Plant Archives Vol. 20, Supplement 1, 2020 pp. 335-338 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF SPRAYING DATES AND CONCENTRATIONS WITH NPK NANOPARTICLES ON THE GROWTH AND YIELD OF BEANS (*VICIA FABA* L.)

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Abstract

A field experiment was carried out during the agricultural season 2018/2019, in one of the agricultural fields at Al-Rumaitha district, 25 km north of Al-Muthanna Governorate, to study the effect of dates and concentrations of spraying with NPK nanoparticles on growth and yield of beans, the experiment was applied according to the arrangement of the split-plot, as the spraying times were set at the main plots (branching stage and the beginning of flowering and at 50% flowering), whereas, the concentrations of spraying NPK nanoparticles were placed in the secondary plates (0, 5 and 10 mL^{-1}), using the Randomized Complete Block Design (R.C.B.D) with three replicates. The results showed a significant effect of spray dates, as the second date exceeded the height of the plant, the number of branches and the number of pods per plant and also gave the highest yield of seeds, significant differences when increasing concentrations of NPK nanostructures in the spray solution, the concentration exceeded 10 mL^{-1} in the characteristics of vegetative growth, such as plant height, number of branches and the length of the pod, Interaction between dates and concentrations of spraying with NPK nanoparticles showed a significant increase in total seed yield, the second date, with the highest concentration of fertilizer, gave the highest average seed yield.
***Keywords*:** Spraying, dates, concentrations, NPK nanoparticles, growth, yield, beans (*Vicia faba* L.)

Introduction

Beans (*Vicia faba* L.) is one of the world's important winter food crops for the legume family (Fabaceae), the importance of beans is an important food source because its seeds contain a high percentage of proteins ranging from 28-38%, a good source of vitamins, fiber and mineral elements, as well as containing amino acids and sugary and starchy materials in good proportions, in addition to the carbohydrates seed content, which in some varieties reaches between 40-46% (Khalil *et al.*, 2015). The bean crop, through its important role in stabilizing atmospheric nitrogen, contributes to improving the physical and chemical properties of soils, roots contain root nodes that coexist with the rhizobium bacteria (Abbas, 2012). The cultivated area in Iraq for the bean crop reached 125 thousand hectares with a productivity of 4000 kg/h^{-1} (C.S.O. Iraq, 2016). One of the modern technologies that contribute to improving and increasing agricultural production on a large scale is nanotechnology, which is one of the promising applications in raising production, both in quantity and quality, increases the absorption of water and nutrients, helps to improve plant growth and increase productivity (Al-Ramadi *et al.*, 2016). Nano-applications in agricultural aspects contribute to the resistance of products to different environmental conditions, by increasing the efficiency of fertilizers manufactured with this technology, the low cost of material, reduced the economic cost of crop production (Singh, 2016). Paper feeding is one of the preferred means as it is easy, economical and fast, no soil problems with it, in addition to being positive with nutrients, because there are many problems with some of these elements when adding them to the soil, caused a decrease in plant readiness (Ali *et al.*, 2014). Spraying nutrients on the leaves is a method through which a rapid response is achieved in the plant obtaining its needs, during the growth stages of the nutrients, which were difficult to satisfy by the roots, reflects positively on the quantitative and qualitative quotient, in addition to the possibility of correcting a nutrient deficiency through paper feeding (Allen *et al.*, 2006). An appropriate date for spraying with compost is also an important factor, because it determines the date when the plant will be more efficient and faster response, to be fully equipped with nutrients (Alag, 2015).

The research aims to determine the most appropriate concentration and best time for spraying with NPK nanoparticles, which contributes to improving the growth and yield of the beans crop.

Materials and Methods

A field experiment was carried out during the agricultural season 2018/2019, in one of the agricultural fields at Al-Rumaitha district, 25 km north of Al-Muthanna Governorate, to study the effect of dates and concentrations of spraying with NPK nanoparticles on growth and yield of beans, the experiment was applied according to the arrangement of the split-plot, as the spraying times were set at the main plots (branching stage and the beginning of flowering and at 50% flowering), It is denoted by symbol (D_1, D_2, D_3) in sequence, whereas, the concentrations of spraying NPK nanoparticles were placed in the secondary plates (0,5 and 10 mL^{-1}), It is symbolized (F_0, F_1, F_2) in sequence, using the Randomized Complete Block Design (R.C.B.D) with three replicates.

Soil servicing operations were performed from plowing, smoothing and leveling and then the field section according to the design used, then, the seeds of the beans variety (Luz De Otono) were planted on (10/15/2018) (Al-Tawki, 2015), cultivation was done on a 3-meter-long lines, the distance between one-to-one and another 75 cm and between a hole and another 20 cm, the nitrogen fertilization process was carried out in the form of 46% N urea fertilizer, according to the fertilizer recommendation, the amount of 80 kg N/ha^{-1}, as for phosphorus, it was added before planting with a quantity of 80 kg P_2O_5/ ha^{-1}, in the form of triple superphosphate fertilizer (46% P) (Abedi, 2011). Weeding and irrigation were carried out whenever needed, the NPK nanoparticles produced by the Iranian company (Van Or Seher Parmes), were sprayed, which contains (N% 8, P% 4, and 5% K), the evening spraying was done with a dorsal sprinkler, a diffuser was added to increase the efficiency of the spray solution, to reduce the surface tension of water and to ensure complete wetness of the leaves.

The data were statistically analyzed according to the design used in the statistical program (GenStat), the difference between mean was compared according to the L.S.D test under the probability level of 5% (Al-Rawi and Khalaf Allah, 2000).

Random samples of field soil were taken from different locations from each replicate, mixed together to form a complex sample with a depth of (0-30) cm to represent the experiment field before planting, a group of required physical and chemical analyzes were performed (Table 1.).

Table 1 : Some soil and water irrigation characteristics.

Attribute		Value	Unit
pH		7.4	
E.C.		3.00	Desimines M^{-1}
CEC		22.4	Centimeter (+) kg $^{-1}$
Nitrogen Ready		20	Mg kg $^{-1}$ soil
Phosphorus Ready		7.5	Mg kg $^{-1}$ soil
Potassium ready		170	Mg kg $^{-1}$ soil
Analysis of minute volumes	sand	210	Kg kg $^{-1}$
	gluten	440	
	Clay	350	
Tissue		Silty clay loam	

Results and Discussions

Height of plant (cm)

Table (2) showed that was a significant difference for spraying dates in plant height, surpassed the second deadline (D_2), gave the highest height of the plant reached 80.27 cm, whereas the first date (D_1) gave the lowest average characteristic of this trait to be 68.27 cm, agreed with Zidane (2018).

Increase plant height by increasing NPK nanoparticles in spray solution, the highest concentration, F_2, recorded the highest average characteristic of 78.96 cm, a significant difference from the treatment of not spraying, which gave the lowest average plant height of 69.02 cm,

Perhaps the reason is due to the role of nitrogen in the elongation and division of cells and the activation of many important enzymes in biological processes, likewise, the role of phosphorus in increasing the activity and growth of the root system and increasing its branching, which contributes to the growth of the vegetative system, also, potassium helps plant roots to grow and plays important roles in the growth stages, in addition to its role in activating many important enzymes in carbohydrate metabolism and the transport of manufactured materials, which contributes to increasing the height of the plant, agreed with Al-Hasany *et al.* (2019).

As for the interaction between the dates and concentrations of spraying with NPK nanoparticles, the results did not show significant differences in the height of the plant.

Table 2 : Effect of dates and concentrations of spraying with NPK nanoparticles and their interaction on plant height (cm).

Mean / F	D			D / F
	D_3	D_2	D_1	
69.02	68.33	75.07	63.67	**F_0**
72.78	72.00	79.13	67.20	**F_1**
78.96	76.33	86.60	73.93	**F_2**
	72.22	80.27	68.27	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		2.52	9.09	

Number of branches (branch/ plant^{-1}):

Table (3) shows that the second date of spraying (D_2) was a significant difference in this capacity, gave the highest average of 5.02 branch/ plant^{-1}, not significantly offset the first date (D_1), which gave an average of 4.98 branch/ plant^{-1}, whereas the third date (D_3) gave the lowest mean of this trait to 4.40 branch/ plant^{-1}, agreed with Hassan (2019).

Significant increase by increasing NPK nanoconcentrations in spray solution, gave F_2 the highest mean average of 5.24 branch/ plant^{-1}, also, the second focus, F_1, was significantly higher, an average of 4.83 branch/plant^{-1} was given for the comparison treatment, which gave the lowest average of 4.33 branch/ plant^{-1}, the reason for the increase in the number of branches is due to the important role of NPK in improving plant growth and increasing photosynthesis, which contributes to breaking the apical sovereignty, the increased branching in the plant (Al-Hasany *et al.*, 2018).

The interaction between the dates and concentrations of spraying with NPK nanoparticles, the results did not show significant differences in the characteristic number of dispersions in the plant.

Table 3 : Effect of spray dates and concentrations with NPK nanoparticles and their interaction on number of branches (branch/ plant^{-1}).

Mean / F	D			D / F
	D_3	D_2	D_1	
4.33	3.93	4.66	4.40	**F_0**
4.83	4.40	5.06	5.03	**F_1**
5.24	4.86	5.33	5.53	**F_2**
	4.40	5.02	4.98	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		0.22	0.14	

Pod length (cm):

Table (4) showed that spraying with NPK nanostructures with the highest concentration is F_2, led to an increase in the length of the pod as it gave an average of 21.19 cm, a significant difference from the comparison treatment F_0, which gave the lowest average characteristic of this attribute to be 18.44 cm, due to the role of nutrients in transporting manufactured materials from the manufacturing sites in the leaf to the rest of the plant, including the pods, which led to an increase in their length (Al-Hasany, 2018; Rasul, 2018). No significant differences appeared between the spraying dates and also the interaction between the spraying dates and concentrations with NPK nanoparticles in the length of the pod.

Table 4 : Effect of spray dates and concentrations of NPK nanoparticles and their interaction in length of pod (cm).

Mean / F	D			D / F
	D_3	D_2	D_1	
18.44	18.13	17.63	19.57	**F_0**
19.33	19.13	20.10	18.77	**F_1**
21.19	21.10	22.17	20.32	**F_2**
	19.46	19.97	19.55	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		1.37	N.S	

Number of pods per plant (pod/ plant^{-1})

Table (5) showed that the superiority of the second date (D_2) in the number of pods and without a significant difference from the third date (D_3), gave averages of 16.52 and 15.77 pod/ plant^{-1}, they differed significantly from the first date (D_1), which gave the lowest average number of pods per plant reached 12.28 pod/ plant^{-1}, the reason for the increase is because spraying during the flowering stages provides nutrients that increase the efficiency of photosynthesis, thus increasing its output, which reflects positively on the increase in the number of pods in the plant (Aied, 2014).

An increase in the number of pods by increasing the NPK nanoparticles in the spray solution, F_2 gave the highest mean value of 18.9 pod/ plant^{-1}, a significant difference from the second focus F_1, which gave an average of 15.33 pod/ plant^{-1} which a significantly increased the comparison treatment, gave the lowest average of this quality to 10.31 pod/ plant^{-1}, agreed with El-Azab *et al.*, (2016). There was no significant difference for the interaction between dates and concentrations of spraying NPK nanoparticles in the number of pods per plant.

Table 5 : The effect of dates and concentrations of spraying NPK nanoparticles and their interaction on the number of pods per plant (pod/ plant^{-1}).

Mean / F	D			D / F
	D_3	D_2	D_1	
10.31	11.13	10.97	8.83	F_0
15.33	15.50	17.50	13.00	F_1
18.92	20.67	21.10	15.00	F_2
	15.77	16.52	12.28	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		2.50	3.04	

Number of seeds per pod (seed/ pod^{-1})

Table (6) indicated that the number of seeds per pod when the nanoparticles NPK were sprayed on the plant, F_2 gave the highest mean value for this characteristic of 4.55 seed/ pod^{-1}, whereas the no-spray treatment gave the lowest average number of seeds per pod amounted to 3.95 seed/ pod^{-1}, the increase may be due to the role of NPK in increasing the vegetative population, providing adequate nutrients, which contributed to increasing the amount of interception of light, thus increasing photosynthesis, then increase the amount of manufactured materials, which plants benefit from in forming their other parts, contribute to the lack of competition and abortion, which led to an increase in the number of seeds per pod (Al-Dulaimi, 2014).

No significant differences appeared between the spraying dates and also the interaction between the spraying dates and concentrations with NPK nanoparticles in the number of seeds per pod.

Table 6 : The effect of dates and concentrations of spraying with NPK nanoparticles and their interaction on the number of seeds per pod (seed/ pod^{-1}).

Mean / F	D			D / F
	D_3	D_2	D_1	
3.95	4.03	3.70	4.13	F_0
4.06	4.00	4.01	4.16	F_1
4.55	4.53	4.23	4.90	F_2
	4.18	3.98	4.40	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		0.43	N.S	

Weight of 100 seeds (g)

Table (7) showed that there were no significant differences in the dates and concentrations of spraying with NPK nanoparticles and their interference in the weight of 100 seeds.

Table 7 : the effect of dates and concentrations of spraying with NPK nanoparticles and their interaction in the weight of 100 seeds (g).

Mean / F	D			D / F
	D_3	D_2	D_1	
128.30	133.30	135.00	116.70	F_0
121.00	124.70	116.7	121.70	F_1
121.90	129.00	125.00	111.70	F_2
	129.00	125.60	116.70	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
N.S		N.S	N.S	

Total seed yield (kg/ ha^{-1}):

Table (8) indicated that there was a significant difference between spraying dates in total seed yield, it exceeded the second date (D_2) and gave the highest average of 3905 kg/ ha^{-1}, whereas the first date (D_1) gave the lowest mean for this trait was 2749 kg/ ha^{-1}, the reason is that spraying at the beginning of flowering helped along the flowering period, which led to the long duration of the various vital events, which contributed to increasing the outcome, or due to the increase in the number of pods per plant (Table 5). This increase was reflected positively on the increase in the total seed yield (ALzubaidy, 2014).

A significant increase in the total seed yield with increased NPK nanostructures in the spray solution, F_2 gave the highest mean value for this trait, 4120 kg/ ha^{-1}, the comparison treatment gave F0 the lowest mean for this trait of 2557 kg/ ha^{-1}, the reason for this increase in the yield of seeds when spraying NPK nanoparticles to increase the two component components is the number of pods per plant (Table 5) and the number of seeds per pod (Table 6). As a result, the total seed yield increased, agreed with Jasim *et al.*, (2016).

There is interaction between the dates and concentrations of NPK nanostructures in the total seed yield, gave (D_2 x F_2) the highest average seed yield of 5122 kg/ha^{-1}, and a significant difference from all other combinations, while it gave (D_1 x F_0) the lowest average for this trait was 2189 kg/ ha^{-1}.

Table 8 : Effect of spray dates and concentrations of nanoparticles and their interaction on total seed yield (kg/ ha^{-1}).

Mean / F	D			D / F
	D_3	D_2	D_1	
2557	2647	2836	2189	F_0
3184	2967	3758	2828	F_1
4120	4008	5122	3231	F_2
	3207	3905	2749	**Mean D**
D × F		**F**	**D**	**L.S.D 0.05**
873.10		354.50	705.90	

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