they gave averages of 2.48 and 2.49, respectively, compared to the spraying treatment with water only, which gave 2.20, while the concentration of 200 mg L^{-1} gave average 2.311. The decrease in area index when lowering the concentration of Moringa nano extract can be attributed to the effect of the morphological growth indicators of the plant, which leads to a lack of available water, which leads to weak growth of plant cells and in turn is reflected in the surface area intercepted by incident solar radiation, the latter of which is an essential part of the process of photosynthesis. This led to a decrease in the leaf area index, which depends on the formation and expansion of cells, and thus a decrease in the leaf area, which directly affects the leaf area index [16].

The results of Table 4 showed that the Maize varieties differed significantly in leaf area index, as the variety NadH315 gave the highest average leaf area index of 2.88, while the varieties NadH9055, NadH362, and NadH386 gave averages of 1.91, 2.51, and 2.52. This difference in the leaf area index is due to the difference. Between varieties in the leaf area of the plant.

The results of Table 4 showed that there was a significant interaction between spraying treatments with Moringa nano extract and Maize varieties in leaf area, and Maize varieties in leaf area index, as the spraying treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1}, when interacted with the NadH315 variety, gave the highest average. For this trait, it was 3.95, while the comparison treatment with the NadH9055 variety gave a lower average for the same trait, which was 1.85.

Table (4): effect of nano-moringa leaf extract on four maize varieties' leaf area index.

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	1.85	1.95	2.17	2.82	2.20
200	1.92	2.16	2.50	2.65	2.31
400	1.92	2.35	2.69	2.95	2.48
600	1.93	2.16	2.74	3.12	2.49
L.S.D	0.234				0.078
Average	1.91	2.15	2.52	2.88	
L.S.D	0.130				

Grains per row (grain row^{-1})

The results are shown in Table 5 that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in the number of grains per row, as they recorded averages of 28.02 and 30.15 grains row^{-1}, respectively, compared to the spraying treatment with water only, which gave an average of 23.79 grains row^{-1}, which did not differ significantly from the concentration of 200 mg L^{-1}. The increase in the number of grains in the row when increasing the concentration of the Moringa nano extract can be attributed to the role of organic extracts in increasing the height of the plant and thus increasing the leaf area and thus obtaining a high photosynthesis process and transporting its products to the downstream. At the same time, the height of the plant reduces the shading of the leaves above the ear, which is reflected in an increase in the rate of pollination and fertilization, and the number of grains increases [17].

The results are shown in Table 5 that the Maize varieties differed significantly in the number of rows in the ear, as the NadH362 and NadH9055 varieties gave the highest average number of grains per row, as the recorded averages reached 32.31 and 31.02 grains row^{-1}, respectively, while the NadH386 and NadH315 varieties gave the lowest averages, amounting to 20.70 and 22.35 grains row^{-1}, in succession. The decrease in the number of grains in a row may be attributed to the long period from emergence until 50% tasseling and silking, which coincided with high temperatures, and this in turn affects the formation of pollen grains with high vitality or leads to the pollen grains stiffening and dying and thus failing. The fertilization process is due to the inability to grow when it falls on the stigmas[18].

The results of Table 5 showed that there was a significant interaction between spraying treatments with Moringa nano extract and Maize varieties in terms of the number of grains per row. The spraying treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1}, when mixed with the variety NadH362, gave the highest average for this trait, amounting to 35.24 grains row^{-1}, while the comparison treatment with the NadH386 variety gave a lower average for the same trait, amounting to 14.51.

Table (5): effect of nano-moringa leaf extract on four maize varieties' grains per row (grain row^{-1}).

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	29.76	27.12	14.51	23.77	23.79
200	32.04	32.52	17.01	16.09	24.42
400	32.21	34.24	23.04	22.47	28.02
600	30.02	35.24	28.25	27.05	30.15
L.S.D	5.229				2.587
Average	31.02	32.31	20.70	22.35	
L.S.D	2.778				

Weight of 500 grains (g)

From the results of Table 6 it is clear that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in the weight of 500 grains, as they gave averages of 117.17 and 117.58 g, respectively, compared to the spraying treatment with water only, which gave an average of 107.16 g, which did not differ significantly. At a concentration of 200 mg L^{-1}, our results are consistent with the results of [19]who found an increase in the weight of grains when applying moringa extract.

The results of Table 6 showed that the Maize varieties differed significantly in the weight of 500 grains, as the NadH315 variety gave the highest average in the 500-grain weight index with an average of 136.42 g, while the NadH9055 variety gave the lowest average of 82.58 g, while the NadH362 and NadH386 varieties recorded averages of 118.50. And 116.33 g, respectively. The increase in the weight of 500 grains in the variety NadH315 may be attributed to the principle of compensation, as the decrease in the number of grains in the ear (Table 5) led to an increase in the weight of the grain, and this is consistent with what was reported [20].

The results of Table 6 showed that there was a significant interaction between spraying treatments with Moringa nano extract and Maize varieties in the weight capacity of 500 grains. The spraying treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1}, when mixed with the variety NadN315, gave the highest average for this trait, amounting to 140.33 g. While the spraying treatment at a concentration of 200 mg L^{-1} with the NadH362 variety gave a lower average for the same characteristic, amounting to 76.33 mg L^{-1}.

Table (6): effect of nano-moringa leaf extract on four maize varieties' Weight of 500 grains (g).

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	78.67	109.67	100.64	139.67	107.16
200	76.33	120.33	117.33	133.67	111.92
400	83.33	124.67	128.67	132.00	117.17
600	90.00	119.33	118.67	140.33	117.58
L.S.D	9.537				5.225
Average	82.58	118.50	116.33	136.42	
L.S.D	4.949				

Grain yield (Mg ha^{-1})

It is evident from the results of Table 7 that spraying Moringa nano extract at two concentrations of 400 and 600 mg L^{-1} caused a significant increase in grain yield, as they gave averages of 5.06 and 5.41 Mg ha^{-1}, respectively, compared to the spraying treatment with water only, which gave an average of 3.63 Mg ha^{-1}, which did not differ significantly from the concentration of 200 mg L^{-1}. The increase in grain yield weight when increasing the concentration of Moringa nano extract at concentrations of 400 and 600 mg L^{-1} can be attributed to its superiority in the number of grains in the row (Table 5), and thus an increase in the number of grains in the ear, which is reflected in the picture as a positive increase in yield[21], and this is consistent with[7] and [21] who found an increase in Maize grain yield when sprayed with moringa extract.

The results of Table 7 showed that the Maize varieties differed significantly in grain yield, with the NadH362 variety giving the highest average, amounting to 6.39 Mg ha^{-1}, while the NadH386 and NadH315 varieties gave the lowest averages, reaching 3.27 and 3.85 Mg ha^{-1}, respectively, while the NadH362 variety gave The average

amounted to 4.62 Mg ha^{-1}. The superiority of the NadH362 variety in grain yield may be attributed to its superiority in the number of grains per row index, which leads to an increase in grain yield, Table 5.

The results of Table 7 showed that there was a significant interaction between the spray treatments with Moringa nano extract and Maize varieties in the grain yield trait. The spray treatment with Moringa nano leaf extract at a concentration of 600 mg L^{-1}, when interacted with the variety NadH362, gave the highest average for this trait, amounting to 7.20 Mg ha^{-1}, while the comparison treatment with the NadH386 variety gave the lowest average, amounting to 1.25 Mg ha^{-1}.

Table (7): effect of nano-moringa leaf extract on four maize varieties' grain yield (Mg ha^{-1})

Nano-Moringa Leaf Extract Concentrations (mg L^{-1})	Maize Varieties				Average
	NadH9055	NadH362	NadH386	NadH315	
0	4.00	5.03	1.25	4.23	3.63
200	4.58	6.37	2.73	2.40	4.02
400	5.08	6.95	3.80	4.40	5.06
600	4.82	7.20	5.28	4.35	5.41
L.S.D	0.583				0.821
Average	4.62	6.39	3.27	4.85	
L.S.D	0.311				

Given the presented results, it is evident how important it is to spray maize with a 600 mg L^{-1} concentration of nano-moringa leaf extract in order to improve its growth characteristics, which in turn positively affected yield. We can advise growing the NadH362 variety of maize and spraying it with 600 mg L^{-1} of Moringa leaf extract, since it was also seen that the maize varieties employed responded differently to the nano-concentrations of Moringa.

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