EFFECT OF SPRAYING BY NITROGEN LOADED ON CHITOSAN NANOPARTICLES ON GROWTH AND PRODUCTIVITY OF GARLIC UNDER SANDY SOIL CONDITIONS

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The field work was carried out at Baloza Research Station of the Desert Research Center, North Sinai Governorate, during the two consecutive winter seasons of 2015/2016 and 2016/2017. The experiments were conducted to study the effect of N fertilizer levels as soil addition (0, 50, 75, 100 kg/N/fed); chitosan nanoparticles and N loaded on chitosan nanoparticles treatments as foliar application [Ch, 0.25 (ChN1) and 0.5 (ChN2) mol/L] on growth, yield, chemical composition and storage potential of garlic plants, Chinese cv. grown in sandy soil conditions. Results revealed that N addition at the rate of 100 kg (N/fed) followed by 75 kg (N/fed), were superior significantly in growth, yield, chemical composition and storage potential parameters in both growing seasons, when compared with control treatment. N loaded on chitosan nanoparticles spray at the rate of 0.5 mol/l followed by 0.25 mol/l gave significant increase in all growth, yield, chemical composition and storage characters potential in both growing seasons, when compared to control treatments. At the harvest date, the highest values of investment ratio were obtained with N loaded on chitosan nanoparticles spray at the rate of 0.5 mol/l and N level at the rate of 100 kg N/fed in the first season, and with N level at the rate of 75 kg N/fed in the second season. The same trend of results was obtained with the end of storage period in both seasons. Linear correlation and regression of garlic traits were carried out. It may be worth to mention that with each increase of one gram of plant weight, total yield (ton/fed) of garlic correspondingly increased by 0.069 and 0.074 ton in the first and second seasons, respectively, and with each increase of one of percent of dry matter of garlic bulb,

percent loss in weight of garlic correspondingly decreased 1.477 and 1.246 in the first and second seasons, respectively.

Garlic is one of main economic vegetable crops in Egypt. It has been used for its flavor and medical value. The increment of yield and improving quality of garlic is usually depending on many factors, which affect on plant growth and production. N fertilizer is necessary as success for crop production, especially in poor soil such as North Sinai Governorate, where soil nutrients are insufficient to meet the crop requirements. Many researchers proved that there is a direct relationship between either yield or its components and N fertilizer (Nori et al., 2012).

Moreover, increasing N fertilizer increased number of leaves, leaf length and plant growth. Sardi and Timar (2005) showed that garlic has a high N requirement, particularly in the early stages of growth. The highest yield was obtained with the treatment of 300 kg N/ha.

Availability of N is important for growing plants. It is a main constituent of protein and nucleic acid molecules. It is also a part of chlorophyll molecules. It is well known that the use of fertilizer helps in production and is a quick method to obtain the best yields (Farooqui et al., 2009). Moreover, N application significantly improved bulb yield and yield components (Abreham and Getachew, 2015).

Also, in a study carried out by Gaviola and Lipinski (2008), they showed that red and white garlic cultivars yielded 10 and 12 tons/ha with application160 and 180 kg N/ha, respectively. On the other hand, Saigusa (2000) pointed out that 40 to 70% of N, 80 to 90% of phosphorus, and 50 to 70% of potassium of the normal fertilizers are lost and not absorbed by plants, causing economic and resource losses and dangerously increasing environmental pollution. Recently, the usage of slow release fertilizers has become a new tendency to save fertilizer consumption and to reduce environmental pollution (Wu and Liu, 2008 and Corradini et al., 2010). Also, it was suggested that use of controlled release N fertilizer combined with a supplement of other nutrients would be a sustainable strategy for fertilizer management in garlic production (Bo et al., 2016).

Chitosan is derived from chitin, a polysaccharide found in exoskeleton of shellfish such as shrimp, lobster or crabs and cell wall of fungi (Wojdyla, 2001). Recently, some researchers reported that chitosan enhanced plant growth and development (Chibu and Shibayama, 2003; Gornik et al., 2008 and Said et al., 2012). They reported that application of chitosan to plants increased key enzymes activities of N metabolism (nitrate reductase, glutamine synthetase and protease) as well as, improving the transportation of N in the functional leaves, which in turn, enhance plant

growth. In addition, Mondal et al. (2012) reported that growth, biochemical parameters and yield of okra were increased with increasing concentration of chitosan application up to 125 ppm. Moreover, chitosan treatment improved storability of post-harvest fruits and vegetables, because it forms a semi permeable film that regulates gas exchange and reduce transpiration and respiration, hence water loss was reduced and fruit ripening was slowed down. This effect has been reported by numerous horticultural commodities such as tomatoes and strawberries (Jiang and Li, 2001; Kittur et al., 2001; Bautista-Baños et al., 2006).

The evaluation of nanotechnology and emergence of novel nanodevices and nanomaterials open up new trends in agriculture. There are a large variety of methods that can be used in the production of nanoparticles, using techniques from both physics and chemistry. Chitosan nanoparticles have been investigated as a carrier for drug delivery, meanwhile a few studies have been attempted to discover the potential of chitosan nanoparticles as controlled release for NPK fertilizers. This presents the idea of developing encapsulated fertilizers in which NPK fertilizers are loaded within nanoparticles (Teodorescu et al., 2009). Also, some studies already proved the significance of nanofertilizers and its beneficial effects included the increases of nutrients use efficiency and yield quality, besides reduce soil pollution (Naderi and Danesh-Sharaki, 2013).

Corradini et al. (2010) pointed that the existence of electrostatic interactions between chitosan nanoparticles and the elements N, P and K. The stability of the CS-PMAA colloidal suspension was higher with the addition of N and potassium than with phosphorus, thus due to the higher anion charge from calcium phosphate than the anion charges from potassium chloride and urea. Moreover, Benzon et al. (2015) showed that nanofertilizer application promoted growth, development, and antioxidant activity in rice, demonstrating the potential to improve crop production and plant nutrition. In other words, nanofertilizers simply dissolve in solution and release the nutrient(s) as soluble ions. But, the dissolution rate and extent of nanofertilizers in water/soil solution should be higher than those of the related bulk (Liu and Lal, 2015).

The main objective of this work was to study the effect of N fertilizer levels as conventional fertilizer percent and chitosan nanoparticles, N loaded on chitosan nanoparticles on growth, yield, chemical composition and storage potential of garlic under North Sinai conditions.

MATERIALS AND METHODS

The field work was carried out at Baloza Research Station of the Desert Research Center, North Sinai Governorate, during the two consecutive winter seasons of 2015/2016 and 2016/2017.

The physical and chemical soil characteristics of the studied site were determined according to Page et al. (1982) and Klute (1986),

respectively, as recorded in table (1). The chemical analysis of irrigation water was carried out using the standard method of Page et al. (1982) and presented in table (2).

Table (1). Some physical and chemical properties of the experimental soil site.

Soil depth (cm)	Texture class	Soluble anions (me/l)			pH (Soil paste)	E.C (dSm^{-1})	Soluble cations (me/l)			
		HCO$_3^-$	SO$_4^=$	Cl$^-$			Ca^{+2}	Mg^{+2}	Na$^+$	K$^+$
0-30	Sandy loam	0.75	0.85	4.25	6.7	0.58	1.15	0.45	3.92	0.33

pH: Acidity, E.C.: Electrical conductivity, me/l: milli equivalent per liter

Table (2). Chemical analysis of the irrigation water.

Samples	pH	E.C. (dSm^{-1})	Soluble cations (me/l)				Soluble anions (me/l)		
			Ca^{+2}	Mg^{+2}	Na$^+$	K$^+$	HCO$_3^-$	SO$_4^{-2}$	Cl$^-$
1st season	7.1	5.54	10.1	13.32	39.4	1.17	9.35	15.1	39.5

pH: Acidity, E.C.: Electrical conductivity, dSm^{-1}: decseime per meter

1. Chitosan Nanoparticles

Chitosan (CTS, degree of deacetylation was 0.9, average molecular weight was 6.0, 105, 99.9%); acrylic acid (AA distilled under reduced pressure before use); acrylamide (AM), ammonium persulfate (APS, recrystallized from distilled water before use), urea CO (NH$_2$)$_2$ and N, N0-methylenebisacrylamide (NNMBA, used as received). All materials were obtained from Sigma Aldrich Egypt.

2. Preparation of Chitosan-coated N

N fertilizer granules from urea were placed into a rotary drum, and the CTS powder was stuck on the granules by epoxy dissolved in acetone. The adhesive was applied by spraying at regular time intervals. The process was finished until compact and homogeneous coating formed on fertilizer granules. The coated granules were dried at room temperature to a constant mass for 8 h. The CTS-coated N fertilizer granules (5 g) were added into a flask with a mechanical stirrer, a condensed and separated by drop funnel. A certain amount of polyethylene glycoloctyl phenylether (OP), sorbite anhydride monostearic acid ester and carbon tetrachloride were added into the flask. The temperature was raised to 65°C using a water bath, while the contents were constantly stirred. After that, the mixed of partially neutralized acrylic acid (AA, by ammonia), acrylamide, N, N0-methylenebisacrylamide (NNMBA) solution, also, ammonium persulfate (APS) solution was slowly

dropped into the flask. The mixture was filtered to remove the carbon tetrachloride after being stirred for 2 h at 65°C and then dried at 70°C in oven to obtain the final product.

The incorporation of N fertilizers with chitosan nanoparticles was carried out by dissolving chitosan nanoparticles in different amounts of N fertilizers, each into 50 ml of nanoparticle solution with magnetic stirring for 6 h at 25°C. The chitosan concentration used in synthesis was 0.2% (w/v). The incorporated N fertilizers into the chitosan nanoparticles resulted in the final concentrations of 0.25, 0.5 mol N fertilizer as ammonium sulphate (20.5% N), and were calculated for requiring quantities according to the study treatments. The quantities were divided and applied four times after 30, 60, 90 and 120 days from planting date.

Organic manure was added at the rate of 20 m³/fed, while calcium super-phosphate (15.5% P_2O_5) at the rate of 300 kg/fed. They were added during land preparation. Potassium sulphate (48% K_2O) was added at the rate of 150 kg /fed, the quantities were divided and applied two times after 60 and 90 days from planting date.

Garlic cloves were planted in the first week of October through the two growing seasons, respectively. Sixteen treatments were used, which were the combination of four N fertilizer levels as soil addition, *i.e.,* 0, 50, 75, 100 kg/N/fed added as ammonium sulphate and four foliar treatments by chitosan nanoparticles. N was loaded on chitosan nanoparticles either with concentration of 0.25 or 0.5 mol/L and control treatment sprayed with tap water.

Experimental plot area was 1/400 fed, [3 m (L0) x 3.5 m (W)], which consisted of five ridges. Garlic cloves were soaked in warm water 12 h before planting, then planted within six lines for each ridge; 10 cm apart between cloves. Two ridges were dedicated for the vegetative growth samples and three ridges for the yield determination.

After 30, 60, 90 and 120 days from planting, chitosan nanoparticles were separated (Ch) at the rate of 0.2% (w/v), and N loaded on chitosan nanoparticles treatments were sprayed at concentrations of 0.25 (ChN1) and 0.5 (ChN2) mol/L on plants, while water was sprayed as a control treatment. All sprayed treatments were applied by hand dropping sprayer. The growing season extended for 180 days.

3. Growth Parameters of Vegetative Growth

After 150 days from planting, nine plants of each replicate were randomly taken for recording vegetative growth characteristics, *i.e.,* plant height and weight, number of leaves/plant and percentage of dry weight of the aerial vegetative parts.

4. Yield and Its Components

At harvesting stage (180 days from planting date) a sample of 20 garlic plants were randomly taken from each experimental plot for yield characteristics, *i.e.,* neck and bulb diameter, average bulb fresh weight, percentage dry matter of bulb were recorded. In addition, total yield (ton/fed), when 50% of leaves pended and turned to yellowish green color. Irrigation was stopped at 15 days before harvest date, plants of each experiment plot were collected and put in shadow and aired place for 10 to 15 days for drying care. After that, every 30 plants were tied together for storage.

5. Chemical Composition

Three samples of garlic bulb from each subplot were taken and oven dried at 70ºC until stable weight, then ground to fine particles and used to determine chemical content, such as minerals and calcium percentage were measured using flame photometer method as described by Brown and Lilliland (1964). Total N was determined using the modified micro Kjeldah method (Cottenie et al*.,* 1982), while total soluble solids (TSS) of garlic cloves were determined using a JK-SR-113ATC digital Refractometer (Shanghi Co. Ld., China) at 20°C (A.O.A.C., 1975).

6. Storage Potential

Uniform samples of garlic plants from each experimental were selected, cleaned, weighted and stored in net bags at room temperature with aeration conditions under shadow for 6 months. Average room temperature was between 23.5 and 25.6ºC and air humidity were 80 and 85%. Examination was carried out to calculate the percentage of loss in weight and decay.

7. Investment Ratio

Investment Ratio (IR) = (total revenue, LE/ total cost, LE) following Rana et al. (1996).

8. Experimental Design and Statistical Analysis

The experimental treatments were arranged in split plot design with four replicates, the main plots were assigned for N levels, whereas, spray treatments rates were randomly arranged in the sub plots. Statistical analyses of obtained data were analyzed according to Thomas and Hills (1975).

RESULTS AND DISCUSSION

1. Plant Growth Parameters

Growth parameters results, *i.e.*, plant height and weight, no. of leaves/plant and leaves dry matter percent are presented in tables (3 and 4) and indicate that there were significant positive effects for both N levels and

foliar application on all investigated growth parameters. From the data, it could remark the following:

− Growth parameter values were superior significantly with N at rate of 100 kg (N/fed), followed by 75 kg (N/fed), when compared with control treatment (without N application). Also, that there were no significant difference between 75 and 100 kg N/fed treatments in all growth parameters measurements in both growing seasons, except the highest value of dry matter percentage of leaves recorded with 100 kg N/fed in the first season only. These results agree with those reported in the study of determination of the optimal source and level of fertilizer by Nori et al. (2012). They found that N had a positive effect on morphological characteristics of garlic. The results showed that the highest leaf length and leaves number were observed with 300 kg N/ha application. Also, increasing N fertilizer enhanced the growth trend of leaves number, length beside plant weight (Sardi and Timar, 2005)

− The highest values of growth parameters were reported with foliar spray by N loaded on chitosan nanoparticles at the rate of 0.5 and 0.25 mol, respectively in both growing seasons, when compared to control treatment.

(foliar spray by tap water). Moreover, no significant difference has been found between foliar spray by chitosan nanoparticles only and N loaded on chitosan nanoparticles at the rate of 0.25 mol in plant weight and percent dry matter of leaves in both growing seasons. The results were in the same line with those reported by Chibu and Shibayama (2003), Gornik et al. (2008) and Said et al. (2012). They showed that chitosan enhanced plant growth and development. Application of chitosan increased key enzymes activities of N metabolism and improved the transportation of N in the functional leaves, which is in turn, enhanced plant growth. The results also, agreed with those obtained by Benzon et al. (2015). They showed that nanofertilizer application promoted the growth, development, and antioxidant activity. Also, the interaction between two factors showed no significant in all growth parameters in both seasons.

2. Yield and Its Components

Tables (4 and 5) presented data of neck and bulb diameter, bulb weight, percent bulb dry matter and total yield/ton per fed. The results indicated that yield and its components were affected by the two investigated factors, *i.e.*, N levels and foliar application. The results could remark the following:

− It is clear from the data that neck and head diameter, head weight, percent head dry matter and total yield significantly increased with N addition at rate of 100 kg (N/fed), followed by 75 kg (N/fed), when compared with control treatment (without N application). No significant differences

observed among treatments in yield and its components, except the height value of neck diameter recorded with N at the rate of 100 kg N/fed in both growing seasons. It is well known that the use of fertilizer improved production (Farooqui et al., 2009). Moreover, the highest yield was obtained with the treatment of 300 kg N/ha (Sardi and Timar, 2005). N application significantly influenced bulb yield and yield component (Abreham and Getachew, 2015).

-   The highest values of neck and head diameter, head weight, head dry matter (%) and total yield were recorded with foliar spray as compared with control treatment (spray by tap water) in both growing seasons. The same trend was observed with Benzon et al. (2015), that there were no significant differences between N loaded on chitosan nanoparticals application at the rates of 0.5 and 0.25 mol, regarding neck and head diameter, head weight, head dry matter (%) and total yield in both growing seasons, except the highest values of head diameter and percent head dry matter, which were superior significantly with N loaded on chitosan nanoparticals application at the rates of 0.5 mol in the second season only. Nanofertilizer application promoted the growth, development and antioxidant activity, also demonstrating the potential to improve crop production and plant nutrition.

-   The interaction between the two factors showed that the highest values of head weight were recorded with N level at the rate of 100 kg N/fed combined with N loaded on chitosan nanoparticles at the rate of 0.5 and 0.25 mol, respectively in the first season only.

3. Chemical Content

Obtained results in table (6) indicated significant positive effect for both studied factors, *i.e.,* N levels and N loaded on chitosan nanoparticles application on chemical components.

-   The highest values of N (%) were recorded with N application at the rate of 100 kg N/ fed, and the highest values of T.S.S. were observed with N application at the rate of 75 and 50 kg N/fed in both growing seasons. Also, no significant differences among all N levels observed on Ca (%) content in both seasons. Availability of N is important for growing plants. It is a main constituent of protein and nucleic acid molecules. It is also a part of chlorophyll molecules (Farooqui et al., 2009).

-   The highest values of N, Ca (%) and T.S.S. were recorded with N loaded on chitosan nanoparticles spray at the rate of 0.5 mol. No significant differences were observed when compared with N loaded on chitosan nanoparticles spray at the rate of 0.25 mol in both seasons. On the other

Table (3). Effect of N levels and chitosan spray on plant height (cm), number leaves/plant, fresh plant weight (g/plant) of garlic plant through 2015/2016 and 2016/2017 seasons.

Characters	Plant height (cm)					No. of leaves/plant					Plant weight (g/plant)				
Chitosan / N treatments (kg N)	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄
2015/2016															
Control	34.67	35.97	44.13	46.43	40.30	6.63	6.40	7.77	8.60	7.35	90.4	91.1	95.6	97.3	93.6
50	50.67	50.67	58.60	59.13	54.77	8.50	9.97	10.73	11.90	10.28	117.8	134.7	137.8	139.6	132.5
75	53.23	58.63	62.30	67.47	60.41	9.77	11.87	12.90	13.40	11.98	175.5	172.1	170.3	181.3	174.8
100	54.40	61.53	63.10	64.07	60.78	11.47	12.23	14.10	14.07	12.97	167.2	188.6	191.0	197.9	186.2
Mean	48.24	51.70	57.03	59.28		9.09	10.12	11.38	11.99		137.8	146.6	148.7	154.0	
2016/2017															
Control	33.28	31.10	38.03	41.47	35.97	7.21	6.84	9.03	7.97	7.76	87.8	84.6	93.2	96.1	90.4
50	47.59	46.63	50.93	51.34	49.12	7.82	9.10	9.50	11.81	9.56	92.2	135.3	145.1	142.9	128.9
75	55.58	67.39	69.33	74.25	66.64	9.87	11.93	12.84	13.55	12.05	154.9	185.0	174.0	185.5	174.8
100	60.68	69.24	71.12	72.41	68.36	10.16	12.45	13.97	14.60	12.79	165.9	187.8	190.4	197.5	185.4
Mean	49.28	53.59	57.35	59.87		8.77	10.08	11.33	11.98		125.2	148.2	150.7	155.5	
L.S.D at 0.05			Sea. 1	Sea. 2				Sea. 1	Sea. 2				Sea. 1	Sea. 2	
N application			2.40	4.79				1.07	1.06				19.74	13.48	
Chitosan			2.49	4.40				0.65	0.80				9.21	10.38	
N X Chitosan			NS	NS				NS	NS				NS	NS	

Control: spraying with water
*Ch: Chitosan nanoparticles only
*Nitrogen loaded on chitosan nanoparticles: ChN1/0.25 ml: ChN2/0.5 mol

Table (4). Effect of N levels and chitosan spray on neck and bulb diameter (mm) and dry matter of leaves (%) of garlic plant through 2015/2016 and 2016/2017 seasons.

2015/2016

Characters	Dry matter of leaves (%)					Neck diameter (mm)					Bulbing ratio (mm)				
Chitosan	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄
N treatments (kg N)															
Control	17.4	17.5	19.0	17.5	17.9	7.3	8.0	8.7	8.3	8.1	32.3	32.6	33.2	34.7	33.2
50	17.6	18.5	18.5	20.1	18.7	9.3	10.3	11.0	11.7	10.6	37.0	40.8	46.2	48.1	43.0
75	19.8	21.2	22.0	22.2	21.3	12.0	12.0	13.0	13.5	12.6	53.6	58.7	61.6	61.4	58.8
100	22.9	23.1	25.5	26.2	24.4	13.7	13.7	15.0	15.0	14.3	56.2	61.1	62.4	61.6	60.3
Mean	19.4	20.1	21.2	21.5		10.6	11.0	11.9	12.1		44.8	48.3	50.8	51.5	

2016/2017

	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄
Control	18.5	18.6	20.4	18.6	19.0	7.8	8.7	9.3	8.8	8.7	38.8	39.1	39.8	41.6	39.8
50	20.7	22.3	22.1	23.2	22.1	9.0	10.2	10.5	10.3	10.0	36.7	40.7	46.4	48.5	43.1
75	20.7	21.5	22.4	24.1	22.2	11.9	11.8	13.0	13.2	12.5	56.8	59.7	60.0	64.7	60.3
100	21.4	21.9	24.2	26.2	23.4	13.0	13.2	15.5	17.0	14.7	60.2	65.7	63.8	68.1	64.4
Mean	20.3	21.1	22.3	23.0		10.4	11.0	12.1	12.3		48.1	51.3	52.5	55.7	

L.S.D at 0.05	Sea. 1	Sea. 2				Sea. 1	Sea. 2				Sea. 1	Sea. 2			
N application	1.99	2.22				0.92	1.16				1.89	7.32			
Chitosan	1.26	1.81				0.78	0.86				1.91	2.46			
N X Chitosan	NS	NS				NS	NS				NS	NS			

Control: spraying with water
*Ch: Chitosan nanoparticles only
*Nitrogen loaded on chitosan nanoparticles: ChN1/0.25 mol: ChN2/0.5 mol

Table (5). Effect of N levels and chitosan spray on bulb weight (g), dry matter of bulb (%) and total yield (ton/fed) of garlic plant through 2015/2016 and 2016/2017 seasons.

Characters	N (%)					Ca (%)					T.S.S.				
Chitosan / N treatments (kg N)	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄
2015/2016															
Control	1.69	1.53	1.77	2.03	1.76	0.88	1.02	1.11	1.31	1.08	28.37	26.40	27.67	29.43	27.97
50	2.22	2.52	2.52	2.36	2.41	0.88	1.02	1.18	1.28	1.09	29.70	27.30	30.20	30.30	29.38
75	2.75	2.75	2.93	3.08	2.88	0.93	1.18	1.27	1.23	1.15	29.43	30.34	31.57	30.70	30.51
100	2.78	3.44	3.74	3.82	3.45	1.01	1.17	1.33	1.36	1.22	27.80	29.73	31.00	30.85	29.85
Mean	2.36	2.56	2.74	2.82		0.93	1.10	1.21	1.30		28.83	28.44	30.11	30.32	
2016/2017															
Control	1.67	1.49	1.97	2.09	1.80	1.09	1.06	1.37	1.42	1.23	30.98	27.46	30.42	32.91	30.44
50	2.63	3.06	3.06	2.82	2.89	1.39	1.37	1.32	1.51	1.40	33.61	30.49	34.26	34.21	33.14
75	2.68	2.74	3.11	3.12	2.91	1.08	1.26	1.23	1.27	1.21	32.68	32.98	34.46	35.36	33.87
100	2.85	3.35	3.20	3.77	3.29	0.97	1.23	1.29	1.36	1.21	27.19	29.06	29.63	30.54	29.11
Mean	2.46	2.66	2.84	2.95		1.13	1.23	1.30	1.39		31.12	30.00	32.19	33.25	

L.S.D at 0.05	Sea. 1	Sea. 2				Sea. 1	Sea. 2				Sea. 1	Sea. 2			
N application	0.23	0.35				NS	NS				1.62	3.52			
Chitosan	0.19	0.26				0.11	0.15				1.33	1.52			
N X Chitosan	0.38	NS				NS	NS				NS	NS			

Control: spraying with water
*Ch: Chitosan nanoparticles only
*Nitrogen loaded on chitosan nanoparticles: ChN1/0.25 mol: ChN2/0.5 mol

Table (6). Effect of N levels and chitosan spray on N, Ca (%) and T.S.S of garlic bulb during 2015/2016 and 2016/2017 seasons.

Characters	N (%)					Ca (%)					T.S.S				
Chitosan	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄	Control	Ch	ChN1	ChN2	X̄
N treatments (kg N)															
2015/2016															
Control	1.69	1.53	1.77	2.03	1.76	0.88	1.02	1.11	1.31	1.08	28.37	26.40	27.67	29.43	27.97
50	2.22	2.52	2.52	2.36	2.41	0.88	1.02	1.18	1.28	1.09	29.70	27.30	30.20	30.30	29.38
75	2.75	2.75	2.93	3.08	2.88	0.93	1.18	1.27	1.23	1.15	29.43	30.34	31.57	30.70	30.51
100	2.78	3.44	3.74	3.82	3.45	1.01	1.17	1.33	1.36	1.22	27.80	29.73	31.00	30.85	29.85
Mean	2.36	2.56	2.74	2.82		0.93	1.10	1.21	1.30		28.83	28.44	30.11	30.32	
2016/2017															
Control	1.67	1.49	1.97	2.09	1.80	1.09	1.06	1.37	1.42	1.23	30.98	27.46	30.42	32.91	30.44
50	2.63	3.06	3.06	2.82	2.89	1.39	1.37	1.32	1.51	1.40	33.61	30.49	34.26	34.21	33.14
75	2.68	2.74	3.11	3.12	2.91	1.08	1.26	1.23	1.27	1.21	32.68	32.98	34.46	35.36	33.87
100	2.85	3.35	3.20	3.77	3.29	0.97	1.23	1.29	1.36	1.21	27.19	29.06	29.63	30.54	29.11
Mean	2.46	2.66	2.84	2.95		1.13	1.23	1.30	1.39		31.12	30.00	32.19	33.25	
L.S.D at 0.05	Sea. 1		Sea. 2			Sea. 1		Sea. 2			Sea. 1		Sea. 2		
N application	0.23		0.35			NS		NS			1.62		3.52		
Chitosan	0.19		0.26			0.11		0.15			1.33		1.52		
N X Chitosan	0.38		NS			NS		NS			NS		NS		

Control: spraying with water

*Ch: Chitosan nanoparticles only

*Nitrogen loaded on chitosan nanoparticles: ChN1/0.25 mol: ChN2/0.5 mol

hand, there were no significant differences between treatments of N loaded on chitosan nanoparticles and chitosan nanoparticles only regarding N and Ca% in both seasons.

− Some studies already proved the positive significance of nanofertilizers. Some beneficial effects include increases in nutrient use efficiency (Naderi and Danesh-Sharaki, 2013). Also, nanofertilizers simply dissolve in solution and release the nutrient(s) as soluble ions (Liu and Lal, 2015).

− The interaction between the two factors showed that the heights value of N (%) were recorded with N level at the rate of 100 kg N/fed combined with N loaded on chitosan nanoparticles at the rate of 0.5, followed by 0.25 mol, respectively in the first season only.

4. Storage Potential

Data presented in table (7) clear the percentage of loss in weight and decay of garlic. These parameters were affected with the two investigated factors, *i.e.,* N levels and chitosan nanoparticles application. Obtained data could remark the following:

− The lowest values of loss in weight percent were recorded with N level at the rate of (75 kg N/fed) when compared with control treatment. No significant differences recorded among N levels at the rate of 50, 75 and 100 kg N/fed, in both seasons. On the other hand, the highest value of decay (%) was recorded with control treatment but no significant differences found between N level at the rate of 75 and 100 kg N/fed, in both seasons.

− The lowest values of loss in weight percent were recorded with N loaded on chitosan nanoparticles application at the rate of 0.5 mol when compared with control treatment. No significant differences among all chitosan nanoparticles application were observed in both seasons. On the other hand, the highest value of decay (%) was recorded with control treatment. Chitosan treatments may improve storability of post-harvest vegetables, because it forms a semi permeable film that regulate the gas exchange and reduce transpiration, respiration and water loss, also fruit ripening is slowed down. These effects have been reported for numerous horticultural commodities; such as tomatoes, strawberries and bell pepper (Jiang and Li, 2001; Kittur et al., 2001; Bautista-Baños et al., 2006).

5. Investment Ratio (IR)

The final goal of any agricultural application is to get profitable yield as a gain from the investment as the highest possible rate of revenue. Table (8) shows the calculation of input for all treatments, while table (9) gives the investment ratio for all treatments

at the harvest date and after 6 months from storage. Data presented in table (8) show that the fixed cost for one fed of garlic under control (without N addition), 50, 75 and 100 kg N/fed were 10000, 10450, 10675 and 10900 LE in the first season and 12550, 13250, 13600 and 13950 LE, respectively in the second season. While, price of one kg of garlic at harvest date and after six months from storage were 2 and 9 LE in the first season and 3.5 and 13 LE in the second season, respectively.

Table (7). Effect of [N] levels and chitosan spray on percent loss in weight and percent decay and disease after six month of storage periods during 2015/2016 and 2016/2017 seasons.

Characters	Percent loss in weight					Percent decay				
2015/2016										
Chitosan [N] Treatments (kg N)	Cont.	Ch	ChN1	ChN2	$\overline{X}$	Cont.	Ch	ChN1	ChN2	$\overline{X}$
Control	56.10	52.40	51.10	48.57	52.04	36.27	28.93	27.77	29.00	30.49
50	54.13	47.77	47.60	44.33	48.46	29.00	26.00	24.33	25.00	26.08
75	52.90	43.63	42.47	42.50	45.38	25.67	25.00	22.33	20.87	23.47
100	55.53	43.70	42.83	44.17	46.56	24.00	21.67	21.10	20.57	21.83
Mean	54.67	46.88	46.00	44.89		28.73	25.40	23.88	23.86	
2016/2017										
Control	58.63	51.33	45.14	48.23	50.83	39.27	33.01	29.52	32.47	33.57
50	54.37	44.15	47.35	41.37	46.81	31.64	29.78	27.59	29.55	29.64
75	53.14	42.24	40.85	41.30	44.38	32.49	29.03	24.39	24.78	27.67
100	52.80	41.73	42.69	42.15	44.84	27.55	27.05	27.09	25.20	26.72
Mean	54.74	44.86	44.01	43.26		32.74	29.72	27.15	28.00	
L.S.D at 0.05				Sea. 1	Sea. 2				Sea. 1	Sea. 2
N application				3.35	2.71				1.35	2.71
Chitosan				2.52	2.79				1.61	2.10
N X Chitosan				NS	NS				NS	NS

The increasing cost of input units and of price final products in the second season, was due to The Central Bank of Egypt decided Edit exchange of Egyptian pound against US dollar, it lead to higher prices in November 2016. Also, N loaded on chitosan nanoparticles treatments was not calculated in input costs, because it represents a little value. From data presented in table (9), the highest values of investment ratio were obtained with N level application at the rate of 100 kg N/fed and N loaded on chitosan nanoparticles spray at the rate

of 0.5 mol at harvest date in the first season. However, the highest values were obtained with N level at the rate of 75 kg N/fed and N loaded on chitosan nanoparticles spray at the rate of 0.5 mol at the harvest date in the second season. The same trend of results was obtained after storage period in both seasons.

Table (8). Fixed and variable input and output for garlic production (LE/fed).

Items	Unit	Counts	First season		Second season	
			Unit cost	Total LE	Unit cost	Total LE
Fixed cost/fed						
Land preparation	Hour	4.0	50	200	75.0	300
Organic fertilizer	m³	20.0	100	2000	130.0	2600
Chemical fertilizer as				1200		1450
Calcium super-phosphate						
Potassium sulphate						
Garlic seed	kg	350.0	10	3500	12.0	4200
Labor cost	Worker/day					
1. **Fertilizer add**		5.0	60	300	80.0	400
2. **Planting cloves**		10.0	60	600	80.0	800
3. **Seasonal labor**		15.0	60	900	80.0	1200
4. **Harvest labor**		5.0	60	300	80.0	400
Pesticides	Liter	7.0	100	700	120.0	840
Foliar fertilizer	Liter	3.0	100	300	120.0	360
Total				10000		12550
Variable cost						
Ammonium sulphate (20.5% N)	Packet					
100 kg N/fed		10.0	90	900	140.0	1400
75 kg N/fed		7.5		675		1050
50 kg N/fed		5.0		450		700
Chitosan nanoparticles cost	Liter	1.0	350	1	450.0	
Storage cost for 6 months				1000		1500
Output (price of kg)						
1. Yield at harvest	kg	1.0	2		3.5	
2. Yield after 6 months storage	kg	1.0	9		13.0	

Table (9). Investment ratio (IR) for N levels and chitosan nanoparticles application treatments (LE input/ LE output) during 2015/2016 and 2016/2017 seasons.

	2015/2016							
Characters	**Investment ratio at harvest date**				**Investment ratio after storage**			
Chitosan **N treatments (kg N)**	**Control**	**Ch**	**ChN1**	**ChN2**	**Control**	**Ch**	**ChN1**	**ChN2**
control	0.63	0.61	0.70	0.75	1.13	1.20	1.40	1.57
50	1.16	1.14	1.17	1.37	2.18	2.46	2.52	3.15
75	1.40	1.66	1.87	1.91	2.72	3.87	4.44	4.53
100	1.66	1.66	1.87	1.94	3.04	3.87	4.41	4.47
	2016/2017							
control	0.88	0.95	1.01	1.06	1.21	1.55	1.85	1.83
50	1.45	1.51	1.59	1.85	2.21	2.82	2.81	3.64
75	1.88	2.57	2.78	3.08	2.95	4.98	5.51	6.07
100	2.35	2.38	2.76	2.91	3.72	4.67	5.32	5.67

### 3. Correlation and Regression of Some Garlic Traits

It is being worth to mention that fresh plant weight (g) of garlic was significantly positively correlated with number of leaves/plant (Fig. 1). Corresponding correlation coefficients (r) were 0.915 and 0.924 in the first and second seasons, respectively. Corresponding coefficients of determination were 0.838 and 0.853 in the first and second seasons, respectively. It means that 83.3 to 85.3% of plant fresh weights were related to leaves number per plant. In addition, linear regression coefficients of plant weight on leaves number were 14.06 and 1.36 in the first and second seasons, respectively, which are indicated that for each increase of one leaf, fresh weight of plant correspondingly increased by 14.06 and 15.36 g.

Similarly, highly significant positive correlation was assisted between total yield (ton/fed) and fresh weight of plant (g). Corresponding regressions coefficients were 0.069 and 0.074 in the first and second seasons, respectively. This indicated that for each increase of one gram of plant weight and total yield (ton/fed) of garlic correspondingly increased by 0.069 and 0.074 ton in the first and second seasons, respectively.

Moreover, fig. (2) indicates that dry matter of garlic bulb (%) was significantly positively correlated with N content (%) of bulb. Corresponding correlation coefficients (r) were 0.953 and 0.833 in the first and second seasons, respectively. This indicated that for each increase of one percent of N content, dry matter (%) of garlic bulb correspondingly increased by 3.477

and 3.990 in the first and second seasons, respectively. Also, percentage of loss in weight of garlic was significantly negatively correlated with dry matter of bulb (%). Corresponding regression coefficients were -1.477 and -1.246 in the first and second seasons, respectively, which indicated that for each increase of one percent of dry matter of garlic bulb, percentage of loss in weight of garlic correspondingly decreased 1.477 and 1.246 in the first and second seasons, respectively.
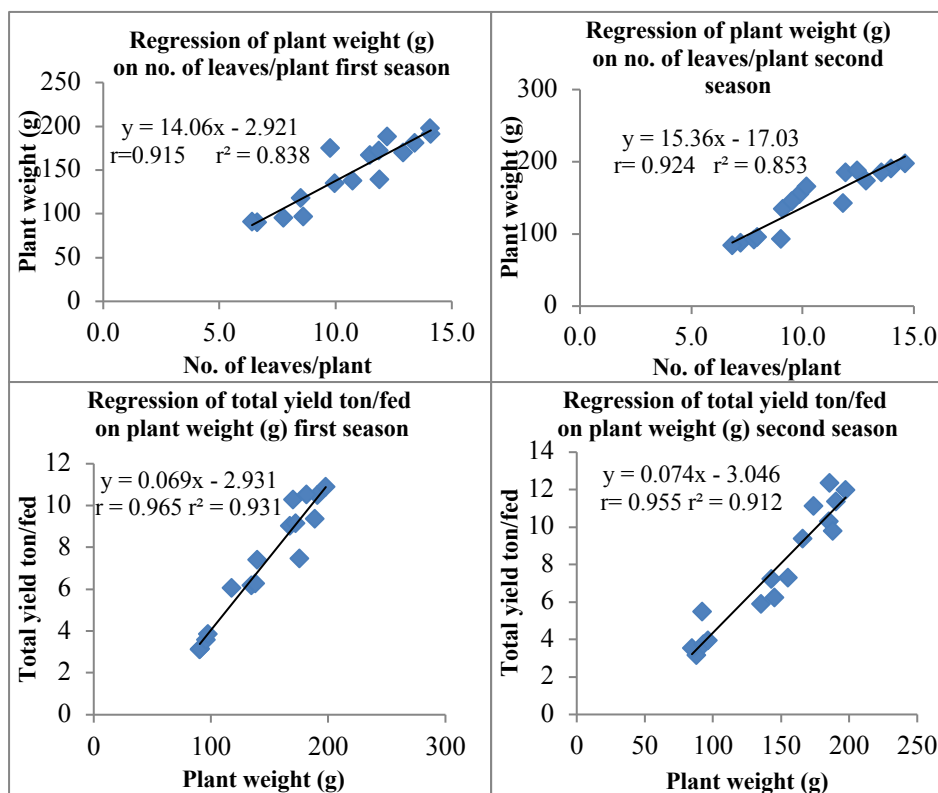
Fig. (1). Correlation coefficients (r), coefficients of determination (r²) and regression coefficients of garlic yield on plant fresh weight and plant fresh weight on number of leaves/plant.
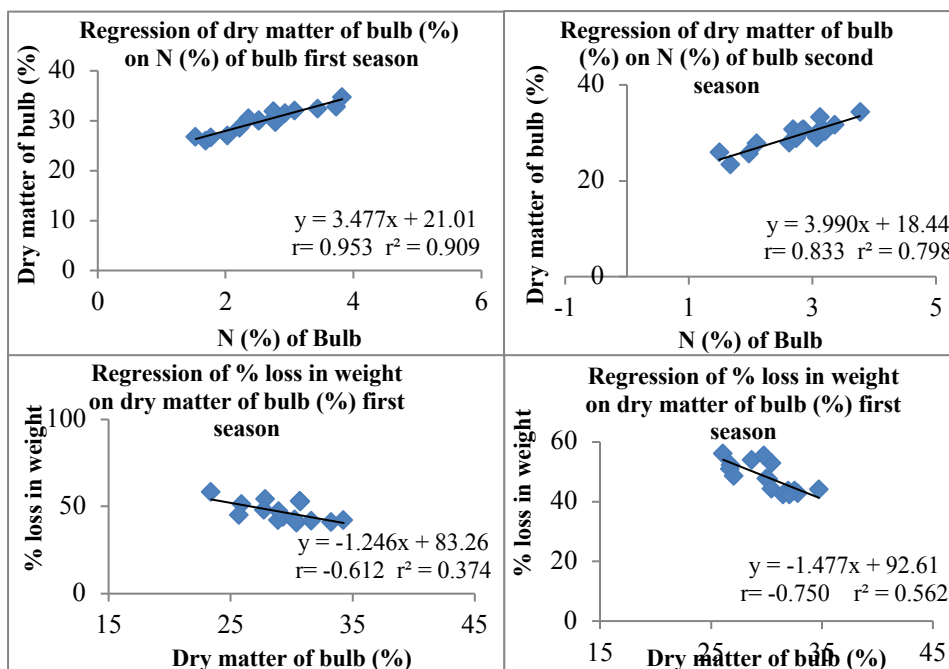
Fig. (2). Correlation coefficients (r), coefficients of determination (r²) and regression coefficients of dry matter of bulb (%) on N (%) of bulb and head percentage loss in weight on dry matter of bulb (%).

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تأثير الرش بالنتروجين المحمل على جزيئات الكيتوزان المتناهية في الصغر على النمو والإنتاجية للثوم تحت ظروف الأراضي الرملية

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في دراسة أجريت في محطة بحوث بالوظة التابعة لمركز بحوث الصحراء بمحافظة شمال سيناء خلال موسمي الزراعة ٢٠١٦/٢٠١٥ و٢٠١٧/٢٠١٦ لدراسة تأثير إضافة مستويات من التسميد النتروجيني كإضافة أرضية بمعدل ٥٠، ٧٥ و١٠٠ بالإضافة إلى معاملة الكنترول بدون إضافة والرش الورقي بالنانوشيتوسان والنتروجين المحمل على النانو شيتوسان بمعدل ٠.٧٥ و٠.٥ مول/لتر ومعاملة الكنترول الرش بالماء على النمو، المحصول، التركيب الكيميائي والقدرة التخزينية لصنف الثوم الصيني تحت ظروف الأراضي الرملية.

أظهرت النتائج أن إضافة النتروجين بمعدل ١٠٠ كجم/فدان تبعه معدل ٧٥ كجم/فدان تفوقًا معنويًا في معظم صفات النمو، المحصول، التركيب الكيميائي والقدرة التخزينية للثوم مقارنًا بمعاملة الكنترول (بدون إضافة) في كلا الموسمين. أعطت معاملة النتروجين المحمل على النانو شيتوسان بمعدل ٠.٥ مول/لتر وتبعة معدل ٠.٢٥ مول/لتر تفوقًا معنويًا في صفات النمو، المحصول، التركيب الكيميائي والقدرة التخزينية للثوم مقارنًا بمعاملة الكنترول (بدون إضافة) في كلا الموسمين. عند الحصاد وجد أن أعلى قيمة لمعامل الإستثمار تحققت مع معاملة إضافة النتروجين بمعدل ١٠٠ كجم/فدان ومعاملة الرش الورقي بالنتروجين المحمل على النانوشيتوسان بمعدل ٥ مول/لتر في الموسم الأول. بينما تفوقت معاملة إضافة النتروجين بمعدل ٧٥ كجم/لتر مع الرش الورقي بالنتروجين المحمل على النانوشيتوسان بمعدل ٠.٥ مول/لتر في الموسم في الموسم الثاني. أظهرت العلاقة الخطية إرتباطًا إيجابيًا بين وزن النبات والمحصول الكلي للثوم حيث أن كل زيادة قدرها واحد جرام في وزن النبات أعطت زيادة في المحصول الكلي قدرها ٠.٠٦٩ و٠.٠٧٤ طن في الموسم الأول والثاني على التوالي. كما أظهرت العلاقة الخطية أن كل زيادة قدرها ١٪ في نسبة المادة الجافة في النبات قللت نسبة الفقد في الوزن أثناء فترة التخزين قدرها ١.٤٧٧ و١.٢٤٦ في الموسم الأول والثاني، على التوالي.