J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (11): 543–548, 2018

Implications of Applying Nano-Hydroxyapatite and Nano-Iron Oxide on Faba Bean *(Vicia faba L.)* Productivity

Abdel-Salam, M. A.
Soil and Water Department, Faculty of Agriculture, Benha University.

ABSTRACT

Nano P fertilization and nano Fe foliar spray were assessed for their effect on productivity of faba bean (Vicia faba L.) grown on a light clay soil in Meet-Halfa, Qalubiya governorate, Egypt in a factorial randomized complete block field experiment involving two factors : 1-*P application* with 5 treatments: P_0,P_1,P_2,P_3 and P_4 i.e. none, 20 kg P ha^{-1} (as triple super phosphate TSP), 40 kg P ha^{-1}(as TSP), 20 kg P ha^{-1}(as nano-hydroxyapatite HANP) and 40 kg P ha^{-1}(as HANP) respectively; 2-*Fe foliar spray* with 4 treatments: Fe_0, Fe_1, Fe_2 and Fe_3 i.e. none, 150 mg Fe L^{-1} (as nano iron oxide Fe_3O_4), 300 mg Fe L^{-1} (as nano Fe_3O_4) and 300 mg Fe L^{-1} (as Fe-EDTA) respectively. Rate of spray was 1200 L ha^{-1}. At either low or high rate, nano P, was more effective than non-nano P in increasing plant height and number of pods. For seed yield and N, P and Fe uptake by seeds at the same rate of P, the high rate of nano-P gave higher values than the high rate of TSP-P. Though the low rate of nano-P ranked third next to the high rate of TSP-P, the difference between the low rate of nano-P and the high rate of TSP-P was slight. Nano iron in both rates (the high and the low) was the most effective iron treatment. It increased the values of different parameters at low and high doses as follows: 11.8 and 20.1% for seed yield respectively. Respective increases for other traits are 25.6 and 35.5% for plant height; 21.8 and 36.9% for number of pods, 16.2 and 32.4%for N uptake ;15.7 and 31.0% for P uptake and 45.4 and 70.13% for Fe uptake.

Keywords: Nano-Hydroxyapatite - Nano-Iron - Faba Bean – N, P and Fe uptake.

INTRODUCTION

Faba bean (*Vicia faba, L.*) is one of the most common leguminous crops in Egypt, used mainly for human nutrition(Kasem, 2012) due to being a source of vitamins, minerals and starch further more it is an alternative source of protein (Chaieb *et al.*, 2011; Smith *et al.*, 2013; Heuzé *et al.,* 2018).Many regions such as China, Middle East, Mediterranean region, Ethiopia, Central and East Asia, Oceania and the Americas produce faba bean (Bond *et al*., 1985).It is considered a multipurpose crop not only used as food but also used as a fodder (hay, silage and straw) or green manure due to its high content of nitrogen (Singh *et al*., 2012; Heuzé*et al.,* 2018). Faba bean (*Vicia faba L*) is adaptable plant which can grow under different climatic conditions (Singh *et al*., 2013) moreover, it is a tolerant plant to biotic and abiotic stress (Singh and Kumar, 2009).It grows in soils with different pH values ranging from 6.5 to 9.0 (Jensen *et al*., 2010) while the maximum N fixation by nodule bacteria requires a neutral to alkaline medium (Singh *et al*., 2013). This plant has unique potentials in biological N-fixation (symbiotically with Rhizobium), itcould reach up to 300 kg N ha^{-1}(Singh *et al*., 2013) therefore it contributes to soil fertility effectively (Gasim and Link, 2007) and considered an effective choice for cropping system (Jensen *et al*., 2010).Framers growing beans do not need to use large amounts of nitrogen fertilizers compared with other crops (Chaieb *et al*., 2011). Egyptian soils suffer from deficiency of phosphorus (El-Agrodi et *al.,* 2011) and applied phosphorus is tightly retained in soil due to many factors such as clay minerals (Devau *et al*., 2010) and high pH. Most of P retention in alkaline soils occur in calcareous soils, calcium ions retain P by precipitating P on the surface of calcium carbonate also it produce low soluble salt of calcium phosphate (Osemwotai *et al*., 2005; Shen *et al.,* 2011); therefore the available fraction or plants is very low. Increasing soil pH and calcium carbonate content reduce the availability of iron (Horneck and Abak, 2004; Ye *et al*., 2015). Phosphorus and iron are essential and critical nutrients which limit plant growth and production particularly for legumes (Latati *et al.* 2016; Fouda, 2017), they affect nodules formation hence N-fixation (Broughton *et al.,* 2003; Latati *et al.,* 2014; Brear *et al*., 2013).Nano-fertilization technique depends on minimization of bulk materials to get at least one dimension smaller than 100 nm that produce high surface-to-volume ratio (Montalvo *et al*, 2015). Nano-fertilizers are more reactive and soluble compared with their ordinary counter parts (Naderi and Danesh-Shahraki, 2013; Rameshaiah and Jpallavi, 2015; Janmohammadi *et al*, 2016), easily to disperse with high resistance to soil fixation (Naderi and Danesh-Shahraki 2013), and easily to be absorbed by plants and slowly released to supply nutrients for prolonged period (Rameshaiah and Jpallavi, 2015).

The current study focuses on the efficiency of fertilizers with nano P and nano Fe on faba bean *(Vicia faba L.)* productivity.

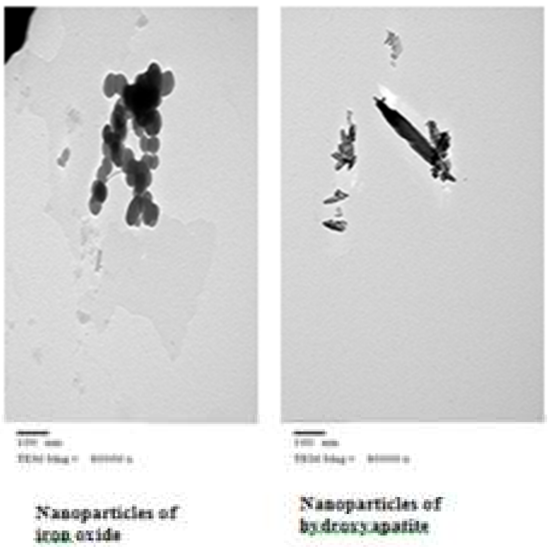
MATERIALS AND METHODS

A Field experiment was carried out to investigate the effect of using fertilizers with nano P and nano Fe on productivity of faba bean grown on a light clay soil in Meet-Halfa, Qalubiya governorate, Egypt using a factorial randomized complete block design with two factors in 3 replicates. Factor 1-*P application* with 5treatments : P_0,P_1,P_2,P_3 and P_4 are none, 20 kg P ha^{-1} (as triple super phosphate TSP), 40 kg P ha^{-1}(as TSP), 20 kg P ha^{-1}(as nano-hydroxyapatite HANP) and 40 kg P ha^{-1}(as HANP) respectively; factor 2-*Fe foliar spray* with 4 treatments : Fe_0, Fe_1, Fe_2 and Fe_3 are none, 150 mg Fe L^{-1} (as nano iron oxide Fe_3O_4), 300 mg Fe L^{-1} (as nano Fe_3O_4) and 300 mg Fe L^{-1} (as Fe-EDTA) respectively. Rate of spray was 1200 L ha^{-1}. Therefore there were 20 treatment combinations. The plot area was 10.5m^2. Sources of fertilizers and contents of their nutrients were as follows: TSP (210 g P kg^{-1}), HANP (180 g P kg^{-1}), nano iron oxide Fe_3O_4 (720 g Fe kg^{-1}) and Fe-EDTA (120g Fe kg^{-1}). Images1 and 2 show micrographs of the nanoparticles of iron oxide and hydroxyapatite. P was applied in 2 equal splits, the first at sowing and the second before the first irrigation (El-Ghamry *et al.,* 2009). Spraying was done twice, 30 and 45 days after sowing at a spray rate of 1200 L ha^{-1} each time. All plots received 15 kg N ha^{-1} (as urea 460 g N kg^{-1}) + 53 kg K ha^{-1}(as K sulphate 410 g K kg^{-1}). Soil was sampled before conducting the experiment and analyzed for its main properties according to Gupta (2009) and results are shown in Table 1.

Table 1. Main properties for soil of the experiment.

Soil property	Texture class [1]	CEC ($cmol_c kg^{-1}$)	EC ($dS m^{-1}$) (paste extract)	pH (1.:2.5 w:v)	OM ($g kg^{-1}$)	$CaCO_3$ ($g kg^{-1}$)	Total[2] ($mg kg^{-1}$) N	P	Fe	Available[3] ($mg kg^{-1}$) N	P	Fe
Value	LC[1]	32.8	1.13	7.7	8.52	14.5	213	81	119	41.6	1.39	18.7

1: LCl : Light Clay
2: Digestion with conc.H_2SO_4 +H_2O_2 (Idera et al, 2014).
3: Extractants KCl (N); $NaHCO_3$ (P); DTPA (Fe) (Lindsay and Norvell, 1978).



Images 1and 2.Transmission electron microscopy (TEM) images of nanoparticles of iron oxide and hydroxyapatite respectively.

Bean seeds (var. Misr-1) were placed in a sucrose solution then mixed thoroughly with a carrier of rhizobium bacteria (*Rhizobium leguminosarum, viciae*), then planted on 1st of November. The distance between ridges was 60cm and between hills was 25cm; two seeds were sown per hill. At end of season (180 days after sowing) 10 plants were sampled per each plot, to determine crop traits and yield. Seed samples were taken to determine contents of N, P and Fe (Chapman and Pratt, 1961).

RESULTS AND DISCUSSION

Plant height:

The lowest plant height (83.25 cm) did not receive either phosphorus or iron (Table 2). Application of P or Fe, singly or combined, gave an increase ranging from 1.7% by Fe_1P_0 to 86.3% by Fe_2P_4. The main effect of P showed highest plant height by the high HANP, with the following descending order: $P_4>P_3>P_2>P_1>P_0$.The HANP treatments averaged 44.4% for low HANP and 60.2% for high HANP. The TSP-P treatments gave lower values than given by HANP; averaging 21.4% for low TSP-P and 35.5% for high TSP-P. The main effect of Fe showed highest plant height by the high nano-Fe followed by the low nano-Fe following a descending order of: $Fe_2>Fe_1>Fe_3>Fe_0$. Thus the nano forms of iron were more effective and gave increases of 25.6% by low rate and 35.5% by the high one. Spraying with Fe-EDTA caused an average increase of 16.9%.There was an interaction caused by the application of P and foliar iron; there was no significant difference between Fe_2 and Fe_3 under P_0 indicating that under no addition of P the high rate of Fe either as nano-Fe or as non-nano EDTA-Fe had the same effect on plant height.

Table 2. Effect of P and Fe application on plant height and number of bean pods plant^{-1}.

Parameter	Plant height (cm)					Number of pods (Pods Pl^{-1})				
Applied P (P)	Foliar Fe (Fe) Fe_0	Fe_1	Fe_2	Fe_3	Mean	Foliar Fe(Fe) Fe_0	Fe_1	Fe_2	Fe_3	Mean
P_0	83.25	84.68	91.01	91.99	88.23	11.01	14.58	16.06	15.05	14.18
P_1	85.69	115.61	132.37	94.79	107.11	16.18	17.68	19.49	17.88	17.81
P_2	96.75	128.45	138.50	114.38	119.52	17.79	21.94	25.52	20.58	21.46
P_3	98.33	136.75	142.68	131.97	127.43	19.94	23.31	25.33	19.70	22.07
P_4	124.30	147.89	155.06	137.97	141.31	21.62	27.93	32.05	25.23	26.71
Mean	97.66	122.68	132.32	114.22		17.31	21.09	23.69	19.69	
LSD $_{(0.05)}$	P = 0.51 Fe = 0.45			P Fe = 1.01		P = 0.42 Fe = 0.38			P Fe = 0.84	

Notes: P_0, P_1, P_2, P_3 and P_4 are: none, 20 kg P ha^{-1}(as triple super phosphate TSP), 40 kg P ha^{-1}(as TSP), 20 kg P ha^{-1}(as nano-hydroxyapatite HANP) and 40 kg P ha^{-1}(as HANP) respectively. Fe_0, Fe_1, Fe_2 and Fe_3 are: none, 150 mg Fe L^{-1}(as nano Fe_3O_4), 300 mg Fe L^{-1}(as nanoFe_3O_4) and 300 mg Fe L^{-1}(as Fe-EDTA).

Number of pods plant^{-1}:

Number of pods had the same trend as plant height. Lowest number (11.01) received neither P nor Fe (Table 2). Application of P or Fe singly or combined gave an increase ranging from 32.4% by Fe_1P_0 to 191.1% by Fe_2P_4. Applied P gave average increases of number of pods plant^{-1} in the following descending order: $P_4>P_3>P_2>P_1>P_0$; a pattern similar to that of plant height. The highest increase in number of pods was obtained by the nano-P from. The low rate of nano-P caused increase of 55.6% while the high rate gave increase of 88.4%. The main effect of iron foliar application showed increase in number of pods in the following descending order: $Fe_2>Fe_1>Fe_3>Fe_0$.The trend was similar to that of plant height where the nano form of iron in both rates gave the highest increase. The high rate of nano-iron gave an increase of 36.9% and the low rate gave 21.8% while Fe-EDTA gave the lowest increase (13.7%).

Under Fe_2 there was no significant difference between P_2 and P_3.This shows that under foliar spraying with the high rate of nano-Fe the high rate of TSP-P and the low rate of nano-P had the same effect on the number of pods. Under Fe_3 there was a significant difference between P_2 and P_3 where P_2 surpassed P_3. This reflects that the high rate of TSP-P gave higher number of pods than the low rate of nano-P when spraying with Fe-EDTA.

Seed yield:

As in plant height and number of pods the lowest seed yield (1.862 Mg ha^{-1}) neither received P nor Fe (Table3). Iron and phosphorus application singly or combined increased seed yield from 14.9% by Fe_1P_0 to 154.6% byFe_2P_4. On average applied P increased seed yield as follows: $P_4>P_2>P_3>P_1>P_0$.Thereforethe highest increase in seed yield occurred with high rate of nano-P (104.1%) and the low rate of nano-P gave the third increase (71.3%) which was slightly lower than the second increase given by the high rate of TSP-P (80.8%). Foliar application with iron in average increased seed yield in the following descending order: $Fe_2>Fe_1>Fe_3>Fe_0$, a pattern similar to those of plant height and number of pods. Such results show that both rates of nano-Fe the high (20.1%) and the low (11.8%) were the most efficient in increasing seed yield. The low rate of nano-Fe gave higher seed yield than the high rate of Fe-EDTA.

Table 3. Effect of P and Fe application on seed yield and Fe uptake of faba bean *(Vicia faba L.)*.

Parameter	Fe-Uptake by seeds (g ha^{-1})					Yield of seeds (Mg ha^{-1})				
Applied P	Foliar Fe(Fe)				Mean	Foliar Fe(Fe)				Mean
(P)	Fe_0	Fe_1	Fe_2	Fe_3		Fe_0	Fe_1	Fe_2	Fe_3	
P_0	53.29	70.76	83.61	72.99	70.16	1.862	2.140	2.372	2.315	2.172
P_1	63.00	89.13	101.33	87.15	85.15	2.163	2.563	2.802	2.505	2.508
P_2	108.40	162.37	196.89	153.04	155.17	3.553	4.029	4.298	3.834	3.928
P_3	109.44	166.60	190.49	139.31	151.46	3.425	3.794	4.095	3.568	3.721
P_4	140.97	201.84	235.45	183.80	190.52	4.244	4.425	4.741	4.322	4.433
Mean	95.02	138.14	161.56	127.26		3.049	3.390	3.662	3.309	
LSD $_{(0.05)}$	P = 0.31 Fe = 0.28		P Fe = 0.62			P = 0.01 Fe = 0.01		P Fe = 0.015		

***see notes of table 2.**

Assessment on response of seed yield and yield components to treatments:

These increases in yield and its components could be the crucial role of P in enhancing plant growth, increasing plant metabolism and cell division (Ndakidemi and Dakora, 2007; Abdalsalam and Al-Shebani, 2010).Phosphorus is required by plants particularly at initiation phase of flowering, seed and fruit formation(Ndakidemi and Dakora, 2007). Fertilization with P is responsible for increasing number of pods $plant^{-1}$ and seed $spod^{-1}$(Singh *et al*., 2011; Zafar *et al*., 2011) and thus increasing seed yield of legumes(Rahman *et al*., 2008; Hussain *et al*., 2012; Ndor *et al*., 2012). Phosphorus increases nodulation and photosynthesis resulting in increased N-fixation and eventually increasing yield and its components (Nyoki and Ndakidemi, 2013). The results show significant increases in yield and yield components due to nano-hydroxyapatite-P compared with TSP as sources of P. Mikhak *et al*. (2017) suggested using nano-hydroxyapatite as a promising alternative source of P and stated that such source mitigates the negative effects of using traditional sources of P. Liu and Lal (2014) found that application of nano-hydroxyapatite increased biomass of soybean compared with water-soluble P. Taskin *et al.* (2018) stated that HANP increased P uptake and growth of lettuce grown on a calcareous soil compared with the soluble source of P (H_3PO_4). Faba bean showed a positive response to foliar application of micro nutrients (Jasim *and Obaid,* 2014; Salem *et al*., 2014) Increasing yield and its components are associated with foliar application of iron and the increases were attributed to Fe roles in many physiological processes in plant such as reparation, metabolism, phyto-hormones formation, redox reactions and particularly chlorophyll biosynthesis (Zargar *et al.,* 2015; Mohammadi *et al.,* 2018). Compared with Fe-EDTA, nano iron oxide caused greater plant weight due to increasing chlorophyll (Rui *et al.,*2016). Nadi *et al.* (2013) found that spraying nano iron chelates at 600 mg Fe L^{-1} increased seed yield of faba bean. Afshar *et al.* (2013) obtained an increase in the number of cowpea seeds pod^{-1} due to application of iron oxide nano particles. Abou El-Nasr *et al.* (2015) reported that foliar application of nano iron oxide for pear at rate of 250 mg Fe L^{-1} resulted in increased plant height and dry weight compared with Fe-chelate at the same rate.

Nutrient uptake by seeds:

Uptake of Fe by seeds was lowest (53.29 g ha^{-1}) in the treatment receiving neither P nor Fe (Table 3) ; their application singly or combined increased Fe uptake by seeds from 18.2% by Fe_0P_1 of no Fe foliar spray and the low rate of TSP-P to 341.8% by Fe_2P_4 of high nano Fe and the high nano P. Application of P, on average, increased Fe uptake by seeds in the following descending order:$P_4>P_2>P_3>P_1>P_0$, a pattern similar to that of the seed yield. Revealing that at the same rate of P, the nano forms gave higher values than TSP-P. The high rate of P (40 kg P ha^{-1}) as nano-P gave an increase in Fe uptake by seeds of 171.6% while the TSP-P gave 121.2%. The low rate of P (20 kg P ha^{-1}) as nano-P gave an increase of 115.9% while the TSP-P gave 21.3%. The main effect of iron foliar application increased Fe uptake by seeds in the following descending order: $Fe_2>Fe_1>Fe_3>Fe_0$, indicating that nano iron at both rates (the high and the low) was most effective in increasing Fe uptake by seeds since it gave increases of 70.3 and 45.4% at the high and low rates respectively while Fe-EDTA gave an increase of 33.9%.

Under each of Fe_0 and Fe_1, P_3caused higher uptake than P_2. This shows that under no iron foliar spray as well as under the low rate of nano-iron the low rate of nano-P gave higher Fe uptake by seeds than the high rate of TSP-P, unlike the main effect of phosphorus application. This demonstrates that with low or no application of foliar iron the effect of low rate of nano-P surpassed the effect of the high rate of TSP-P. Under no added P (P_0) Fe_3 was higher than Fe_1. This indicates that with no added P the high rate of Fe-EDTA gave an increase at Fe uptake by seeds higher than the low rate of nano iron, unlike the main effect of iron foliar spray.

Table 4. Effect of P and Fe application on N and P uptake by seeds of faba bean *(Vicia faba L.)*.

Parameter	N-Uptake by seeds (kg ha^{-1})					P-Uptake by seeds (kg ha^{-1})				
Applied P (P)	Foliar Fe(Fe)				Mean	Foliar Fe(Fe)				Mean
	Fe_0	Fe_1	Fe_2	Fe_3		Fe_0	Fe_1	Fe_2	Fe_3	
P_0	62.95	76.99	90.68	84.68	78.89	6.79	8.12	9.29	8.92	8.28
P_1	81.26	101.30	114.88	98.53	98.99	9.18	11.27	12.87	11.05	11.09
P_2	153.50	182.30	205.52	172.13	178.36	16.78	19.94	22.44	18.90	19.52
P_3	147.24	166.60	189.82	156.04	164.93	16.30	18.52	20.93	17.25	18.25
P_4	191.80	212.40	242.34	205.27	212.95	20.99	23.20	26.22	22.48	23.22
Mean	127.35	147.92	168.65	143.38		14.01	16.21	18.35	15.72	
LSD $_{(0.05)}$	P = 0.30 Fe = 0.27		P Fe = 0.60			P = 0.09 Fe = 0.08		P Fe = 0.18		

***see notes of table 2.**

The lowest N and P uptake by seeds (62.95 and 6.79 kg ha^{-1} respectively) did not receive either phosphorus application or iron foliar spray (Table 4). For each of the uptake of N and P, there was an increase due to applied P or foliar Fe singly or combined with increases ranging from 22.3% for N uptake and 19.6% for P uptake by Fe_1P_0 to respective increases of 285.0 and 286.2% by Fe_2P_4. Applied P showed an average N- and P-uptake in the following descending order: $P_4>P_2>P_3>P_1>P_0$, a pattern similar to that of seed yield and Fe uptake. This indicates that at the same rate of P the nano-P gave higher uptake of N and P than TSP-P. The high rate of nano-P gave an increase of 169.9 and 180.4% for uptake of N and P by seeds respectively while the respective increases of high rate of TSP-P gave an increase of 126.1 and 132.5%. The low rate of nano-P gave an increase of 109.1 and 120.4% for N and P uptake respectively while the respective increases for the low rate of TSP-P were 25.5 and 33.9%. Though the low rate of nano P ranked third in increasing N and P uptake by seeds, next to the high rate of TSP-P, the increase of N and P uptake by the low rate of nano-P to the high rate of TSP-P was slight. Iron foliar spray, on average, increased N and P uptake in the following descending order: $Fe_2>Fe_1>Fe_3>Fe_0$. This shows that the nano form of iron at both the high and the low rates was more effective in increasing N and P uptake by seeds, the respective increases in the high rate of nano-Fe were 32.4 and 31.0 % while the low rate gave respective increases of 16.2 and 15.7 %.Spraying with Fe-EDTA, gave an increase of 11.7 and 12.2 % for N and P uptake of seeds respectively.

Assessment on response of N, P and Fe uptake by seeds to treatments:

Studies on the efficiency of nano-hydroxyapatite showed more increases in plant growth compared with water soluble P (Liu and Lal, 2014) and high use efficiency of P fertilizer (Taskin *et al.*, 2018). The effectiveness of nano-hydroxyapatite could be attributed to the tiny size of their particles (Montalvo *et al.*, 2015), the high mobility in reaching plant roots in addition being a non-soluble and slow release P form that supplies P over the time of growth and mitigating chemical reactions in soil which hinder P-precipitation; hence increasing P-availability for plants. Phosphorus has a vital role in improving root growth, length and density (Lopez- Bucio*et al*., 2003; Desnos, 2008); hence greater acquisition of nutrients by plants (Shen *et al.,* 2011).The increase in N-uptake could be attributed to the P-responsibility for nodulation in legumes, consequently; the higher nodulation the higher nitrogen fixation and the higher nitrogen content (Singh *et al*., 2011). P-addition improves symbiotic association between rhizobium and legume roots (Rotaru, 2010; Hussain, 2017), increasing nodules number, size and nitrogenase activity (Al-Niemi *et al.,* 1998). Increasing N-uptake upon iron fertilization could be attributed to the vital role of iron in increasing nodule formation and enhancing symbiotic association hence increasing nitrogen fixation (Brear *et al.*, 2013). Nitrogenase is responsible for the process of conversion the atmospheric nitrogen to ammonia upon two essential iron-components, iron-protein (small component) which is reduced then supply molybdenum-iron protein (large component) with electrons that includes the catalytic site (Dixon and Kahn, 2004). Slatni *et al.* (2008) noted a positive correlation between nodule formation and iron content in common bean (*Phaseolus vulgaris* L.). Foliar application of iron resulted in increasing nodulation and nitrogen fixation of peanut plants (O'Hara *et al.*, 1988). Abou El-Nasr *et al.* (2015) reported that the foliar application with nano-particles of iron oxide at concentration of 250 mg L^{-1} achieved the maximum content of nitrogen in pear leaves. Stamford *et al.* (2006) stated that increasing P-application increased P-uptake by cowpea plants. Askary et *al.* (2017) stated that Fe, P and K uptake increased significantly in the presence of iron particularly iron nano-particles.

CONCLUSION

Application of nano forms of P and Fe proved more efficient than their ordinary counterparts (P added as triple super phosphate and Fe as Fe-EDTA) in increasing plant height, number of pods, seed yield and Fe, N and P uptake by seeds of faba bean. The low rate of nano Fe proved more efficient than the high rate of Fe-EDTA. Although the low rate of nano P ranked third next to the high rate of triple super phosphate P,increasing seed yield and Fe, N and P uptake by seed, the difference in regarding the high rate of triple super phosphate was slight.

REFERENCES

Abdalsalam A.A., and Al-Shebani Y.A., 2010. Effect of various nitrogen and phosphorus fertilization levels on growth, yield and yield attributes of local mungbean (*Vigna radiata* L.) R. Wilczek) in Yemen. Egypt. J. Appl. Sci. 25 (2A): 57-71.

Abou El-Nasr M.K., El-Hennawy H.M., El-Kereamy A.M.H., Abou El-Yazied A., and Salah Eldin T.A., 2015.Effect of magnetite nanoparticles (Fe_3O_4) as nutritive supplement on pear saplings. Middle East J. Appl. Sci. 5(3):777-785.

Afshar R.M., HadiH., and Pirzad A., 2013. Effect of nano-iron on the yield and yield component of cowpea (*Vigna unguiculata*) under end season water deficit. Int. J. Agri. Res. Rev. 3(1): 27-34.

Al-Niemi T.S., Kahn M.L., and McDermott T.R., 1998. Phosphorus uptake by bean nodules. Plant and Soil198(1): 71–78.

Askary M., Amirjani M.R., and Saberi T., 2017. Comparison of the effects of nano-iron fertilizer with iron-chelate on growth parameters and some biochemical properties of *Catharanthus roseus*. J. Plant Nutr. 40(7):974–982.

Bond D.A., Lawes D.A., Hawtin G.C., Saxena M.C., and Stephens J.H., 1985. Faba bean (*Vicia faba* L.). P. 199-265*In:* Summerfield RJ., Roberts E.H. (Eds) *Grain Legume Crops*, Collins, London, UK.

Brear E.M., Day D.A., and Smith P.M.C., 2013. Iron: an essential micronutrient for the legume-rhizobium symbiosis. Front. Plant. Sci. 4: 359.

Broughton J.W., Hernandez G., Blair M., BeebeS., Gepts P., and Van derleyden J., 2003. Beans (*Phaseolus spp*) model food legumes. Plant Soil 252:55-128.

Chaieb N., Bouslama M., and Mars M.,2011. Growth and yield parameters variability among faba bean (*Vicia faba* L.) Genotypes. J. Nat. Prod. Plant Resour.1(2): 81-90.

Chapman H.D., and Pratt P.F., 1961. Methods of analysis for soils, plants and waters. Univ. California, Berkeley, CA, USA.

Desnos T., 2008. Root branching responses to phosphate and nitrate. Curr. Opin. Pl. Bio. 11: 82–87.

Devau N., Cadre E.L.,Hinsinger P., and Gerard F., 2010. A mechanistic model for understanding root-induced chemical changes controlling phosphorus availability. Ann. Bot. 105(7): 1183–1197.

Dixon R., and Kahn D., 2004. Genetic regulation of biological nitrogen fixation. Nat. Rev. Microbiol. 2: 621– 631.

El-Agrodi M.W., Mosa A.A., and Elsherpiny M.A., 2011. Inorganic phosphorus forms in alluvial and calcreous soils as affected by different phosphorus application levels and incupation periods. J.Soil Sci. and Agric. Eng., Mansoura Univ. 2 (12): 1195 – 1206.

El-Ghamry A. M., Mosa A.A., and El-Naggar E.M., 2009. Optimum time for phosphorus fertilization on Egyptian alluvial soil.. Acta Agronomica Hung. 57(3):363-370.

Fouda K.F., 2017.Effect of phosphorus level and some growth regulators on productivity of faba bean (*Vicia Faba L*.). Egypt. J. Soil Sci.57(1):73-87.

Gasim S., and Link W., 2007. Agronomic performance and the effect of self-fertilization on German winter faba beans. J. Cent. Eur. Agric. 8(1):121-128.

Gupta P.K., 2009 Soil, plant, water and fertilizer analysis. Agrobios, India.

Heuzé V., Tran G., Delagarde R., Lessire M., Lebas F., 2018. *Faba bean (Vicia faba)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO.https://www.feedipedia.org/node/4926

Horneck Y., and Abak K., 2004. Inheritance of tolerance to leaf iron deficiency chlorosis in tomato. Euphytica139: 51-57.

Hussain A., Ali A., and Noorka I.R., 2012. Effect of phosphorus with and without rhizobium inoculation in nitrogen and phosphorus concentration and uptake by Mungbean (*Vigna radiata* L). J. Agric. Res. 50(1): 49-57.

Hussain R.M., 2017. The effect of phosphorus in nitrogen fixation in legumes. Agric. Res. & Tech. 5(1): 555652.

Idera F., Omotola O., Paul U.J., and Adedayo A., 2014. Evaluation of the Effectiveness of Different Acid Digestion on Sediments. J. App. Chem. 7(12):39-47.

Janmohammadi M., Amanzadeh T., Sabaghnia N., and Dashti S., 2016. Impact of foliar application of nano micronutrient fertilizers and titanium dioxide nanoparticles on the growth and yield components of barley under supplemental irrigation. Acta Agric. Slov. 107(2): 265-276.

Jasim A.H., and Obaid A.S., 2014. Effect of foliar fertilizers spray, boron and their interaction on broad bean (*Vicia faba L.*) yield. Scientific Papers, Ser. B, Horticulture, 58: 271-276

Jensen E.S., Peoples M.B., Hauggaard-Nielsen H., 2010. Faba bean in cropping systems. Field Crop Res.115(3):203-216.

Kasem F.E.A. 2012. Studies on Fertilizer Requirements of Faba Bean. M. Sc. Thesis Fac. Agric., Cairo University, Egypt.

Latati M., Bargaz A., Belarbia B., Lazali M., Benlahrech S., Tellah S., Kaci G., Drevon J., and Ounane S.M., 2016. The intercropping common bean with maize improves the rhizobial efficiency, resource use and grain yield under low phosphorus availability. Eur. J. Agron. 72:80-90.

Latati M., Blavet D., Alkama N., Laoufi H., Drevon J., Gérard F., Pansu M., and OunaneS.M., 2014. The intercropping cowpea-maize improves soil phosphorus availability and maize yields in an alkaline soil. Plant Soil 385:181–191.

Lindsay W.L., and Norvell W.A.,1978. Development of DTPA soil test for Zinc, Iron, Manganese and Copper. Soil Sci. Soc. Am. J. 42:421-428.

Liu R.Q., and Lal R., 2014. Synthetic apatite nanoparticles as a phosphorus fertilizer forsoybean (Glycine max). Sci. Rep. 4: 5686.

Lopez-Bucio J., Cruz-Ramırez A., and Herrera-Estrella L., 2003. The role of nutrient availability in regulating root architecture. Curr. Opin. Pl. Bio. 6: 280–287.

Mikhak A., Sohrabi A., Kassaee, M. Z. and Feizian M., 2017.Synthetic nanozeolite/nanohydroxyapatite as a phosphorus fertilizerfor German chamomile (Matricariachamomilla L.). Ind. Crops Prod. 95:444–452.

Mohammadi M., Hoseini N.M., Chaichi M.R., Alipour H., Dashtak, M., and Safikhani S., 2018.Influence of nano-iron oxide and zinc sulfate on physiological characteristics of peppermint. Commun. Soil Sci. Pl. Analysis 49(18): 2315–2326

Montalvo D., McLaughlin M.J., and Degryse F., 2015. Efficacy of hydroxyapatite nanoparticles as phosphorus fertilizers in Andisols and Oxisols. Soil Sci. Soc. Am. J. 79:551–558.

Naderi M.R., and Danesh-Shahraki A., 2013.Nanofertilizers and their roles in sustainable agriculture. Int. J. Agri. Crop. Sci. 5(19): 2229-2232.

Nadi E., Aynehband A. and Mojaddam M., 2013. Effect of nano-iron chelate fertilizer on grain yield, protein percent and chlorophyll content of Faba bean (*Vicia faba* L.). Int. J. Bioscis. 3 (9):267-272.

Ndakidemi P.A., and Dakora F. D., 2007. Yield components of nodulated cowpea (*Vigna unguiculata*) and maize (*Zea mays*) plants grown with exogenous phosphorus in different cropping systems. Aust. J. Exp. Agric. 47:583-589.

Ndor E., Dauda N., Abimuku E., Azagaku D. and Anzaku H., 2012. Effect of phosphorus fertilizer and spacing on growth, nodulation count and yield of cowpea (*Vigna unguiculata*(L) Walp) in Southern Guinea Savanna Agro-ecological Zone, Nigeria. Asian J. Agric. Sci. 4(4):254-257.

Nyoki D., and Ndakidemi P.A., 2013.Economic benefits of *Bradyrhizobium japonicum* inoculation and phosphorus supplementation in cowpea (*Vigna unguiculata*(L) Walp) grown in northern Tanzania. American J. Res. Comm. 1(11):173-189.

O'Hara G.W., DilworthM.J., Boonkerd N., and Parkpian P., 1988. Iron-deficiency specifically limits nodule development in peanut inoculated with Bradyrhizobium sp. New Phytol. 108(1): 51–57.

Osemwotai O., Ogboghodo I.A., and Aghimien E.A., 2005. Phosphorus retention in soils of Nigeria- a review. Agric. Rev. 26(2):148-152.

Rahman M.M., Bhuiyan M.M.H., Sutradhar G.N.C., and Paul A.K., 2008. Effect of phosphorus, molybdenum and rhizobium inoculation on yield and yield attributes of Mungbean. International Journal of Sustain. Crop Prod. 3(6):26-33.

Rameshaiah G. N., and Jpallavi S., 2015. Nano fertilizers and nano sensors–an attempt for developing smart agriculture. Int. J. Eng. Res. Gen. Sci. 3(1): 314-320.

Rotaru V., 2010. The effects of phosphorus application on soybean plants under suboptimal moisture conditions. Lucrari Ştiinţifice 53(2):27- 30.

Rui M., Ma C., Hao Y., Guo J., Rui Y., Tang X., Zhao Q., Fan X., Zhang Z., Hou T., and Zhu S., 2016. Iron oxide nanoparticles as a potential iron fertilizer for peanut (Arachishypogaea). Front. Plant. Sci. 7:815.

Salem A.K., El-Harty E.H., Ammar M.H., and Alghamdi S.S., 2014. Evaluation of faba bean (*Vicia faba L.*) performance under various micronutrient foliar applications and plant spacing. Life Sci. J. 11(10): 1298-1304.

Shen J., Yuan L., Zhang J., Li H., Bai Z., Chen X., Zhang W., and Zhang F., 2011.Phosphorus Dynamics: From Soil to Plant. Plant Physiol. 156:997-1005.

Singh A., Baoule A., Ahmed H., Dikko A., Aliyu U., Sokoto M., Alhassan J., Musa M., and Haliru B., 2011. Influence of phosphorus on the performance of cowpea (Vigna unguiculata (L) Walp.) varieties in the Sudan savanna of Nigeria. Agric. Scis. 2(3):313-317.

Singh A.K., and Kumar P., 2009. Nutrient management in rainfed dryland agroeosystemin the impending climate change scenario. Agril. Situ. India66(5):265-270.

Singh A.K., Bharati R.C., Manibhushan N.C., and Pedpati A., 2013. An assessment of faba bean (Vicia faba L.) current status and future prospect. African J. Agric. Res., 8(50):6634-6641.

Singh A.K., Bhatt B.P., Upadhyaya A., Kumar S., Sundaram P.K., Singh B.K., Chandra N., and Bharati R.C., 2012. Improvement of faba bean (Vicia faba L.) yield and quality through biotechnological approach: A review. Afr. J. Biotechnol. 11(87):15264-15271.

Slatni, T., Krouma, A., Aydi, S., Chaiffi, C., Gouia, H. and Abdelly, C. 2008. Growth, nitrogen fixation and ammonium assimilation in common bean (*Phaseolus vulgaris* L) subjected to iron deficiency. Plant Soil 312(1-2):49–57.

Smith L.A., Houdijk J.G.M., Homer D., and Kyriazakis I., 2013. Effects of dietary inclusion of pea and faba bean as a replacement for soybean meal on grower and finisher pig performance and carcass quality. J. Anim. Sci. 91(8): 3733-3741.

Stamford N., Santos C., and Dias S., 2006. Phosphate rock biofertiliser with acidithiobacillus and rhizobia improves nodulation and yield of cowpea (*Vigna unguiculata*) in greenhouse and field conditions. TG: Tropical Grasslands 40:222-230.

Taskin, M.B., SahinO., Taskin H., Atakol O., Inal A., and Gunes A., 2018. Effect of synthetic nano-hydroxyapatite as an alternative phosphorus source on growth and phosphorus nutrition of lettuce (Lactuca sativa L.) plant. J. P. Nut.41(9):1148–1154.

Ye L., Li L., Wang L., Wang S., Li S., Du J., Zhang S., and Shou H., 2015. MPK3/MPK6 are involved in iron deficiency-induced ethylene production in Arabidopsis. Front. Plant Sci. 6:953.

Zafar M., Abbasi M., Rahim N., Khaliq A., ShaheenA., Jamil M. and Shahid M., 2011. Influence of integrated phosphorus supply and plant growth promoting rhizobacteria on growth, nodulation, yield and nutrient uptake in *Phaseolus vulgaris*. Afr. J. Biotechnol. 10:16793-16807.

Zargar S.M.,Agrawal G.K., Rakwal R., and Fukao Y., 2015.Quantitative proteomics reveals role of sugar in decreasing photosynthetic activity due to Fe deficiency. Front. PlantSci. 6:592.

تداعيات إضافة نانو هيدروكسي اباتيت و نانو أكسيد الحديد على إنتاجية الفول البلدى (*Vicia faba L.*)

محمد على أحمد عبد السلام

قسم الأراضى و المياة - كلية الزراعة - جامعة بنها - مصر

تم تقييم تاثير التسميد بالنانو فوسفور و الرش بالنانو حديد على إنتاجية الفول البلدى (*Vicia faba L.*) المزروع في ارض قوامها light clay بميت حلفا محافظة القليوبية ، مصر باستخدام تصميم قطاعات تامة العشوائية. التجربة كانت عاملية متعلقة بعاملين الأول هو إضافة الفوسفور و تم على خمس مستويات P_0، P_1، P_2، P_3، P_4 و هم على الترتيب كالتالى : عدم إضافة P ، إضافة P بمعدل ٢٠ كجم P هكتار$^{-1}$ على صورة تربل سوبر فوسفات، إضافة P بمعدل ٤٠ كجم P هكتار$^{-1}$ على صورة تربل سوبر فوسفات، إضافة P بمعدل ٢٠ كجم P هكتار$^{-1}$ على صورة نانو هيدروكسي اباتيت، إضافة P بمعدل ٤٠ كجم P هكتار$^{-1}$ على صورة نانو هيدروكسي اباتيت و الثاني هو الرش الورقى بالحديد و تم على اربع مستويات Fe_0، Fe_1، Fe_2، Fe_3 و هم على الترتيب كالتالى : عدم إضافة Fe ، إضافة Fe بمعدل ١٥٠ مليجرام Fe لتر$^{-1}$ على صورة نانو أكسيد حديد ، إضافة Fe بمعدل ٣٠٠ مليجرام Fe لتر$^{-1}$ على صورة نانو أكسيد حديد، إضافة Fe بمعدل ٣٠٠ مليجرام Fe لتر$^{-1}$ على صورة حديد مخلبى (Fe-EDTA). علما بان معدل الرش كان ١٢٠٠ لتر هكتار$^{-1}$. كلا المعدلان المستخدمان من إضافة نانو فوسفور (المنخفض والمرتفع) كانا اعلى تاثيرا من إضافة الفوسفور على صورة لا يتواجد بها على صورة نانو فزادا من طول النبات و عدد القرون. بالنسبة الى محصول الحبوب و امتصاص N و P و Fe بواسطة الحبوب فوجد انة عند نفس معدل الإضافة أعطى الفوسفور المضاف على صورة نانو قيم اعلى من الفوسفور المضاف على صورة تربل سوبر فوسفات. و بالرغم من ان المعدل المنخفض من P المضاف على صورة نانو كان ترتيبه الثالث تاليا لل P المضاف على صورة تربل سوبر فوسفات الا ان الفروق بينهم كانت طفيفة. الحديد المضاف على صورة نانو في كل من معدلي الإضافة (المنخفضة و المرتفعة) كان افضل معاملات الحديد تأثيرا. زاد من قيم مؤشرات مختلفة عند المعدل المنخفض و المرتفع منة كالتالي على نفس الترتيب: ١١.٨ و ٢٠.١% بالنسبة لمحصول الحبوب، ٢٥.٦ و ٣٥.٥% بالنسبة لطول النبات، ٢١.٨ و ٣٦.٩% بالنسبة لعدد القرون، ١٦.٢ و ٣٢.٤ بالنسبة لامتصاص N ، ١٥.٧ و ٣١.٠% بالنسبة لامتصاص P، ٤٥.٤ و ٧٠.١٣% بالنسبة لامتصاص Fe.