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Foliar Applications of Nano Chitosan-Urea and Inoculation with Mycorrhiza on Kohlrabi (*Brassica oleracea var. gongylodes*, L.)

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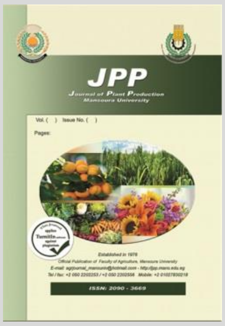

ABSTRACT

The current research aims at producing high kohlrabi knob yield with better quality traits using nano-chitosan-urea (versus urea) as a foliar spray in presence of mycorrhiza (AMF) as plant inoculants either solely or in combinations with each other. This investigation was carried out under the field conditions for two successive seasons (2015/2016 and 2016/2017). In this concern, microrrhizal inoculations were set up in the main plots whereas the foliar application of nano-urea was arranged in the sub-plots, comprising 5 treatments, i.e. spray with water, spray with ordinary urea at a rate of 1500 mg N L^{-1}, spray with nano-urea at rates of 500 mg N L^{-1}, 1000 mg N L^{-1}, and 1500 mg N L^{-1} (designated U0, U1, U2, U3, and U4 respectively). Generally, spraying kohlrabi plants with different urea forms increased significantly the studied vegetative growth parameters as well as the yield quantity and quality traits in the following order U4>U1=U3>U2>U0. Likewise inoculating plants with AMF improved significantly the investigated growth parameters and yield components. It seems that inoculating plants with AMF did not affect significantly the above-mentioned growth parameters and yield components when plants sprayed with nano-chitosan-urea at a rate of 1500 mg N L^{-1}. Thus, spraying plants with 1000 mg N L^{-1} as nano chitosan-urea together with plant inoculation with AMF (U3M1) is the recommended solution to cut off the inputs of chemical N fertilizers by 33.3% as this integrated treatments recorded comparable results with the ones attained for the application of the full dose of urea.

Keywords:Kohlrabi, Arbuscular mycorrhizal fungi, foliar spray, nitrogen, nano-fertilizer

INTRODUCTION

Kohlrabi (*Brassica oleraceae var. gongylodes*) is an edible plant that belongs to Brassicaceae family (Ćosić *et al.*, 2015). This vegetable crop is consumed worldwide as raw, cooked or fried (Salehi, 2019) because of its high content of vitamin C, potassium and antioxidants (Dhaliwal, 2017). In spite of that, the available information related to its production seemed to be rare in Egypt.

Nitrogen, as an essential nutrient for plant growth (Liu *et al.*, 2014), takes place in the formation of amino acids, enzymes, nuclear acids (DNA and RNA) and chlorophyll (Khalil *et al.*, 2016). Its application can considerably improve the growth parameters and the outcome yield of Kohlrabi (Morsy, 2019). However, it is not preferable to use nitrate fertilizers for vegetable production because considerable amounts of nitrate ions accumulate in the edible plant parts (Wang *et al.*, 2002) and this may be of potential risks on human health (Ahmadil *et al.*, 2010). Thus, urea is the optimum nitrogen (N) fertilizer in some vegetable production (Ghormade *et al.*, 2011) that can reduce nitrate accumulation in the edible vegetables parts (Gunes *et al.*, 1994). It is worthy to mention that soil application of urea is associated with low nutrient use efficiency (NUE) and therefore, high losses of nutrients probably take place from soil surfaces to water bodies (Guo *et al.*, 2018). This might, in turn, negatively affect the ecosystem (Mohammed *et al.*, 2019) causing eutrophication, and contamination for the underground water (Wang *et al.*, 2002; Bobbink *et al.*, 2012 and Manjunatha *et al.*, 2016) beside of its implications on losing soil biodiversity (Ghormade *et al.*, 2011). Alternatively, foliar application of ammonia can increase the utilization of nutrients by plants (Mondal and Mamun, 2011) because ammonia is used in relatively smaller quantities (when sprayed on plants) rather than the soil application (Gul *et al.*, 2011) and within several hours, urea is absorbed by plant shoots (Mondal and Mamun, 2011).

Chitosan is a natural, safe and cheap product that is widely used in production of horticultural crops (Malerba *et al.*, 2016); beside of its beneficial effects on the physiological characteristics of the grown plants (Sharif *et al.*, 2018). This product is a natural biodegradable one derived from crustaceous shells such as crabs and shrimps (Freepons, 1991). Its polycationic nature (Bautista-Baños *et al.*, 2006) can guarantee its usage for increasing plant protection (Terry and Joyce, 2004). Moreover, the degraded chitin can be used as an efficient nitrogen source (Kim, 2005). In this concern, Chitosan nanoparticles (0.5 or 1 %) seemed to be an efficient amendment for increasing tomato growth (plant height, fresh, dry weight and leave area), early and total yield per plant and per feddan and average fruit weight beside of improving the quality of fruits (vitamin C, acidity and total sugars) as compared to the non-amended treatment (Shams and Morsy, 2014). It was found that the nanoparticles of chitosan guarantee more uniform distribution of the foliar spray of nutrients on plant shoots; hence increase their effectiveness on plants. Thus, spraying kohlrabi with nano-chitosan-urea can probably improve N uptake and

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utilization by the grown plants.

Arbuscular mycorrhizal fungi (AMF) is a symbiotic micro-organism that "requires continuous exchange of nutrients between the two partners" (Chen *et al*., 2018). In this concern, plants exchange carbon for nutrients (Allen *et al*., 2018) while AMF has the ability to improve P availability in soil (Mohammed *et al*., 2019), deliver it to root cortical cells (Ferlian *et al.*, 2018) and hence increase its uptake by the grown plants (Ardakani *et al*., 2011) especially that the traditional P- fertilizers are rapidly fixed in soils upon application (Mohammed *et al*., 2019). AMF can also access organic nitrogen in soil (Chen *et al*., 2018; Bukovská *et al*., 2018; Hestrin *et al*., 2019) and its extended hyphae increases the absorption area of the plant roots (Wiedenhoeft, 2006). Moreover, AMF rapidly assimilate ammonia and nitrate into amino acids (Chen *et al.*, 2018) and then translocated to the host plant (Xing *et al*., 2019). Thus, AMF increases the utilization of N by plants (Verzeaux *et al*., 2017; Vadeboncoeur *et al*., 2015, Mollavali *et al*., 2018 and Zhang *et al*., 2018). Probably, the combination between AMF and the nano- chitosan-urea increase the growth parameters of kohlrabi and improve the quality of the outcome yield

Thus, the current study aims at producing high quality yield of kohlrabi using low inputs of chemical fertilizers i.e. nano-chitosan-urea and mycorrhiza either solely or in combinations to minimize the negative consequences of the agrochemicals on the environment.

MATERIALS AND METHODS

Materials of study

Surface soil samples (0-30 cm) were collected from the Experimental Farm of the Faculty of Agriculture, Moshtohor, Benha University,Egypt. These samples were air dried, sieved to pass through a 2-mm sieve then analyzed for their particle size distribution and chemical characteristics as outlined by Sparks *et al*. (1996) and Klute (1986) and the obtained results are presented in Table 1.

Table 1. Physical and chemical analysis of the soil.

Season	Sand	Silt	Clay	Texture	pH	EC	O.M	$CaCO_3$	N	P %	K
	%					(dS m^{-1})	g kg^{-1}				
2015	21.06	25.16	53.78	Clay	8.2	1.03	1.01	153	1.2	3.1	1.1
2016	21.25	26.21	52.54	Clay	8.5	0.95	1.13	144	1.4	4.2	1.3

pH in soil:water suspension (1:2.5), EC in soil paste extract, O.M: organic matter content

Seeds of kohlrabi (*Brassica oleracea* var. *gongylodes* cv. White Vienna) were obtained from Modesto Seed Co. Inc., Modesto, California. Cultures of Mycorrhyza (AMF) were prepared by the strains that were brought from the Microbiology Department, Faculty of Agriculture, Benha University, Egypt. Nano particles (i.e., nano- chitosan-urea; 1500 mg N L^{-1}) were obtained from the Nanotechnology & Advanced Material Central Laboratory (NAMCL), Agricultural Research Center (ARC), Egypt.

The field study

A field experiment was carried out at the Experimental Farm, Faculty of Agriculture, Moshtohor, Benha University in a split plot design for two successive seasons (2015/2016 and 2016/2017). This experiment comprised ten treatments with three replicates in which the Mycorrhyza (AMF) inoculant was conducted in the main plots (none-inoculated and inoculated treatments designated as M0 and M1 respectively) where roots were dipped for about 30 minutes in a solution consisted of biofertilizer cultures. The foliar application of nano-urea (urea loaded on synthesized nanoparticles of chitosan) was arranged in the sub-plots, comprising 5 treatments, i.e. no urea spray (spray with water), spray with ordinary urea at a rate of 1500 mg N L^{-1}, spray with nano-urea at rates of 500 mg N L^{-1}, 1000 mg N L^{-1}, and 1500 mg N L^{-1} (designated U0, U1, U2, U3, and U4 respectively). In each season, the foliage was sprayed three times during the growth period i.e. 30, 40 and 50 days after transplanting. The experimental plot included 5-ridges each of 60 cm wide and 3.5 long with 30 cm apart on one side of ridges and plot area was 10.5 m^2. Kohlrabi plants (*Brassica oleracea var. gongylodes* cv. White Vienna) were transplanted at the first week of October in the two growing seasons and harvested after 10 weeks from transplanting. All plants received the recommended dose of P (77 kg P ha^{-1}) as calcium super phosphate (16% P_2O_5) and 86 kg K ha^{-1} as potassium sulphate fertilizers (48 % K_2O). All plots receive Farmyard manure at a rate of 24 mega-gram ha^{-1} during land preparation. Other agricultural practices of growing kohlrabi plants were carried out as commonly followed in the district. At the physiological maturity growth stage, plants were harvested and the growth parameters and yield components were estimated.

Measurements

To evaluate quantity and quality features of kohlrabi, four plants were chosen to represent each treatment and the following measures were estimated: plant length (cm), knob diameter (cm), average weight of knob (g $plant^{-1}$), total fresh yield (t ha^{-1}). Total chlorophyll was measured in plant leaves according to the procedures outlined by AOAC (2000).

Sub-samples of kohlrabi leaves were then oven dried at 70 °C for 48 h, weighed, ground, and undergo wet digestion using a mixture of conc. sulphuric and perchloric acids (2:1 ratio) as described by Chapman and Pratt (1961). N, P and K were determined in the plant digests according to AOAC (2000) as follows: N by micro-Keldahl, P by spectrophotometer (Jenway 6705 UV/Vis) using ammonium molybdate and ascorbic acid reagents and K by flame photometer (Jenway PFP7).

Four kohlrabi knobs (representing each plot) were dried at 70 °C for 48 h and then their dry weights were measured. Percentages of fiber and L-ascorbic acid (mg 100 g^{-1} F.W) were also determined according to AOAC (2000).Carbohydrates content was calculated according to Merrill and Watt (1973).

Statistical analysis

A split plot design in factorial arrangement was used for treating the obtained data using, Duncan's Multiple Range Test at 5 % level to compare between treatment means as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Results

Kohlrabi vegetative growth, chlorophyll and NPK content

Data Table 2 show that, spraying kohlrabi plants with the different urea forms increased significantly the studied vegetative growth parameters i.e. plant length and knob diameter as well as NPK contents and total chlorophyll in leaves (*P*<0.05). It seems that the nano-chitosan increased significantly the efficiency of urea utilization by the grown plants, hence their dual application "urea and nano-chitosan" increased significantly the above-mentioned growth parameters especially with the foliar spray of 1500 mg N L^{-1} (U4). This level recorded the highest increases in plant height and chlorophyll content in leaves during the two seasons of study. Moreover, reducing the level of "urea+nano chitosan" from 1500 to 1000 mg N L^{-1} (U3) recorded comparable increases in the vegetative growth parameters of plants when compared with the full application dose of urea U1. The results also reveal that the lowest level of "urea+nanochitosan" (500 mg N L^{-1}) was not efficient enough to increase the investigated growth parameters when compared with the other N-treatments; in spite of that the outcome results stood significantly higher than the control ones (U0). Generally, the efficiency of N-fertilizers can be arranged as follows: U4>U3>U1>U2>U0 for both plant height and chlorophyll content (during both seasons of study) while the corresponding sequence for knob diameter (during both seasons) was: U4>U3=U1=U2>U0. It is worthy to mention that the highest concentrations of N in leaves were recorded for U4 treatment followed by U1 then U3. It is worthy to mention that the variations between U1 and U3 seemed to be insignificant during the first season; on the other hand, the lowest N-content was detected in plants sprayed with distilled water U0. The concentrations of P and K did not differ significantly among the different N-sources (except for U2 and U1 which recorded significant variations in P content in leaves only during the second growing season). On the other hand, inoculating plants with AMF increased significantly all the studied growth parameters as compared with the non-inoculated plants

The combination between these two factors (urea forms and AMF) was also significant for improving the following parameters: plant height, total chlorophyll as well as NPK contents in leaves. The highest increases in both plant height and total chlorophyll content in leaves were detected in plants that received 1500 mg N L^{-1} (in presence or absence of AMF). It seems that inoculating plants with AMF did not affect significantly the above-mentioned growth parameters when plants sprayed with nano-chitosan-urea at a rate of 1500 mg N L^{-1} (U4M1). In case of knob diameter, the variations seemed to be insignificant among urea treatments (with or without AMF) except for U0M0, U0M1 and U2M1. Reducing the level of nanochitosan-urea from 1500 to 1000 mg N L^{-1} recorded comparable increases in both plant height and the chlorophyll content with the treatments that received the full dose of urea (i.e. presence or absence of AMF) during both seasons of study. The highest concentrations of N in plants were detected in U4M1 followed by U4M0 U3M1, U1M1 and U1M0 with no significant variations among these treatments.

Table 2. Vegetative growth, chlorophyll content and NPK of kohlrabi plant as affected by nano chitosan-urea and inoculation with mycorrhiza and their interaction during the winter seasons of 2015/2016 and 2016/2017.

Nano-Chitosan-Urea	Inoculation with Mycorrhiza (M)											
	2015/2016 season			2016/2017 season			2015/2016 season			2016/2017 season		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
	Plant length (cm)						Knob diameter (cm)					
U0	44.74 f	45.81 f	45.28 E	47.21 f	48.54 f	47.88 E	6.013 c	7.150 bc	6.582 C	6.787 c	7.767 bc	7.277 C
U1	52.52 cd	53.94 bc	53.23 C	54.10 cd	54.74 bcd	54.42 C	7.833 abc	9.220 ab	8.527 B	8.267 abc	9.350 ab	8.808 B
U2	48.81 e	50.71 de	49.76 D	49.81 ef	52.09 de	50.95 D	7.213 bc	8.453 ab	7.833 B	7.590 bc	8.820 abc	8.205 B
U3	53.51 bc	55.27 b	54.39 B	55.50 bc	57.84 b	56.67 B	8.003 abc	9.0270 ab	8.515 B	8.220 abc	9.463 ab	8.842 B
U4	60.50 a	60.74 a	60.62 A	62.24 a	63.44 a	62.84 A	8.893 ab	9.870 a	9.382 A	9.063 abc	10.380 a	9.72 A
Mean	52.02 B	53.29 A		53.77 B	55.33 A		7.591 B	8.744 A		7.985 B	9.155 A	
	Total chlorophyll (mg 100 g^{-1} FW)						N (g kg^{-1})					
U0	117.7 e	122.0 e	119.8 E	118.9 f	141.5 e	130.2 E	2.927 f	3.083 ef	3.005 D	3.067 f	3.243 ef	3.155 D
U1	159.9 b	162.4 b	161.1 C	176.8 bc	172.2 c	174.5 C	3.507 bcd	3.673 b	3.590 B	3.547 bcd	3.733 b	3.640 B
U2	137.5 d	146.2 c	141.9 D	152.3 d	153.7 d	153 D	3.187 ef	3.353 cde	3.270 C	3.237 ef	3.433 cde	3.335 C
U3	162.6 b	166.2 b	164.4 B	173.4 c	185.4 b	179.4 B	3.327 de	3.543 bcd	3.435 B	3.267 def	3.573 bc	3.420 C
U4	195.7 a	194.6 a	195.1 A	252.7 a	247.4 a	250.1 A	3.620 bc	3.977 a	3.799 A	3.570 bc	4.157 a	3.864 A
Mean	154.7 B	158.3 A		174.8 B	180.0 A		3.313 B	3.526 A		3.338 B	3.628 A	
	P (g kg^{-1})						K (g kg^{-1})					
U0	0.296 b	0.320 ab	0.308 B	0.166 c	0.260 b	0.213 C	1.720 e	2.280 b	2.000 A	1.947 bc	2.843 a	2.395 A
U1	0.293 b	0.3433 ab	0.318 AB	0.250 b	0.290 b	0.270 B	1.990 c	2.347 b	2.168 A	1.680 c	2.877 a	2.278 A
U2	0.296 b	0.3467 ab	0.321 AB	0.240 b	0.260 b	0.250 BC	1.817 de	2.367 b	2.092 A	1.927 bc	2.827 a	2.377 A
U3	0.323 ab	0.3367 ab	0.330 AB	0.2833 b	0.373 a	0.328 A	2.000 c	2.373 b	2.187 A	1.800 bc	2.933 a	2.367 A
U4	0.330 ab	0.380 a	0.355 A	0.2933 b	0.356 a	0.325 A	1.917 cd	2.527 a	2.222 A	2.060 b	2.753 a	2.407 A
Mean	0.308 B	0.3453 A		0.2467 B	0.308 A		1.889 B	2.379 A		1.883 B	2.847 A	

Values followed by the same letters are not significantly different by Duncan's test at 0.05 level.

Nano- Chitosan-Urea (U): no urea spray (U0), spray with ordinary urea at a rate of 1500 mg N L^{-1} (U1), spray with nano chitosan-urea at rates of 500 mg N L^{-1} (U2), spray with nano chitosan-urea at rates of 1000 mg N L^{-1} (U3) and spray with nano chitosan-urea at rates of 1500 mg N L^{-1} (U4). Inoculation with Mycorrhiza: with (M1) and without (M0).

Knob weight and Kohlrabi yield

Spraying plants with the different urea forms increased significantly the fresh and dry weights of knobs as well as the total yield per hectare as compared with the control treatment U0 (Table 3). In this concern, the highest increases were recorded for the application of 1500 mg N L^{-1} "nanochitosan-urea" (during both seasons of study) followed by the application of either 1000 mg N L^{-1} as "nanochitosan-urea" or 1500 mg N L^{-1} urea. No significant variations were detected between these two treatments. Application of 500 mg N L^{-1} recorded the lowest increases in the outcome yield among the investigated N-treatments in spite of that such increases were significantly higher than the control one (distilled water). Likewise, inoculating plants with AMF improved significantly fresh and dry weights of knob as well as the outcome yield during the two seasons of study as compared with the non-inoculated treatment. It is worthy to mention that the foliar application of 1500 mg N L^{-1} as "nano-chitosan-urea" together with plant inoculation with AMF recorded the highest significant increases in the above-mentioned parameters; however, such increases seemed; to some extent, comparable with the results of the non-inoculated plants sprayed with the same level of "nano-chitosan-urea".

Table 3. Fresh and dry weights of knob, and total yield of kohlrabi plant as affected by nano chitosan-urea and inoculation with mycorrhiza and their interaction during the winter seasons of 2015/2016 and 2016/2017.

Nano-Chitosan-Urea	Inoculation with Mycorrhiza (M)											
	2015/2016 season			2016/2017 season			2015/2016 season			2016/2017 season		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
	Fresh weight of knob (g)						Dry weight of knob (g)					
U0	201.70 g	232.80 f	217.25 D	209.10 h	220.30 g	214.70 E	17.69 f	19.33 f	18.51 E	17.56 e	18.43 e	17.99 E
U1	350.50 d	358.30 c	354.40 B	396.80 d	392.40 d	394.60 C	27.74 d	28.55 cd	28.15 C	28.41 c	29.08 c	28.75 C
U2	275.00 e	274.80 e	274.90 C	328.70 f	336.20 e	332.45 D	24.61 e	24.49 e	24.55 D	24.01 d	24.05 d	24.03 D
U3	370.50 b	375.10 b	372.80 B	415.20 c	396.10 d	405.65 B	30.01 bc	30.02 bc	30.02 B	30.32 bc	32.11 ab	31.22 B
U4	417.50 a	414.10 a	415.80 A	430.20 b	460.20 a	445.20 A	31.02 ab	32.21 a	31.62 A	31.54 ab	32.97 a	32.26 A
Mean	323.04 B	331.02 A		356.00 B	361.04 A		26.21 B	26.92 A		26.37 B	27.33 A	
	Total yield (t ha^{-1})											
U0	13.32 e	16.73 d	15.03 E	10.70 f	14.77 e	12.73 D						
U1	24.97 b	25.26 b	25.11 C	28.37 c	28.24 c	28.31 B						
U2	19.79 c	19.74 c	19.76 D	22.70 d	23.06 d	22.88 C						
U3	26.20 b	26.27 b	26.23 B	29.32 bc	28.13 c	28.72 B						
U4	29.75 a	29.65 a	29.70 A	30.56 ab	32.08 a	31.32 A						
Mean	22.80 B	23.53 A		24.33 B	25.26 A							

See footnote Table 4

Quality of kohlrabi knobs

The quality traits of kohlrabi were significantly higher in plants sprayed with urea. According to Table 4, spraying plants with 1500 mg N L^{-1} as "nanochitosan-urea" recorded the highest increases in contents of both carbohydrate and L-ascorbic acid during both seasons of study. The corresponding increases that occurred in the carbohydrate content in knobs due to the application of 1500 mg N L^{-1} urea came second; however, in case of L-ascorbic acid, the application of 1000 mg N L^{-1} as "nanochitosan-urea" seemed to be more efficient than 1500 mg N L^{-1} urea. The lowest contents of carbohydrates were detected in knobs of the control treatment. On the other hand, urea applications decreased significantly the fiber content in knobs as compared with the control treatment except for the application of 500 mg N L-1 as "nano-chitosan-urea" (first season only). It seems that the variations in fiber contents among the other N-sources seemed to be insignificant.

Inoculating plants with AMF improved significantly L-ascorbic acid in knobs while decreased their contents of fibers during both seasons of study. The effect of plant inoculation on the carbohydrate content of knobs was, on the other hand, not significant. Generally, inoculating plants with AMF was not efficient enough for improving any of the studied quality traits when applied at a rate of 1500 mg N L^{-1} as "nano-chitosan-urea"; however, the effect of AMF inoculation was more pronounced with decreasing the rate of plant spray with "nanochitosan-urea" or even for plants that were sprayed by 1500 mg N L^{-1} urea

Table 4. Quality of kohlrabi knobs as affected by nano chitosan-urea and inoculation with mycorrhiza and their interaction during the winter seasons of 2015/2016 and 2016/2017.

Nano-Chitosan-Urea	Inoculation with Mycorrhiza (M)											
	2015/2016 season			2016/2017 season			2015/2016 season			2016/2017 season		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
	Carbohydrates (%)						Fiber (%)					
U0	5.463 c	5.440 c	5.452 D	5.547 e	5.827 cde	5.687 C	1.49 ab	1.41 abc	1.45 A	1.66 a	1.47 abc	1.57 A
U1	6.087 b	6.740 a	6.413 B	6.597 b	6.303 bc	6.450 B	1.58 a	1.20 d	1.39 AB	1.60 ab	1.29 c	1.44 B
U2	6.043 b	5.873 bc	5.958 C	5.763 de	6.223 bcd	5.993 C	1.51 a	1.18 d	1.35 B	1.59 ab	1.30 c	1.44 B
U3	6.200 b	6.713 a	6.457 B	6.623 b	6.297 bc	6.460 B	1.38 abc	1.30 bcd	1.34 B	1.47 abc	1.42 bc	1.45 B
U4	6.743 a	6.860 a	6.802 A	7.300 a	7.357 a	7.328 A	1.38 abcd	1.28 cd	1.33 B	1.41 bc	1.40 bc	1.40 B
Mean	6.107 A	6.325 A		6.366 A	6.401 A		1.47 A	1.27 B		1.54 A	1.38 B	
	L-ascorbic acid (mg 100 g^{-1} F.W)											
U0	37.25 e	39.40 e	38.33 D	47.05 i	48.83 h	47.94 E						
U1	56.40 c	50.45 d	53.42 C	53.38 g	58.60 e	55.99 D						
U2	49.47 d	58.53 bc	54.00 C	58.17 e	56.36 f	57.26 C						
U3	58.51 bc	59.87 b	59.19 B	59.78 d	61.05 c	60.42 B						
U4	63.95 a	65.54 a	64.74 A	68.21 b	69.96 a	69.08 A						
Mean	53.12 B	54.76 A		57.32 B	58.96 A							

See footnote Table 4

Discussion

Inoculating plants with AMF increased significantly the concentrations of NPK nutrients within plant shoots. This might be attributed to the concurrent increases that occurred in the absorbing area of the plant roots via the extended mycorrhizal hyphae (Wiedenhoeft, 2006); beside of the increases that took place in P availability in soil (Bi *et al.*, 2018; Ren *et al.*, 2019). Also, AMF inoculation probably utilized organic nitrogen (Chen *et al.*, 2018; Bukovská *et al.*, 2018; Hestrin *et al*., 2019) that was found in farm yard manure while decreased N loses from soil (Teutscherova *et al*., 2019). This might, in turn, increase the growth parameters of the kohlrabi plants and improve their outcome yield quantity. Moreover, AMF improved significantly the quality of kohlrabi knobs i.e. higher L.ascorbic acid and lower fiber content within knobs. Similar results were reported by Mohammed *et al.* (2019) who reported the positive effects of AMF inoculation on improving kohlrabi growth parameters i.e. plant height and chlorophyll content in leaves.

Results also highlighted the significance of using nano-chitosan-N fertilizer for improving klorabi growth parameters and the outcome knob yield as well as its quality traits. In this concern, the highest increases were attained for the application of 1500 mg N L^{-1}. Reducing the dose of nano-chitosan-urea application to 1000 mg N L^{-1} resulted also in significant increases in the outcome yield quantity and quality and these results were comparable with those obtained from the full application dose of urea. Probably, the large surface area and small size of chitosan (Djiwanti and Kaushik, 2019) accounts for increasing the N-utilization when used as carriers for N fertilizers (Kalia and Kaur, 2019). Its worthy to mention that inoculating plants with AMF was not efficient enough for improving the plant growth when associated with the highest application rate (1500 mg N L^{-1}) of nano-chitosan-urea. This is probably because nanochitosan induces both local and systemic plant defense responses (Al-Dhabaan *et al*., 2018); hence acted as a fungicide (Saharan and Pal, 2016; de Oliveira and Junior, 2020). Accordingly, plant inoculation with AMF did not affect significantly the growth and the outcome yield of plants that received the highest application rate of nano-chitosan-urea. Further studies are needed, in this concern, to study the negative impact of nanochitosan on AMF inoculation in plants.

In conclusion, spraying “AMF inoculated kohlrabi plants” with nanochitosan is a recommended procedure for improving the growth performance and productivity of kolorabi. Such a combined treatment can potentially cut off the inputs of N by 33.3% while recorded comparable results with the ones obtained from spraying plants with the full dose of urea

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تطبيق الرش الورقى بالنانو شيتوزان- يوريا والتلقيح بالميكورهيزا على نبات الكرنب أبو ركبة (*Brassica oleracea var. gongylodes*).

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يهدف البحث الحالي إلى إنتاج محصول عالي من الكرنب أبوركبة مع صفات ذات جودة أفضل باستخدام الرش الورقى بالنانوشيتوزان-يوريا (مقابل اليوريا) وفي وجود الميكورهيزا (AMF) كملقح للنبات إما كل منهم منفرد أو بتوليفة مع بعضهم البعض. تم إجراء هذه التجربة في ظل الظروف الحقلية لموسمين متتاليين (٢٠١٦/٢٠١٥ و ٢٠١٧/٢٠١٦). وفي هذا الصدد، تم وضع التلقيح بالميكورهيزا فى القطع الرئيسية ، في حين تم ترتيب معاملات الرش الورقي المستخدم للنانو يوريا في القطع الفرعية، والتي تضم ٥ معاملات، هى الرش بالماء، والرش باستخدام اليوريا العادية بمعدل ١٥٠٠ ملليجرام N لتر$^{-1}$، والرش مع النانو يوريا بمعدلات ٥٠٠، ١٠٠٠، و ١٥٠٠ ملليجرام N لتر$^{-1}$ (U0، U1، U2، U3، U4 على التوالي). وبشكل عام، فإن رش نباتات الكرنب أبوركبة بصور مختلفة من اليوريا زاد بشكل كبير من قياسات النمو الخضري المدروسة وكذلك كمية المحصول ومواصفات الجودة بالترتيب التالي U0 <U2 <U3 = U1 <U4. وبالمثل، فإن تلقيح النباتات باستخدام الميكورهيزا AMF قد حسن بشكل كبير من قياسات النمو التي تم فحصها وكذلك مكونات المحصول. ويبدو أن تلقيح النباتات باستخدام الميكورهيزا AMF لم يؤثر بشكل كبير على معاملات النمو المذكورة أعلاه ومكونات المحصول عندما تم رش النباتات باستخدام النانو شيتوزان-يوريا بمعدل ١٥٠٠ ملليجرام N لتر$^{-1}$. وبالتالي ، فإن معاملات الرش الورقى التي تحتوي على ١٠٠٠ ملليجرام N لتر$^{-1}$ في صورة نانو شيتوزان-يوريا مع تلقيح النبات بالميكورهيزا AMF (U3M1) هي الحل الموصى به لتوفر نسبة من الأسمدة النيتروجينية قدرها ٣٣.٣٪ حيث سجلت هذه المعاملات المتكاملة نتائج قابلة للمقارنة مع تلك التى أخذت جرعة كاملة من اليوريا.

الكلمات الدالة: الكرنب أبوركبة، فطر الميكورهيزا، الرش الورقى، النيتروجين، الأسمدة النانو