J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (10): 467 - 472, 2018

Response of Lettuce (*Lactuca sativa L.*) to Foliar Spray Using Nano-Urea Combined with Mycorrhiza

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

ABSTRACT

A factorial randomized complete block field experiment was carried out on lettuce (*Lactuca sativa var. longifolia cv.* Balady), grown on a heavy clay *torrifluvent* soil during two successive seasons (2016/2017 and 2017/2018) at the farm of the Faculty of Agriculture, Moshtohor, Benha University to study foliar application with nano-urea and biofertilization using Vesicular Arbusclar mycorrhiza (VAM). Factor 1 included 2 treatments: none (B_0) and VAM (B_1); Factor 2 included 5 treatments: no urea spray (spray with water) (N_0), spray with ordinary urea at 5000 mg N L^{-1} (N_1), spray with nano-urea at 2500 mg N L^{-1} (N_2), 3750 mg N L^{-1} (N_3) and 5000 mg N L^{-1}(N_4). Spray was in 3 times 30, 40 and 50 days after transplant at a rate of 1200 L ha^{-1}each time. All growth parameters of plant height, number of leaves $plant^{-1}$, fresh and plant dry weight increased by N or VAM singly or combined. Highest positive response occurred in plant height as well as weight and given by N_3B_1. All nano-urea treatments surpassed the ordinary one, particularly the middle nano rate. The highest nano rate seemed excessive since N_3 did not continue to score further increase. Contents on N, P and K increased by nano-urea. NO_3-N increased progressively with increased application of urea, and the increase progressed with increased rate of nano-urea. The nano application proved practical and more efficient since a concentration of as low as 2500 mg N L^{-1} proved superior to that of 5000 and mg N L^{-1} ordinary urea N.

INTRODUCTION

Lettuce is an important leafy vegetable in Egypt (Khalil *et al.,* 2016) with leaves of high moisture, minerals and vitamins (USDA, 2011). Its leaves contain high moisture, minerals and several vitamins such as vitamin A, B, C and K (USDA, 2011). Vegetables (including lettuce) are grown in Egypt, mainly under open field conditions, although production under greenhouses is expanding, and the government established about 40 000 ha greenhouse area during the year 2017 (Elings and Raeza, 2017). Lettuce is grown in Egypt for local consumption and export (Midan and Sorial, 2011).

Nitrogen is essential for plant growth (Liu *et al.,* 2014) and involved in important syntheses and formation of many important substances and compounds plant such as amino acids, enzymes, DNA, RNA and chlorophyll (Khalil *et al.,* 2016), therefore it must be available for plants in adequate amounts. Yield of lettuce and weight per lettuce head depend on the amount of N available for the crop (Hosseny and Ahmed, 2009) but the amount must be adequate not excessive (Liu *et al.,* 2014). Excessive application of N to crops in general leads to unwanted environmental consequences including accumulation of high nitrate and nitrite contents leafy vegetables and fruits, among other problems such as eutrophication, environmental contamination in underground waters used for drinking (Wang *et al.,* 2002 and Bobbink *et al.,* 2012). Nitrates and nitrites may accumulate in edible plant tissues particularly in leafy vegetables (Wang *et al.,* 2002), especially lettuce with contents of up to 2500 mg NO_3-N kg^{-1} fresh weight (Dapoigny et al 2000). Consumption of such plants causes detrimental effects on health (Ahmadil *et al.,* 2010). To avoid application of excessive rates of N to crops, particularly the edible leafy ones, foliar spray of N as urea is preferred (Mondal and Al-Mamun, 2011), particularly when in nano forms, a technique which proved effective for plant nutrition due to its high absorption and utilization efficiency by plants (Mondal and Mamun, 2011and Manjunatha *et al.,* 2016). Foliar spray usually uses low amounts of fertilizer N (Gul *et al.,* 2011), and urea is a source of N with high concentration of N nutrient (Abu-Rayyan *et al.,* 2004 and PEI, 2014). It can be used as foliar spray on plant with no scorching damage on leaves compared with fertilizers of salt nature (Mondal and Mamun, 2011). The use of nano-scale urea as foliar fertilization showed preference to the non-nano methods (Manjunatha *et al.,* 2016). Nano particle of any material are particles with extremely small size of less than 100 nm Ø (DeRosa *et al.,* 2010). Nano-fertilization is gaining popularity since it proved practical and highly effective (DeRosa *et al.,* 2010, EL-Aila *et al.,* 2015 and Manjunatha *et al.,* 2016).

The purpose of the current study is to assess the effect of foliar application with nano-urea and biofertilization with Vesicular Arbusclar mycorrhiza (VAM) on lettuce plant (*Lactuca sativa var. longifolia cv.* Balady).

MATERIALS AND METHODS

1. Experimental

An experiment was carried out on lettuce plants, (*Lactuca sativa var. longifolia cv.* Balady), grown on a heavy clay *torrifluvent* soil (Table 1) during two successive seasons (2016/2017 and 2017/2018) at the Experimental Farm, Faculty of Agriculture, Moshtohor, Benha University to study the response to foliar spray with nano-urea (urea loaded with synthesized nanoparticles of chitosan) and biofertilization with Vesicular Arbusclar mycorrhiza (VAM).

Table 1. Main properties of the soil used in the experiment.

Soil property	Value
% Sand	11.8
% Silt	29.6
% Clay	58.6
Texture	Heavy clay
CEC ($cmol_C kg^{-1}$)	43.4
EC (dS m^{-1})	1.3
pH	7.6
Organic Matter (g kg^{-1})	20.1
$CaCO_3$ (g kg^{-1})	17.2
Available N, P and K (mg kg^{-1})	
N	30
P	5
K	115

Notes: Texture: according to the international soil texture triangle; EC in paste extract; pH: in 1:2.5 (w:v) soil:water suspension .Extracts of NPK : KCl (N), $NaHCO_3$ (P); NH_4-OAc (K)

The design was a randomized complete block in 3 replicates, factorial with two factors; factor 1 included 2 treatments, none and biofertilization (designated B_0 and B_1 respectively). Factor 2 included 5 treatments, no urea spray (spray with water), spray with ordinary urea of 5000 mg N L^{-1}, spray with nano-urea of 2500 mg N L^{-1}, 3750 mg N L^{-1}, and 5000 mg N L^{-1} (designated N_0,N_1, N_2, N_3, and N_4 respectively). Spraying was in 3 times 30, 40 and 50 days after transplant. Spray rate at each time was 1200 L ha^{-1}. Lettuce was transplanted on 4th of October and harvested on 14th of January. Transplants were inoculated with VAM by dipping the roots for 30 minutes in a 40 % sucrose solution containing VAM culture. Cultures were prepared by the Botany Department, Faculty of Agriculture, Moshtohor, Benha University. The plot area was 13.3 m^2 each consisting of 5-ridges each is 60-cm wide and 3.5-m long with 20 cm between ridges. All plots received 63 kg P ha^{-1} (as Ca-superphosphate, 70 g P kg^{-1}) and 80 kg K ha^{-1} (as K-sulphate 400 g K kg^{-1}) during soil preparation. Other agricultural practices were done as followed by farmers in the district. At harvest, four plants from each plot were randomly taken for determination of plant height, number of leaves, and weight per plant. Fig 1 shows an image of urea loaded with synthesized nanoparticles of chitosan under Transmission electron microscopy (TEM).

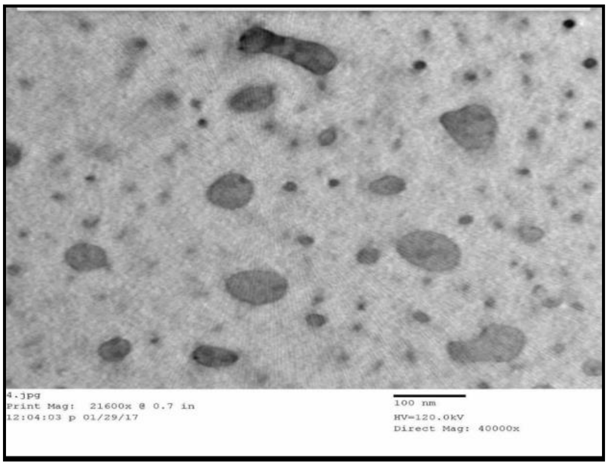

Fig. 1. Transmission electron microscopy (TEM) image of urea loaded with synthesized nanoparticles of chitosan.

2- Laboratory analyses:

Chemical analyses were done according to methods cited in Chapman and Pratt (1961) and black *et al.* (1965). Nitrate-N in lettuce leaves was determined according to (Cataldo *et al*, 1975) while carotene, chlorophyll were by method cited in AOAC (1990).

RESULTS AND DISCUSSION

Plant height (Table 2):

Plant height was lowest (21.63 cm) where plants received neither N nor biofertilizer. Treatment by either N or VAM or both gave increases ranging from 42.6% by N_0B_1 to as high as 101.0% N_3B_1 (Table 2). The main effect of N-fertilization was $N_3 > N_2 > N_4 > N_1 > N_0$ indicating an increase by urea application, particularly the nano forms, and especially the middle nano rate.

The high nano urea was therefore excessive and must have had caused a retardation of plant growth. The high positive response to the middle nano-urea was particularly marked under conditions of no VAM (93.6%) than in VAM's presence (41.0%). On the other hand the decreasing effect of the highest nano-urea (N_4) relative to the middle one (N_3) was more marked in absence of VAM (12.5%) than in its presence (8.0%). Such results indicate that the positive effect of VAM alleviates the negative effect of excessive nano-urea.

The main effect of VAM showed an increase in plant height averaging 13.0%, and was much pronounced where no urea was applied (N_0) (42.6%) indicating high response to VAM where no N was applied.

Number of leaves plant^{-1} (Table 2):

The number of leaves per plant underwent a pattern which is rather similar to that of plant height (Table 2). The lowest value was 18.0 given by plants receiving neither N nor biofertilizer. Plants treated with either N or VAM or both increased their number of leaves by 18.3% due to N_1B_0 up to as high as 94.4% due to N_3B_1. The main effect of N-fertilization resembled that of plant height, i.e. $N_3 > N_2 > N_4 > N_1 > N_0$ demonstrating increased number of leaves upon urea application, particularly nano form, and especially the middle nano-rate. Increasing the nano form above its middle rate caused no further increase, but a decrease averaging 21.5% compared with leaves of the middle nano-rate. The increase in leaves number caused by the middle nano-urea was more in absence of VAM (55.6%) than in its presence (45.8%). On the other hand the decrease caused by the excessive nano-urea relative to the middle rate was less (19.1%) with VAM's presence but greater in VAM's absence (25.0%) thus demonstrating the biofertilizer's ability to reduce the excessive nano-urea effect.

The main effect of VAM was an average of 26.5% increase, and was much apparent where no urea was applied (33.3 %) also with the highest nano urea (34.7%) indicating high response to VAM where no N was applied and the VAM ability to reduce the excessive nano urea effect.

Table 2. Effect of urea foliar spray and VAM biofertilization on lettuce (means of two seasons 2016/17 and 2017/18): Plant height and number of leaves plant-^{1}

Biofertiliztion (B)*	Urea N-Fertilization (N)*											
	N_0	N_1	N_2	N_3	N_4	mean	N_0	N_1	N_2	N_3	N_4	mean
	Plant height (cm)						Number of leaves plant^{-1}					
B_0	21.63	32.95	38.16	41.88	36.63	34.25	18.0	21.3	23.0	28.0	21.0	22.3
B_1	30.84	37.08	42.05	43.48	40.00	38.69	24.0	26.7	27.0	35.0	28.3	28.2
mean	26.24	35.02	40.10	42.68	38.32		21.0	24.0	25.0	31.5	24.7	
LSD 0.05	B:0.46 N:0.65 BN:0.91						B:0.8 N:1.2 BN:1.6					

***Notes: N_0 and N_1 are spray with water (no N) and spray with urea N solution of 5000 mg N L^{-1} respectively. N2, N3, and N4 are nano urea spray with 2500 mg N L^{-1}, 3750 mg N L^{-1}, and 5000 mg N L^{-1} respectively. The two biofertilization treatments are B0: none and B1: VAM biofertilization, respectively.**

Fresh weight plant^{-1} (Table 3):

The response resembled that of plant height as well as that of the number of leaves plant^{-1}. The non-treated plants showed the lowest fresh weight of 275.7 g plant^{-1} which increased by addition of fertilizers (Table 3). The increase ranged from 30.2% due to N_0B_1 and up to 142.4% due to N_3B_1, reflecting growth enhancement due to combining biofertilization with nano-urea at its medium rate. The main effect of N-fertilization took exactly the same pattern of plant height demonstrating increased fresh plant weight due to urea application, particularly nano form, and especially the middle nano-rate. The highest average increase of 63.8% was given by the middle nano-urea. Further increase of nano-urea caused no further increase but a decrease of 25.5% reflecting a negative implication on plant growth at such excessive nano-urea.

The main effect of biofertilization was an average increase of 34.0%, and the increase was particularly marked (49.4%) where no urea was applied thus indicating that VAM's positive effect is more in absence of N.

Dry weight plant^{-1} (Table 3):

The pattern of response to treatments concerning the dry weight of lettuce was similar to that of the fresh weight (Table 3). Dry weight of the non-treated plants was lowest (12.10 g plant^{-1}) increasing upon application of the biofertilizer or urea or both ranges starting from 22.8% by N_1B_0 to as high as 155.7% by N_3B_1, with a clear indication of a cumulative positive effect of combining the middle rate of nano-urea with VAM on plant growth. Urea gave positive effects with increases of the nano forms surpassing the non-nano form. The highest increase was that of the middle nano-urea (an average of 89.1%), after which, no further increase occurred, but a decrease of 36.0% (as related to the weight given by the middle nano-urea). The excessive nano-urea thus proved of no further positive effect.

The main effect of biofertilization was an average increase of 27.4%. The increase was particularly marked (44.7%) where no urea was applied**,** which shows that the positive response to VAM was much apparent where no N was applied.

Assessment of response of plant growth parameters:

The response of each of the plant growth parameters (i.e. plant height, number of leaves plant^{-1}, fresh and dry weights) to the various treatments was nearly identical exhibiting increases due to urea fertilization. Nitrogen is essential for growth of plants; particularly leafy vegetables (Sreeramulu *et al.,* 1996 and Hosseny and Ahmed, 2009) provided its application in non-excessive rates (Liu *et al.,* 2014). The soil of the current experiment was extremely poor in its contents of available N, thus the response to N application was significant. The nano form of application was superior to the ordinary urea spray. Such superiority was shown when a concentration of 2500 mg nano-urea N L^{-1} surpassed the effect of 5000 mg ordinary urea N L^{-1}. This demonstrates the high efficiency of the nano technique over the ordinary techniques of nutrient delivery (DeRosa *et al*., 2010 and EL-Aila *et al* 2015). Increased growth due to VAM was reported by Siddiqui and Pichtel (2008) and Cantrell and Linderman (2001). The non-continued increase at the high nano-urea indicates a retarding effect caused by excessive N. Crops respond negatively to excessive N, particularly the edible leafy ones (Mondal and Al-Mamun, 2011). Superiority of the nano-spray of urea over the ordinary urea spray was maintained up to a concentration of 3750 mg N L^{-1} above which level there was a decrease in the values of plant growth parameters with a spry solution concentration of 5000 mg N L^{-1}. A retarding effect at such level of concentration must have had occurred. The alleviation of the retarding effect caused by presence of VAM is an indication of the mycorrhiza harnessing the negative effect caused by abiotic stresses on lettuce (Cantrell and Linderman, 2001). Generally, the nano techniques of fertilization proved more effective giving more growth and nutrient contents than the ordinary forms (DeRosa *et al*. 2010, EL-Aila *et al.,* 2015 and Manjunatha *et al 2016*). Chamola *et al,* (1999) Stated that VAM increases plant growth through enhancing nutrient uptake and plant resistance to pathogen infection.

Table 3 . Effect of urea foliar spray and VAM biofertilization on lettuce (means of two seasons 2016/17 and 2017/18): fresh and dry weight of leaves per plant .

Biofertiliztion (B)*	N-Fertilization (N)*											
	N_0	N_1	N_2	N_3	N_4	mean	N_0	N_1	N_2	N_3	N_4	mean
	Fresh weight plant^{-1} (g)						Dry weight plant^{-1} (g)					
B_0	275.7	359.0	439.0	458.3	371.7	380.7	12.10	14.86	19.69	25.05	16.84	17.71
B_1	412.0	445.7	557.0	668.3	467.7	510.1	17.51	17.78	27.66	30.94	18.95	22.57
mean	343.8	402.3	498.0	563.3	419.7		14.80	16.32	23.68	27.99	17.90	
LSD 0.05	B:9.6 N:11.0 BN:15.5						B:1.02 N:0.73 BN:1.94					

***See footnotes of Table 2**

Total N content in dry matter plant (Table 4):

The pattern of response was in line with those of the growth parameters (Table 4). The non-treated N_0B_0 plants contained 9.68 g N kg^{-1} dry matter plant, while all treatments receiving amendments raised N contents with a maximum content of 44.27 g kg^{-1} given by the middle nano-urea combined with VAM .Increases ranged from 101.2% due to N_1B_0 to 357.3% due to N_3B_1 .The increase in plant N is a manifestation of the considerable positive effect of N and VAM application singly or combined. The highest increase was given by the middle nano-urea (averaging 134.7%) after which no further increase occurred, but a decrease (averaging 18.3%, as related to what was given by the middle nano-urea). Thus the high nano-urea was excessive and caused a decrease in N content in plant tissues.

The main effect of biofertilization was an average increase of 49.2%. The increase was particularly marked (133.9%) where no urea was applied, which shows that VAM's positive effect was much apparent where no N was applied.

NO_3-N in fresh plant tissues (Table 4):

All treatments providing N to plant caused an increase in the contents of nitrate nitrogen in fresh plant tissues (Table 4). The non-treated plants showed contents of 285.0 mg kg^{-1} while the treated showed higher contents ranging from 320.2 mg kg^{-1} (by N_1B_0) to 393.7 $mgkg^{-1}$ (by N_3B_0). The four urea treatments caused an increase in NO_3-N, particularly the nano-ones, especially the first nano-rate (average of 19.2%). NO_3-N progressed only up to the first nano-rate, after which there was a decrease followed by lower contents, but all of urea application had higher NO_3-N than with no added urea treatment. The increased NO_3-N progressed with the increase in urea and its application rates, only where urea was applied non-combined with VAM while when combined with VAM NO_3-N decreased with the increase in urea except for N_2 where it increased. This reflects the ability of VAM to reduce NO_3-N in leaves.

The main effect of biofertilization showed no significant response with a slight decrease in NO_3-N averaging 3.2%. Biofertilization increased NO_3-N where no urea was added as well as where ordinary urea was sprayed while it decreased under foliar spray with nano-urea where N_2 gave the highest decrease.

Assessment of response of N contents in plant:

The range of 285 to 394 mg NO_3-N obtained in the current study is in agreement with ranges reported by Abu-Rayyan *et al.,* (2004) of between 24 mg kg (for the non-fertilized plants) up to as high a 743 mg kg^{-1} (for plants given nitrate fertilizers) with urea-fertilized plants exhibiting lower values than the nitrate-fertilized ones. Increased total-N and NO_3-N in plant caused by application of urea and nano-urea is a direct outcome of fertilization with N. The higher N given by the nano spray up to the middle nano- rate coincided with the greater growth parameter indicating greater efficiency of nano-urea (Manjunatha *et al.*, 2016), particularly its middle rate. The highest NO_3-N obtained at rates beyond the middle nano-urea coincided with the retarding effect caused by the high nano-urea. Abu-Rayyan *et al.,* (2004) added different nitrogen forms to lettuce and found that urea was the most effective one that increased N and nitrate content in lettuce.

VAM ability to increase nutrient acquisition by plant could explain the increase of N uptake due to biofertilizaion with VAM (Abbott and Robson, 1982). The increase in nutrient uptake results in higher growth by plant and increase in sugar content. Behr and Wiebe, (1992) reported a negative correlation between sugar content in lettuce and its nitrate content.

Table 4. Effect of urea foliar spray and VAM biofertilization on lettuce (means of two seasons 2016/17 and 2017/18): Contents of total –N and NO_3-N in fresh leaves

Biofertiliztion (B)*	Nitrogen content in dry leaves (g kg^{-1})						NO_3-N in fresh leaves (mg kg^{-1})					
	N-Fertilization (N)*											
	N_0	N_1	N_2	N_3	N_4	mean	N_0	N_1	N_2	N_3	N_4	mean
B_0	9.68	19.48	24.12	31.62	26.55	22.29	285.0	320.2	379.6	393.7	348.9	345.5
B_1	22.64	27.24	36.65	44.27	35.46	33.25	343.0	333.4	368.8	302.2	325.4	334.6
mean	16.16	23.36	30.39	37.94	31.00		314.0	326.8	374.2	348.0	337.2	
LSD 0.05	B:1.71	N:0.66	BN:0.94				B:ns**	N:23.6	BN:33.4			

***See footnotes of Table 2. ** ns: not significant.**

P and K contents in dry matter plant (Table 5):

The pattern of response regarding P as well as K contents in plant was in line with that of N contents (Table 5). The non-treated N_0B_0 plants contained 2.337 g P kg^{-1} dry matter plant, while all treatments receiving amendments raised P contents with a maximum of 6.497 g kg^{-1} given by the middle nano urea combined with VAM. Comparable values for K were 35.39 g K kg^{-1} by N_0B_0 and 81.97 g K kg^{-1} by the middle nano-urea+VAM.

Table 5. Effect of urea foliar spray and VAM biofertilization on lettuce (means of two seasons 2016/17 and 2017/18): Contents of P and K in dry leaves.

Biofertiliztion (B)*	Phosphorus content (g kg^{-1})						Potassium content (g kg^{-1})					
	N-Fertilization (N)*											
	N_0	N_1	N_2	N_3	N_4	mean	N_0	N_1	N_2	N_3	N_4	mean
B_0	2.337	3.187	3.957	4.967	3.827	3.655	35.39	49.16	56.99	59.87	53.00	50.88
B_1	3.127	4.080	5.107	6.497	4.773	4.717	52.12	68.90	76.50	81.97	71.10	70.12
mean	2.732	3.633	4.532	5.732	4.300		43.76	59.03	66.74	70.92	62.05	
LSD 0.05	B:0.002	N:0.128	BN:0.182				B:0.37	N:1.39	BN:1.96			

***See footnotes of Table 2**

Increases ranged from 36.4% due to N_1B_0 to 178.0% due to N_3B_1, for P contents while respective increases for K content were 38.9 and 131.6 %. The increase in K and P contents is a manifestation of the considerable positive effect of N and VAM application singly or combined. The highest increase was given by the middle nano-urea (averaging 109.8 and 62.1% for P and K contents respectively) after which no further increase occurred, but a decrease (averaging 25.0 and 12.5% for P and K contents respectively as related to what was given by the middle nano-urea). The high application of nano-urea caused a decrease in P and K contents. Yildirim *et al.*, (2007) studied the effect of foliar application with different rates of urea on broccoli and found that increasing urea rates increased P and K uptake.

The main effect of biofertilization was an average increase of 29.1% for P and 37.8% for K. Such increases were particularly marked (33.8% for P, and 47.3% for K) where no urea was applied. This illustrates that VAM has a marked positive effect in increasing nutrient contents even under absence of N- application. Dar and Resh, (2017) stated that VAM increases nutrient uptake by plant especially phosphate.

CONCLUSION

Nano technique in foliar spray of urea proved extremely efficient in increasing growth parameter of lettuce. A foliar spray using as little concentration as 2500 mg nano- urea N L^{-1} proved more effective than foliar spray with ordinary urea at 5000 mg N L^{-1}. A foliar spray with 3750 mg nano-urea N L^{-1} increased growth parameters by surpassing those given by the 5000 mg N L^{-1} soluble urea by up to 100% or more. Application of nano-urea must not exceed the 3750 mg N L^{-1}, otherwise a decrease would occur at the excessive 5000 mg nano-urea N L^{-1}. Nitrate N increases with increased application of urea; however presence of VAM would harness the retarding effect of excessive nano-urea application.

REFERENCES

Abbott L.K., and Robson A.D., 1982. The role of vesicular arbuscular mycorrhizal fungi in agriculture and the selection of fungi for inoculation. Aust. J. Agric. Res. 33(2) 389 – 408.

Abu-Rayyan A., Kharawish B.H., and Al-Ismail K., 2004. Nitrate content in lettuce (*Lactuca sativa* L) heads in relation to plant spacing, nitrogen form and irrigation level. J. Sci. Fd. Agric. 84:931- 936.

Ahmadil H., Akbarpour V., Dashti F., and Shojaeian A., 2010. Effect of different levels of nitrogen fertilizer on yield, nitrate accumulation and several quantitative attributes of five Iranian spinach accessions. Amer. Euras. J. Agric. Environ. Sci. 8(4):468-473.

AOAC., 1990. Official Methods of Analysis (12th Ed.). Association of Official Agriculture Chemists, Washington, D.C., USA.

Behr U., and Wiebe H.J., 1992. Relation between photosynthesis and nitrate content of lettuce culfivars. Sci. Hortic. (Amsterdam) 49:175-179.

Black C.A., 1965. Methods of soil analysis, American Society of Agronomy, Medison, Wisconsin, USA.

Bobbink R., Bal D., Van Dobben H.F., Jansen A.J.M., Nijssen M., Siepel H., Schamineé J.H.J., Smits N.A.C., and De Vries W., 2012. The effects of nitrogen deposition on the structure and functioning of ecosystems P. 39-71 *In:* Smits N.A.C., and Bal D. (eds), Recovery strategies for nitrogen-sensitive habitats. aAlterra ageningen ur & natura 2000 programme directorate of the ministry of economic affairs, agriculture and innovation, EU.

Cantrell I.C., and Linderman R.G., 2001. Pre-inoculation of lettuce and onion with VA mycorrhizal fungi reduces deleterious effects of soil salinity. Pl. Soil 233:269–281.

Cataldo D.A., Haroon M., Schader L.E., and Yongs V.L., 1975. Rapid colorimetric determination of nitrate in plant tissue by nitration of Salicylic acid. Commun. Soil Sci. Plant Anal. 6(1): 71-80

Chamola B.P., Giri B., and Mukerji K.G., 1999. Vesicular Arbuscular Mycorrhizal Fungi: Biofertilizer for the Future. P. 225-234 *In:* Singh J. and Aneja K.R (eds.), From ethnomycology to fungal biotechnology exploiting fungi from natural resources for novel products. Springer Science+Business Media, New York, USA.

Chapman H.D., and Pratt R.A., 1961. Methods of Analysis for Soils and plants. Division of Agricultural Science, University of California, Riverside, U.S.A.

-Dapoigny L., De-Tourdonnet S., Roger-Estrade J., Jeuffroy M., and Fleury A., 2000. Effect of nitrogen nutrition on growth and nitrate accumulation in lettuce (Lactuca Sativa L.), under various conditions of radiation and temperature. Agronomie 20:843–855.

Dar M.H., and Resh Z.A., 2017. Vesicular Arbuscular Mycorrhizal (VAM) Fungi- as a Major Biocontrol Agent in Modern Sustainable Agriculture System. Russ. Agric. Sci. 43(2):138–143.

DeRosa M.R., Monreal C., Schnitzer M., Walsh R., and Sultan Y., 2010. Nanotechnology in fertilizers. National Nanotech. J. 5(2): 91-96.

El-Aila H.I., EL-Sayed S.A.A, and Yassen A. A., 2015. Response of spinach plants to nanoparticles fertilizer and foliar application of iron. International J. Environ., 4(3):181-185.

Elings A., and Raeza E., 2017. Protected horticulture in Egypt: A study on the technology of protected cultivation in Egypt. Report WPR-704. Wageningen University & Research, BU Greenhouse Horticulture. Netherlands Enterprise Agency.

Gul H., Said A., Saeed B., Mohammad F., and Ahmad I., 2011. Effect of foliar application of nitrogen, potassium and zinc on wheat growth. ARPN J. Agric. Biol. Sci., 6(4):56-58.

Hosseny M.H., and Ahmed M.M.M., 2009. Effect of nitrogen, organic and bio fertilization on productivity of lettuce (cv. Romaine) in sandy soil under Assiut conditions. Ass. Univ. Bull. Environ. Res. 12(1):79-93.

Khalil M.A.I., Mohsen A.A.M., and Abdel-Fattah M.K., 2016. Effect of bio and mineral nitrogen fertilization on growth, yield and quality of lettuce plants under sandy soil conditions. Middle East Journal of Applied Sciences 6 (2):411-417.

Liu C.V., Sung Y., Chen B., and Lai H., 2014. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa L.*). Int. J. Environ. Res. Public Health 11(4):4427-4440.

Manjunatha S.B., Biradar D.P., and Aladakatti Y.R., 2016. Nanotechnology and its applications in agriculture: A review. J. Farm Sci. 29(1):1-13.

Midan S.A., and Sorial M.E., 2011. Some antioxidants application in relation to lettuce growth, chemical constituents and yield. Aust. J. Basic Appl. Sci. 5(6): 127-135.

Mondal A., and Mamun A., 2011. Effect of foliar application of urea on the growth and yield of tomato. Front. Agric. China 5(3): 372–374.

PEI, Analytical Laboratories Soil Testing (2014) Urea fertilizer in crop production. 23 Innovation Way Charlottetown, PEC1E 0B7, Canada.

Siddiqui Z.A., and Pichtel J., 2008. Micorrhiza: An overview. P. 1-35. *In:* Siddiqui Z.A., Akhtar M.S., and Futi K. (eds) Mycorrizae :Sustainable agriculture and forestry. Springer Sci. NY, USA.

Sreeramulu K.R., Shetty Y.V., and Selly T.K., 1996. Effect of VA mycorrhiza on the growth of two important leafy vegetables. Madras Agric. J. 83(6):362-364

USDA, Agricultural Research Service. (2011) USDA National Nutrient Database for Standard Reference, Release 24. Nutrient Data Laboratory, Beltsville, MD, USA.

Wang Z.H., Zong Z.Q., Li S.X., and Chen B.M., 2002. Nitrate accumulation in vegetables and its residual in vegetable fields. Environ. Sci. 23(3):79–83.

Yildirim E., Guvenc I., M. Turan, Karatas A.,2007. Effect of foliar urea application on quality, growth, mineral uptake and yield of broccoli (*Brassica oleracea* L., var. *italica*). Plant soil environ. 53(3): 120–128.

استجابة الخس (*Lactuca sativa L.*) للتسميد الورقى بالنانويوريا مع الميكوريزا

محمد على أحمد عبد السلام
قسم الأراضى و المياة - كلية الزراعة - جامعة بنها - مصر.

تم اجراء تجربة عاملية (عاملين) في قطاعات تامة العشوائية على الخس النامى في ارض طينية *torrifluvent* خلال موسمى 2016/ 2017و 2018/2017 بمزرعة كلية الزراعة (مشتهر) جامعة بنها لتقييم اثرالرش الورقى بالنانويوريا و التسميد الحيوى بالميكوريزا (VAM). العامل الأول يشمل مستويين B_0: عدم إضافة ميكوريزا ، B_1: إضافة ميكوريزا و العامل الثانى و يشمل خمسة مستويات N_0 : رش ماء مقطر (عدم إضافة يوريا)، N_1: رش يوريا عادية بمعدل 5000 ملليجرام N لتر$^{-1}$، N_2: رش نانويوريا بمعدل 2500 ملليجرام N لتر$^{-1}$، N_3: رش نانويوريا بمعدل 3750 ملليجرام N لتر$^{-1}$،N_4 : رش نانويوريا بمعدل 5000 ملليجرام N لتر$^{-1}$. الرش تم على ثلاث دفعات بعد 30،40،50 يوم من الزراعة بمعدل 1200 لتر هكتار$^{-1}$ في كل دفعة. جميع مؤشرات النمو من طول نبات، عدد الأوراق لكل نبات، الوزن الطازج والجاف للنبات زادت مع الرش باليوريا والميكوريزا منفردين او مجتمعين. اعلى استجابة لطول النبات وأيضا لوزنة كانت عند معاملة N_3B_1. جميع معاملات النانويوريا تفوقت على اليوريا العادية على الأخص المعدل الأوسط (N_3) من النانويوريا. الإضافة الأعلى للنانويوريا (N_4) تبدو زائدة عن الحاجة حيث انة لم يحدث اى ارتفاع بعد الإضافة الوسطى (N_3). محتوى ال N و P و K في النبات زاد مع إضافة النانو يوريا. محتوى النيتروجين النتراتى (NO_3-N) راد بصورة ملحوظة مع إضافة اليوريا. أضافة اليوريا على صورة نانويوريا اثبتت كفاءة ويمكن استخدامها بصورة عملية حيث ان الإضافة المنخفضة من النانويوريا (N_2) بمعدل 2500 ملليجرام N لتر$^{-1}$ أعطت نتائج اعلى من إضافة اليوريا العادية (N_1) بمعدل 5000 ملليجرام N لتر$^{-1}$.