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Effect of Foliar Application of N P K Nanoparticle Fertilization and Soil Addition of Mineral N P K Fertilization as Combined Treatments on Soil Fertility and Wheat Plant Performance.

Amany E. El-Sonbaty*

Land, Water and Environment Research Institute, Agriculture Research Centre, El-Gama St., Giza, Egypt.

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ABSTRACT

Nanotechnology may be a brilliant solution to many common problems in the agricultural sector in Egypt including the urgent need to reduce mineral fertilization, where many scientific papers have confirmed that Nano-fertilizers possess special attributes that don't exist in their conventional counterparts. So a field trial was implemented to evaluate the effect of foliar application of a different sources of NPK fertilizers *i.e.,* mineral form and Nanoparticle form (NPs) carried on either calcium or chitosan as main plots and soil addition of mineral NPK fertilization at different rates (50+50+25**&** 75+100+50**&** 100+200+75, kg fed^{-1}) as subplots on the fertility of sandy soil having an EC value of 5.14 dSm^{-1} and wheat performance. Plant height and chlorophyll content as well as yield, its components and soil available nutrients were evaluated. The findings indicated that wheat plants sprayed with NPs (carried on either calcium or chitosan) possessed performance better than that sprayed with mineral NPK, where the superior treatment was NPK carried on calcium. All studied parameters increased as the added rate of NPK as soil addition increased. On the other hand, the NPK carried on either calcium or chitosan combined with the lowest rate of NPK (50+50+25) gave grain yield values (3.35 and 3.30 Mg fed^{-1}, respectively) more than that (2.20 Mg fed^{-1}) when plants were sprayed with mineral NPK and simultaneously treated with the highest rate of NPK (100+200+75) thereby it can be concluded that NPs has a vital role in reducing mineral fertilization.

***Keywords*:** Nanoparticle fertilization, nutrient use efficiency, saline soil, wheat productivity.

INTRODUCTION

In Egypt, wheat is the main winter cereal crop, where it has special importance because the local production is not sufficient to face the annual requirements (Kasim *et al.,* 2020). However, total wheat consumption has increased drastically due to overall population growth of about 2.5 % per year. Its area amounted to about 1.2 million ha in the growing season of 2016/2017 producing a total of 8.5 million Mg with an average of 7.00 Mg ha^{-1}; therefore there is an urgent need for reclamation of degraded soils e.g., calcareous, saline and sandy soils with the aim of increasing the area cultivated with wheat according to Economic Affairs Annual Report, (2017).

Currently, the good management of fertilization becomes one of the main challenges in field management. Even though mineral fertilizers are so essential for plants grown, their continued use causes environmental and health hazards e.g., surface and groundwater pollution. So, reducing the quantity of mineral fertilizers applied to the field without their deficiency is the biggest challenge in the agricultural sector (Faiyad and Hozayn, 2020).

Nano fertilizers are a structure in the dimension of 1–100 nm designed to deliver nutrients to crops. Their attributes have been shown to increase productivity via target delivery or/ and slow release of nutrients elements, thus limiting rate of fertilizer addition. The expectations of Nano-enabled agriculture include a pronounced increase in the macro elements use efficiency (Kah *et al.,* 2019). Generally, this technology causes improve plant performance (Abd El-Aziz *et al.,* 2016). On the other hand, Nano fertilizers can lessen the issues like nutrients leaching, plant damage, increasing salinity, environmental pollution and toxicity, caused by the usage of conventional mineral fertilizers. Nano fertilizers provide slow-release of macronutrients because of greater surface area, (Tantawy *et al.*, 2014). El-Shamy *et al.*, (2019) found than exogenous application of Nano NPK at different levels *i.e.*, 10, 50 and 100% significantly increased all the growth criteria chlorophyll content, chemical constituents and yield components of potato plants. The encapsulation of various chemicals in slow-release particles can be so necessary for sustainable agriculture, (Adisa *et al.*, 2019).

Chitosan is a linear copolymer of 2-acetamido-2-deoxy-β-D-glucopyranose and 2-amino-2-deoxy-β-D-glucopyranose (piras *et al., 2014)*. Nano chitosan application is particularly attractive in the case of macro and micronutrients (Deshpande *et al.,* 2017). The demonstrates the possibility to obtain functionalized chitosan Nano substances able to encapsulate NPK plant macro elements, using urea, potassium chloride and calcium phosphate as nutrient sources (Corradini *et al.*, 2010).

Calcium plays an essential role in producing plant tissues, where it enables plants to grow better as well as is responsible for holding together the plant's cell walls. Also, calcium is crucial in sending signals that coordinate certain cellular activities in addition to its role in activating certain enzymes. Generally, it is an important reason for normal roots development, thus increases the production of the crops (Singh, 2020).

* **Corresponding author.**
E-mail address: amanyelsonbaty464@yahoo.com.
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Therefore, the objective of this study was to evaluate the effect of foliar application of different sources of N P K fertilizers i.e., mineral form and Nanoparticle form (NPs) carried on either calcium or chitosan and soil addition of mineral fertilization of NPK at different rates on the fertility of sandy soil having an EC value of 5.14 dSm^{-1} and performance of wheat grown under these conditions.

MATERIALS AND METHODS

1.Experimental Site.

A field trial was executed at a private farm located at El-Amal village, El-Quntra Sharq District, Ismailia governorate, Egypt (30° 51' 0.0" E longitude and 32° 18' 36.0" N latitude) during two successive seasons of 2019/20 and 2020/21.

2.Soil Sampling.

The initial soil sample (at depth of 0-30 cm) was analyzed according to Dane and Topp (2020) and Sparks *et al.,* (2020), where Table1 shows their attributes.

3.Experimental Setup.

A field trial was implemented in a split-plot design with three replicates aiming at evaluating the effect of foliar application of a different sources of N P K fertilizers *i.e.,* mineral form and Nanoparticle form (NPs) carried on either calcium or chitosan as main plots and soil addition of NPK mineral fertilization at different rates (50 N + 50 P + 25K & 75 N + 100 P + 50 K and 100 N + 200 P + 75 K, kg fed^{-1}) as subplots on wheat plants performance and soil fertility.

Table 1. Initial soil characteristics.

Particle size distribution (%)				Texture class	O.M	ESP	$CaCO_3$	Available soil Macronutrients			EC,	pH
C. Sand	F. Sand	Silt	Clay					N	P	K		
						(%)		(mg kg^{-1})			dSm^{-1}	
10.35	70.58	6.21	12.86	Sandy loam	0.65	9.74	12.85	33.25	4.28	176.00	5.14	8.02

Available Micronutrients (mg kg^{-1})			Cations and anions							
			Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
Fe	Mn	Zn	meq L^{-1}							
2.75	1.14	0.58	12.90	8.44	0.85	29.21	---	7.52	25.88	18.00

The treatments total number was 9 with three replicates, where the subplot area was 9.0 m^2 (3.0 m width and 3.0 m length).

Grain of the examined plants "*Triticum aestivium* L. Cv Sakha 93" were obtained from Agric. Res., Center, Giza, Egypt then sown on 20th of November in both studied seasons at rate of 70 kg fed^{-1} .

Phosphorus was added as calcium superphosphate (15.5% P_2O_5) at aforementioned rates during soil preparation before sowing. Nitrogen as urea (46%N) was applied through the soil at aforementioned rates at two equal doses; the1st after month from sowing, while the 2nd after one month later. Potassium was added at aforementioned rates as potassium sulfate (48 % K_2O) at two equal doses with the doses of N-fertilizer. The foliar application of Nano NPK fertilizers was executed after month from sowing and repeated three times with three weeks interval. Nano NPK fertilizers were prepared in National Research Center, Egypt

Nano NPK fertilizers carrier on chitosan–polymethacrylic acid (PMAA) nanoparticle suspension with entrapment of NPK was prepared by polymerizing N, P, or K, each at a time, in CS–PMAA solution in two steps as described by Corradini *et al.,* (2010).

Nano NPK fertilizer carrier on calcium nanoparticles were obtained by polymerization of methacrylic acid (MAA) in the solution process according to Hasaneen *et al.,* (2014). Nitrogen, phosphorus and potassium (NPK) were loaded on the Ca-PMAA nanoparticles using the following concentrations 500, 60, 400 ppm respectively (100% concentration stands for 500 ppm of N, 60 ppm of P and 400 ppm of K in both nano and normal NPK solutions and other concentrations were made from these stock solutions (Hasaneen *et al.,* 2014).

The irrigation process was done using the Nile River under a surface irrigation regime as the plants need.

4.Measurements Parameters.

At a period of 75 days from sowing.

Random samples of seven wheat plants were taken from each sub-plot to determine the following criteria;

- Plant height (cm).
- Total chlorophyll content (mg g^{-1}) was determined in fresh weight as described by Min-Wen (2002).

Then, dried samples were digested by a mixture of sulfuric and perchloric acids (1:1) to determined total N% (using Kjeldahl method), total P% (spectrophotomitrically) and K% (using flam photometer) as well as total Fe, Mn, Zn, mg kg^{-1} (using atomic adsorption) in wheat straw according to Walinga *et al*., (2013).

At harvest stage.

Yield components and qualitative traits were recorded at the harvest stage using random samples of seven wheat plants from each sub-plot as follows:

a- Yield and its components:

- No. of grain $spike^{-1}$.
- Weight of grain $spike^{-1}$.
- Weight of 1000 grain (g).
- Grain yield (Mg fed^{-1}).
- Straw yield (Mg fed^{-1}).

b- Nutrient status and qualitative traits of grains:

- N, P and K (%) as well as Fe, Mn and Zn (mg kg^{-1}) contents of wheat grain was determined as formerly mentioned in straw.
- Protein content in wheat grain was calculated by using the following formula: Protein % = (N) × 5.75 as described by Anonymous, (1990), while total carbohydrates in wheat grain were determined according to Hedge and Hofreiter (1962).

c- Soil analysis:

At harvest stage, available nutrients content in soil (N, P, K, Fe, Mn and Zn, mg kg^{-1}) were determined according to Sparks *et al.,* (2020).

3.Statistical Analysis.

It was done according to Gomez and Gomez, 1984, using CoStat (Version 6.303, CoHort, USA, 1998–2004)].

RESULTS AND DISCUSSION

1.Post-Harvest Soil Analysis.

Figs 1 and 2 illustrate the effect of foliar application of different sources of N P K fertilizers *i.e.,* mineral form and Nanoparticle form (NPs) carried on either calcium or chitosan and soil addition of mineral NPK fertilization at different rates *i.e.,* 50 N + 50 P + 25K **&** 75 N + 100 P + 50 K and 100 N + 200 P + 75 K, kg fed^{-1} on available macro and micronutrients *i.e.,* N, P, K, Fe, Mn and Zn contents in soil, where the data indicate that all studied treatments had an effect reflected on the availability of these nutrients in the soil. The foliar application of NPs (carried on either calcium or chitosan) caused raising availability of studied nutrients in soil compared to foliar application of mineral form, where the increase which owing to NPs carried on calcium was more than that with NPs carried on chitosan.

Also, the values of these nutrients increased as the added rate of NPK as soil addition increased or on other words, the rate of (100 N +200 P +75 K, kg fed^{-1}) led to increase the availability of soil nutrients followed by (75N+100P+50K, kg fed^{-1}) and lately (50N+50P+25K, kg fed^{-1}).

The available macro and micronutrients *i.e.,* N, P, K, Fe, Mn and Zn in the soil after harvesting pronouncedly increased over that before sowing owing to improving plant status and increasing roots activity due to studied treatments thereby raising the soil acidity, which in turn increases the availability of these nutrients.

The obtained results are in harmony with Shawer, and Abdalla (2019) who reported raising soil available N, P, and K content with application of N-Nano-fertilizer. Beside Ahmed *et al.,* (2012) indicated that the application of Nano-fertilizers improved soil fertility.

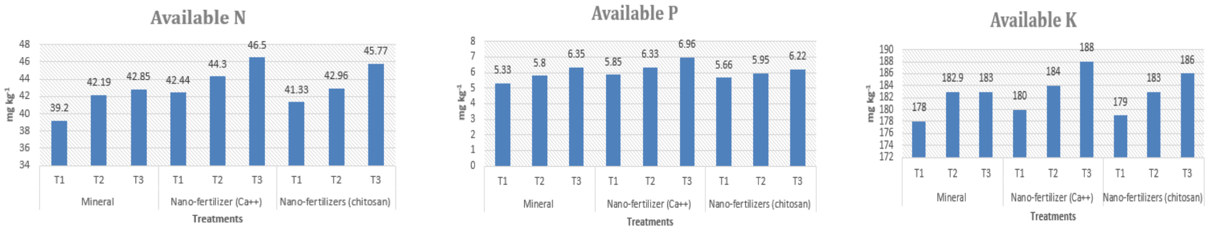

Fig. 1. Macronutrients content in soil at harvest stage (combined data over both seasons).

T1: Soil addition of mineral NPK at rate of 50+50+25, kg fed^{-1} ; T2: Soil addition of mineral NPK at rate of 75+100+50, kg fed^{-1} and T3: Soil addition of mineral NPK at rate of 100+200+75, kg fed^{-1}

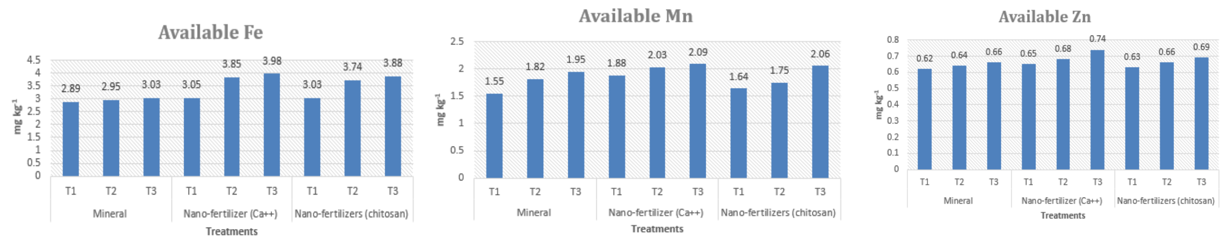

Fig. 2. Micronutrients content in soil at harvest stage (combined data over both seasons).

T1: Soil addition of mineral NPK at rate of 50+50+25, kg fed^{-1} ; T2: Soil addition of mineral NPK at rate of 75+100+50, kg fed^{-1} and T3: Soil addition of mineral NPK at rate of 100+200+75, kg fed^{-1}

2.Wheat Performance and Productivity.

Foliar application of different sources of N P K fertilizers (mineral or NP_S) and soil addition of mineral fertilization of NPK at different rates pronouncedly affected wheat performance at 75 day from sowing expressed in growth criteria and photosynthetic pigment [plant height (cm) and total chlorophyll (mg g^{-1} F.W.)] and chemical constituents in straw *i.e.,* N,P,K (%),Fe, Mn and Zn (mg kg^{-1}) (Table 2), as well as the studied treatments pronouncedly affected grain biochemical traits at harvest stage *i.e.,* protein and carbohydrate (%) and chemical constituents in grain *i.e.,* N,P,K (%),Fe, Mn and Zn (mg kg^{-1}) (Table 3) and yield and its components *i.e.,* No. of grain $spike^{-1}$,weight of grain $spike^{-1}$,weight of 1000 grain (g),grain and straw yield (Mg fed^{-1}) (Table 4).

It is quite obvious from the data presented in Tables 2, 3 and 4 that wheat plants sprayed with NPs (carried on either calcium or chitosan) possessed the highest values of all aforementioned traits compared to that sprayed with mineral N P K, where the superior treatment was NPK carried on calcium. This may be due to that Nano-fertilizer (carried on either calcium or chitosan) were more advantageous compared to the conventional mineral fertilizers because they can triple the effectiveness of the element nutrients, reduce the requirement of mineral fertilizers, increase the resistance of crops to salinity, drought and disease as mentioned by Tantawy *et al.,* (2014) and Abd El-Aziz *et al.,* (2016) in addition to less hazardous to the environment due to Nano-fertilizers as mentioned by Kah *et al.,* (2019). Generally, Nano fertilizers had a role in boosting nutrients uptake and nutrients use efficiency. Even though the role of chitosan in scavenging free radicals in tissues of plants exposed to any environmental stress (Abd El-Aziz *et al.,*2018), the NPK carried on calcium outperformed NPK carried on chitosan and this may be attributed to the vital role of calcium in the formation of cell walls and cell membranes(Singh, 2020).

Table 2. Effect of studied treatments on wheat performance at period of 75 days from sowing (combined data over both seasons).

Treatments	N+P+K Rates (kg fed^{-1})	Growth criteria and photosynthetic pigment		Chemical constituents in straw					
		Plant height, cm	Total chlorophyll, mg g^{-1} F.W.	N	P	K	Fe	Mn	Zn
				(%)			(mg kg^{-1})		
Mineral	50+50+25	72.85	4.85	2.45	0.26	2.55	95.30	74.30	35.87
	75+100+50	75.96	4.96	2.49	0.28	2.78	97.40	77.95	39.00
	100+200+75	85.62	5.14	2.53	0.32	2.85	98.28	79.44	41.59
Mean		78.14	4.98	2.49	0.29	2.73	96.99	77.23	38.82
Nano-fertilizer (Ca^{++})	50+50+25	84.95	4.88	2.65	0.31	2.69	107.40	85.40	39.88
	75+100+50	88.62	5.12	2.78	0.36	3.05	125.39	94.00	47.40
	100+200+75	92.34	5.34	2.74	0.34	3.16	112.00	88.95	45.88
Mean		88.64	5.11	2.72	0.34	2.97	114.93	89.45	44.39
Nano-fertilizers (chitosan)	50+50+25	80.85	4.85	2.54	0.28	2.64	105.54	82.85	37.66
	75+100+50	86.34	5.10	2.73	0.34	2.95	122.45	89.40	45.93
	100+200+75	90.88	5.44	2.70	0.33	3.06	110.85	85.77	44.85
Mean		86.02	5.13	2.66	0.32	2.88	112.95	86.01	42.81
LSD. 5 % Nano-fertilizer		1.81	1.41	ns	0.03	ns	3.95	1.41	1.85
LSD. 5 % Rates		1.15	ns	ns	0.02	ns	3.39	1.99	0.79
Interaction		ns	***	ns	ns	ns	***	*	ns

Table 3. Effect of studied treatments on grain quality at harvest stage (combined data over both seasons).

Treatments	N+P+K Rates (kg fed^{-1})	Biochemical traits of grain		Chemical constituents in grain					
		Protein	Carbohydr-ate	N	P	K	Fe	Mn	Zn
				(%)				(mg kg^{-1})	
Mineral	50+50+25	10.64	66.52	1.85	0.38	1.33	83.20	54.30	29.30
	75+100+50	11.27	69.21	1.96	0.43	1.38	87.40	56.95	31.35
	100+200+75	11.90	74.23	2.07	0.45	1.42	88.39	58.30	33.80
Mean		11.27	69.99	1.96	0.42	1.38	86.33	56.52	31.48
Nano-fertilizer (Ca^{++})	50+50+25	12.02	72.14	2.09	0.42	1.38	87.59	57.60	33.75
	75+100+50	13.51	74.36	2.35	0.48	1.56	97.40	65.85	38.30
	100+200+75	14.09.	75.69	2.45	0.47	1.46	94.33	63.20	35.55
Mean		13.21	74.06	2.30	0.46	1.47	93.11	62.22	35.87
Nano-fertilizers (chitosan)	50+50+25	11.78	69.58	2.05	0.41	1.36	85.66	55.95	31.29
	75+100+50	13.11	70.95	2.28	0.45	1.48	94.88	63.66	37.40
	100+200+75	13.74	73.77	2.39	0.46	1.44	90.54	61.90	33.88
Mean		12.88	71.43	2.24	0.44	1.43	90.36	60.50	34.19
LSD. 5 % Nano-fertilizer		ns	1.25	0.02	0.023	0.014	2.41	3.14	1.28
LSD. 5 % Rates		0.50	1.37	0.01	0.004	0.027	4.09	1.57	1.90
Interaction		ns	ns	***	ns	***	ns	ns	*

Table 4. Effect of studied treatments on yield and its component (combined data over both seasons).

Treatments	N+P+K Rates (kg fed^{-1})	No. of grain spike^{-1}	Weight Of grain spike^{-1}	Weight of 1000 grains, g	Grains yield	Straw yield
					(Mg fed^{-1})	
Mineral	50+50+25	45.00	1.85	43.28	2.10	3.85
	75+100+50	49.00	2.05	47.25	2.18	3.97
	100+200+75	53.00	2.10	51.36	2.20	3.12
Mean		49.00	2.00	47.30	2.16	3.65
Nano-fertilizer (Ca^{++})	50+50+25	52.00	1.98	46.85	3.35	3.97
	75+100+50	58.00	2.13	53.47	3.58	4.25
	100+200+75	62.00	2.17	59.63	3.75	4.68
Mean		57.33	2.09	53.32	3.56	4.30
Nano-fertilizers (chitosan)	50+50+25	49.00	1.95	44.85	3.30	3.94
	75+100+50	54.00	2.11	51.96	3.52	4.20
	100+200+75	58.00	2.15	58.76	3.65	4.55
Mean		53.67	2.07	51.86	3.49	4.23
LSD. 5 % Nano-fertilizer		5.67	0.06	1.41	ns	ns
LSD. 5 % Rates		ns	0.05	0.87	0.83	0.41
Interaction		ns	ns	*	ns	ns

On the other hand, the values of all aforementioned traits increased as the added rate of NPK as soil addition increased and this due to the vital role of nitrogen, phosphorus and potassium in plant nutrition, where nitrogen is an essential nutrient element of all the amino acids in plant structures that are the building blocks of plant proteins in addition to it is a major component of chlorophyll (Artyszak and Gozdowski, 2020), while phosphorus is involved in many key plant functions *e.g.* the transformation of sugars and starches, energy transfer, photosynthesis, nutrient movement within the plant and transfer of genetic attributes from one generation to the next (Kour *et al.,* 2020), whilst potassium is associated with the movement of both water and other nutrients in plant tissue in addition to its importance in protein synthesis, sugar transport, photosynthesis and N and C metabolism (Xu *et al.,* 2020).Thus, raising added rate led to increasing their functions in plants, but here, the major aim was reducing the quantity of mineral NPK applied to the field without NPK deficiency.

In this respect, the data indicate that NPs (carried on either calcium or chitosan) combined with the lowest rate of NPK (50+50+25) realized grain yield values (3.35 and 3.30Mg h^{-1}, respectively) more than that (2.20 Mg h^{-1}) when plants were sprayed with mineral N P K and simultaneously treated with the highest rate of NPK (100+200+75) thereby it can be concluded that NPs has a vital role in reducing mineral fertilization.

Generally, it can be noticed that Nano-fertilizers enhanced the ease of use of nutrients to the plants grown on soil having sandy loam texture and an EC value of 5.14 dSm-1 which enhance pigments formation, photosynthesis rate, dry material production, and result get better in the general growth of the plant and this promoting effect positively reflected on yield and its components as well as biochemical traits of grain. Finally, the wheat performance under the studied condition was improved by applying mineral fertilizer together with Nano-materials.

On the other hand, it can be noticed that the foliar application of mineral NPK fertilizers with wheat plants grown on sandy soil led to reaching the harvesting stage after 170 days from sowing, while wheat plants treated with Ca -NPK and chitosan-NPK nano fertilizers reached the harvesting stage after 125 and 130 days from sowing, respectively. Thus, it can be said that Nano fertilizers resulted in the reduction of the life span of the wheat crop by 26.47% and 23.53 % compared to the normal life span of the wheat crop. These results come in accordance with Ali (2012); Ali and Al-Juthery (2017); Abd El-Azize *et al.,* (2016) and El-Sayed *et al.,* (2020).

CONCLUSION

The current paper confirms some facts as follows;

1. The foliar application of Nano fertilizers can open new perspectives in agricultural practices especially with degraded soils such as saline sandy soil as a result that fertilization by Nanoparticles promises to be a safe way to enrich nutrients to plants without harm to the environment.
2. Nanoparticles possess a role in reducing the quantity of mineral NPK applied to the field without NPK deficiency.
3. Plant performance improves by applying mineral fertilizer with Nano-materials together.
4. Nano- NPK fertilizers carried on calcium is better than that on chitosan due to the role of calcium in plants nutrition.

Generally, it can be concluded that Nano- NPK fertilizers may be a good substitute for mineral NPK-fertilizers in sustainable development.

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تأثير الرش الورقي للأسمدة النانوية NPK والإضافة الأرضية للأسمدة المعدنية NPK كمعاملات مشتركة على خصوبة التربة وأداء نبات القمح

أماني السيد السنباطى

مركز البحوث الزراعيه معهد الاراضى و المياه و البيئه

قسم بحوث خصوبة الأراضي وتغذية النبات -معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصرقد تكون تقنية النانو حلاً رائعًا للعديد من المشكلات الشائعة في القطاع الزراعي في مصر بما في ذلك الحاجة الملحة لتقليل التسميد المعدني، حيث أكدت العديد من الأوراق العلمية أن الأسمدة النانوية تمتلك سمات خاصة لا توجد في نظيراتها التقليدية. لذلك تم تنفيذ تجربة حقليه بنظام القطع المنشقة مره واحدة بهدف تقييم تأثير الرش الورقي لمصادر مختلفة لأسمدة NPK (الصورة المعدنية والصورة النانوية اما محمله على الكالسيوم او الشيتوزان) كمعاملات رئيسية وكذللك الإضافة الأرضية لبعض الأسمدة المعدنيةNPK (50 نيتروجين +50 فسفور+ 25 بوتاسيوم&75 نيتروجين +100 فسفور+ 50 بوتاسيوم&100 نيتروجين +200 فسفور+ 75 بوتاسيوم كجم فدان$^{-1}$) كمعاملات منشقة على خصوبة التربة الرملية ملوحتها حوالي 5.14 ديسيمنز$^{-1}$ وعلى أداء نباتات القمح النامي تحت هذه الظروف. تم تقييم ارتفاع النبات والمحتوي الكلي من الكلوروفيل وكذلك صلاحيه بعض المغذيات في التربة وقت الحصاد. أشارت النتائج إلى أن نباتات القمح التي تم رشها باستخدام NPs (محمولة على الكالسيوم أو الشيتوزان) كان لها أداء أفضل من تلك التي تم رشها بال NPK في الصورة المعدنية، حيث كانت المعاملة المتفوقة هي NPK المحمولة على الكالسيوم. زادت جميع الصفات المدروسة كلما ذاد معدل الإضافة الأرضية لNPK . من ناحية أخرى، فإن الدمج بين NPK المحمولة على الكالسيوم أو الشيتوزان مع أقل معدل من NPK (50 نيتروجين +50 فسفور+ 25 بوتاسيوم كجم فدان$^{-1}$) اعطي محصول حبوب (3.35 و3.30 طن للهكتار على التوالي) أكبر من محصول الحبوب (2.20 طن للهكتار) الذي تم تحقيقه نتيجة الجمع بين الرش الورقي للأسمدة المعدنية مع الإضافة الأرضية باعلي معدل NPK (100 نيتروجين +200 فسفور+ 75 بوتاسيوم كجم فدان$^{-1}$) وبالتالي يمكن استنتاج أن NPs لها دور حيوي في تقليل التسميد المعدني.