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Phosphorus Fertilizer Level Related with Nano-Chitosan Concentration and their Influence on Growth, Yield and Chemical Constituents of Hot pepper

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ABSTRACT

Two field experiments were done at a privet farm in Mansoura, Dakahlia Governorate, Egypt, during the two summer consecutive seasons of 2019 and 2020. The research objective of this work was to examine the influence of foliar application of nano-chitosan at different concentrations (0, 25, 50 and 100 ppm) under different phosphorus fertilizer level (0, 16, 32 and 48 kg P_2O_5/feddan) on hot pepper "cv. Hyffa" productivity. The influence of phosphorus fertilizer, nano-chitosan and their interaction treatments were determined on plant growth, yield components, some chemical constituents. Phosphorus fertilization at 48 kg P_2O_5/feddan significantly increased hot pepper growth (plant height, number of branches per plant and total plant dry weight), yield components parameters (fruit set %, fruit length, fruit diameter, fruit yield per plant and early yield and total yield per feddan) and chemical constituents (total chlorophyll, total soluble solids, vitamin C, total nitrogen%, total phosphorus % and potassium %) as well as capsaicin content in fruits compared to control and the lowest levels under study. In addition, increasing nano-chitosan concentrations gradually increased all measured parameters to reach the highest values with 100 ppm concentration as foliar spray compared to the other treatments under study. Generally, the results of this work demonstrated that foliar applications of 100 ppm nano-chitosan could help enhance hot pepper (*Capsicum annuum*, L.) growth and productivity as well as content of alkaloids (determined as capsaicin) when interacted with 48 kg P_2O_5/feddan under Dakahlia Governorate conditions.

Keywords: Hot pepper , phosphorus, nano-chitosan, plant growth, yield, chlorophyll, capsaicin.

INTRODUCTION

Hot pepper belongs to the family solanaceae and has a large economic value. It is also very marketable among the people for its nutritional and medicinal values; moreover, the extract of hot pepper is utilized in several pharmaceutical products. Hot pepper gives a share in basically to the world diet. Peppers are widely grown in several regions of Egypt and the hot pepper fruits are used as fresh, dried and processed products as well as like vegetables, as spices or condiments. Nutritionally, hot pepper supplies the body with vitamins (A and C), proteins and many of mineral nutrients (Bose *et al*., 1993). However, Agusiobo (1976) and Keshinro and Ketiku (1983) demonstrated that vitamin C gained from pepper is better than that obtained from tomato.

Phosphorus element (P) is one of the main macronutrients for plant development and growth and suitable phosphorus fertilization is fundamental to get optimum yields. The influence of phosphorus on the roots development, nodulation as well as formation and translocation of carbohydrates, also, growth and other agronomic characters are well known. Phosphorus encourages earliness in flowering formation and fruit set including seed formation (Buckman and Brady, 1980). In this concern, a many literatures reported that phosphorus fertilization has positive influence on growth, yield and quality of some medicinal and aromatic plants such as chilli (Tanwar *et al*., 2013; Islam *et al*., 2018 and Alabi and Ayodele, 2019), fennel (Zaki *et al*., 2019) and anise (Sonmez, 2018).

Chitosan, a mutual name to a deacetylated form of chitin, is a naturalist biodegradable material obtained from crustaceous seashells, whose main characteristics matches to its poly cationic nature (Bautista-Baños *et al*., 2006). Moreover, Auffan *et al*. (2009) indicated that nanotechnology utilizes nano-particles including at smaller one dimension in the order of hundred nm or least. In general, chitosan treatment has been demonstrated to stimulate chilli growth and yield (Chookhongkha *et al*., 2012 and Dzung *et al*., 2017) and chemical constituents (Kazemi and Salimi, 2019).

Therefore, to gain acceptable growth, yield and chemical constituents of hot pepper, Hyffa variety during summer season, this work aimed to evaluate the advantageous influences of foliar spraying of nano-chitosan interacted with phosphorus fertilization in terms of enhanced productivity of (*Capsicum annuum*) under Dakahlia Governorate, Egypt conditions.

MATERIALS AND METHODS

This research was conducted to investigate the influence of different levels of phosphorus fertilization (0.0, 16, 32 and 48 kg P_2O_5/feddan), nano-chitosan (0.0, 25, 50 and 100 ppm) and their interaction treatments on plant growth, yield components and chemical constituents of hot

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pepper plant. Table 1 shows physical and chemical analysis of the experimental soil (average of the two seasons) at a depth of 0-30 cm according to Chapman and Pratt (1978).

Experimental design:

The current experiments were set up in a split-plot design with three replicates. The main plots were occupied by 4 phosphorus fertilization levels. While, the sub plots were entitled to 4 nano-chitosan concentrations. The interaction between the main factor and the sub factor resulted in 16 interaction treatments.

Table 1. Physical and chemical properties of experimental farm soil (average of two seasons)

Mechanical analysis			Soil texture
Clay (%)	Silt (%)	Coarse sand (%)	
43.70	31.90	24.40	Loamy

Chemical analysis													
		Soluble cations (m.mol/l)						Soluble anions (m.mol/l)			Available (ppm)		
pH	E.C. (dsm^{-1})	Ca^{++}	Mg^{++}	Na^{+}	Fe	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.10	1.56	2.10	2.80	0.90	0.30	1.65	1.42	3.40	4.08	1.30	155	89	73

The experimental unit area was 16.80 m^2 (4.00 ×4.20 m) included six ridges. Each ridge was 0.7 m wide and four meters length. The distance between hot pepper plants in the ridge was 50 cm, under surface irrigation system. The hot pepper "cv. Hyffa" seedlings were achieved from private nursery in Belbas District, Sharkia Governorate, Egypt. All transplants were similar in growth and 12 -14 cm in length. Seedlings were planted in the experimental units on 5th and 12th May during the 2019 and 2020 seasons, respectively.

Different levels of phosphorus fertilization as calcium superphosphate (15.5 % P_2O_5) was applied during soil preparation. In addition, chitosan ($C_{56}H_{103}N_9O_{39}$) nano crystallite powder was synthesized by high-energy ball milling. The size of nano-particles of chitosan, as obvious from the TEM images established to be 50 nm. Chitosan as solution (96.40%) was brought from Modern Agricide Company (New Cairo, Cairo, Egypt). Furthermore, the nano-chitosan treatments were applied as foliar application at 30, 45, 60, 75 and 90 days after transplanting. All recommended agricultural practices of growing hot pepper plants were done when ever needed. All plants were fertilized with 200 kg potassium sulphate (50 % K_2O) and 400 kg ammonium nitrate (33 % N) per feddan. However, nitrogen and potassium fertilizers were divided into three equal levels and were added to the soil at 35, 60 and 85 days after hot pepper transplanting.

Recorded Data

Plant growth:

After 100 days from transplanting of hot pepper, a sample of 3 plants were randomly taken from each experimental unit and plant growth parameters noticed as plant height, number of branches/plant and total dry weight/plant were recorded

Yield and its components:

Fruits of hot pepper were harvested every 2 days intervals, upon reaching 11-14 cm length. At harvesting stage the yield components expressed as fruit set percentage (number of set flowers/ total number of flowers marked × 100), fruit length, fruit diameter, fruit yield/plant, early fruit yield per feddan and yield/faddan were recorded.

Chemical constituents:

Total chlorophyll content (SPAD unit) was determined in fresh leaves of hot pepper plant after 100 days from transplanting date by using SPAD- 502 meter (Markwell *et al*., 1995). All chemical analyses were done at chemical laboratory of Department of Biochemistry, Faculty of Agriculture, Menufiya University, Egypt. In addition, ascorbic acid (Vitamin C) was determined by titration in the presence of 2, 6 dichlorophenol-indophenol dyes as an indicator against 2% oxalic acid solution as substrate. Vitamin C was determined of fresh fruits according to the method described by AOAC (1990). Total soluble solids (TSS) of hot pepper fruit juice (Brix°): It was determined by using a hand refractometer as Brix degree. Also, N, P and K percentages in hot pepper fruits were determined according to Chapman and Pratt (1978) at the end of experiment. Finally, total capsaicin content in hot pepper fruit (mg/100g as fruit dry weight) was determined under all phosphorus levels interacted with nano-chitosan at 0.0 and 100 ppm concentrations only by the method of Anan *et al*. (1996).

Statistical Analysis:

Collected data of current reseasrch were analyzed according to Gomez and Gomez (1984). Least significance difference (L.S.D.) was used to differentiate means at the at 5 % level of probability. The means were compared utilizing computer program of Statistix version 9 (Analytical software, 2008).

RESULTS AND DISCUSSION

Plant growth:

Data recorded in Table 2 show that, using phosphorus fertilization treatments at high levels (32 and 48 kg P_2O_5/feddan) significantly increased plant height, branch number per hot pepper plant and total plant dry weight compared to control and the lowest level (16 kg P_2O_5/feddan) in both seasons. Generally, hot pepper plant growth parameters were increased with the increasing of the levels of phosphorus to reach its maximum by using that of 48 kg P_2O_5/feddan. Furthermore, all nano-chitosan treatments significantly increased hot pepper plant height, branch number per plant and total plant dry weight compared to unsprayed plants (control). Using 100 ppm of chitosan as nano-particles significantly increased plant growth parameters of hot pepper compared to control and the other concentrations under study. The increases in total plant dry weight were about 14.56 and 10.79 % for 100 ppm nano-chitosan over control treatment in the 1st and 2nd seasons, respectively. These results hold true in the 2019 and 2020 seasons. The interaction treatment between phosphorus fertilization at 48 kg P_2O_5/feddan and nano-chitosan at 100 ppm significantly increased hot pepper growth parameters compared to control and the other ones under study in both seasons. In addition, increasing nano-chitosan concentrations under each phosphorus fertilization level gradually increased hot pepper height, number of branches per plant and total plant dry weight.

The excellent influences of phosphorus fertilizer application on hot pepper growth parameters are due to that, P is a part of molecular frame of vitally serious compounds, RNA and DNA. Also, it function a fundamental role in photosynthesis and cell division (Marshner, 1995). Similar results were found by Alabi and Ayodele (2019) on *Capsicum annuum* plants. Moreover, Khan *et al*. (2002) found that chitosan promoted key enzymes activities of metabolism of nitrogen and improved the transportation of nitrogen in leaves functional which increase plant development and growth. Also, Dzung *et al.* (2017) reported that among treatment, chitosan proved to be the best, which increased chilli fresh weight of shoots, dry weight of shoots and fruit fresh weight by 71.5%, 184%, and 49.8%, respectively, in comparison with control.

Table 2. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on plant height (cm), number of branches /plant and total plant dry weight (g) of hot pepper plant during 2019 and 2020 seasons

Phosphorus fertilization level (kg P2O5/fed.)	Nano-chitosan concentration (ppm) 2019 season: 0.0	25	50	100	Mean (P)	2020 season: 0.0	25	50	100	Mean (P)
					Plant height (cm)					
0	58.00	58.11	59.44	61.22	59.19	61.00	62.11	64.22	66.11	63.36
16	60.11	63.00	63.22	65.89	63.05	60.78	65.55	68.56	70.78	66.42
32	62.89	69.78	74.00	75.44	70.53	64.00	68.78	71.56	73.00	69.33
48	66.22	69.67	74.89	81.11	72.97	67.00	72.00	78.11	83.44	75.14
Mean (N)	61.80	65.14	67.89	70.92		63.19	67.11	70.61	73.33	
LSD at 5%	(P)= 0.87	(N)= 0.85	(P×N)= 1.71			(P)= 0.74	(N)= 1.05	(P×N)= 1.96		
					Number of branches /plant					
0	20.22	21.89	23.33	24.11	22.39	21.22	22.78	24.00	26.11	23.53
16	21.89	23.11	24.55	25.78	23.83	22.45	25.00	27.11	28.55	25.78
32	22.11	23.89	25.44	27.11	24.64	25.55	26.00	27.89	29.22	27.17
48	23.44	24.78	26.22	27.44	25.47	26.11	27.00	28.11	30.78	28.00
Mean (N)	21.92	23.42	24.89	26.11		23.83	25.19	26.78	28.67	
LSD at 5%	(P)= 0.72	(N)= 0.55	(P×N)= 1.20			(P)= 0.63	(N)= 0.44	(P×N)= 0.99		
					Total plant dry weight (g)					
0	108.78	117.16	119.97	120.99	116.72	112.11	118.73	123.63	123.95	119.61
16	113.04	121.30	122.37	127.67	121.10	120.85	126.92	127.54	130.30	126.40
32	115.06	123.68	130.91	133.59	125.81	123.78	127.48	130.96	138.53	130.19
48	118.20	126.35	134.22	139.11	129.47	125.35	128.94	136.68	141.33	133.07
Mean (N)	113.77	122.12	126.87	130.34		120.52	125.52	129.70	133.53	
LSD at 5%	(P)= 0.47	(N)= 1.58	(P×N)= 2.78			(P)= 0.94	(N)= 0.83	(P×N)= 1.71		

Yield and its components:

It is evident from the obtained data in Tables 3 and 4 that, all phosphorus fertilization treatments significantly increased set %, fruit length (cm), fruit diameter (cm), fruit yield per plant (kg), early fruit yield and total yield per feddan of hot pepper compared to control, in most cases, in both seasons. In general, a gradual increase in the recorded yield and its components were observed with increasing phosphorus fertilization levels from 16 to 48 kg P_2O_5/feddan in the two consecutive seasons. Also, using the highest concentrations of nano-chitosan under study recorded the highest values in hot pepper yield components compared to control and the lowest concentration under study. The increases in fruit set percentage were about 6.61 and 9.63 % as well as in total fruit yield per feddan about 24.80 and 31.86 % for 100 ppm concentration over control (unsprayed plants) in the first and second seasons, respectively. In addition, all interaction among phosphorus fertilization levels and nano-chitosan concentration treatments significantly increased hot pepper yield components parameters, in most cases, in both seasons. The plants which sprayed with nano-chitosan at 100 ppm + fertilized with phosphorus at 48 kg P_2O_5/feddan resulted in the highest values in this connection in both seasons, followed by the interaction treatment between that plants which sprayed with nano-chitosan at 50 ppm + 48 kg P_2O_5/feddan. The increases in early fruit yield/faddan (ton) were about 75.74 and 58.60 % for the interaction between nano-chitosan at 100 ppm + phosphorus fertilization at 48 kg/feddan over control treatment (sprayed plants with tap water without phosphorus fertilization) in the 1st and 2nd seasons, respectively.

Generally, as mentioned above, both nano-chitosan and phosphorus fertilization (each alone) increased yield components of hot pepper plant, in turn; they together might maximize their effects leading to longer and wider fruits, earlier fruit yield and heaviest total yield per faddan. Moreover, a suitable supply of phosphorus is in demand for optimum growth and yield output. P element is participated in sundry key plant functions and encourages root growth and provides resistances to root system diseases (Saskatchewan, 1999). These results coincided with those found by Alabi (2006) on pepper, Hegazi *et al.* (2017) on sweet pepper and Assefa *et al.* (2020) on hot pepper. In the same time, chitosan as nano-particles are readily imbibed by the leaves epidermis then translocated to stems which easier the uptake of active molecules and improved growth and yield of several plants (Malerba and Cerana, 2016). Since, Mondal *et al.* (2012) indicated that okra yield attributes as number of fruits /plant and fruit size were increased with increasing concentration of chitosan until 25 ppm, resulted the highest yield of fruit (about 27.9% yield increased over the control). Also, Dehghani *et al.* (2019) pointed out that flower dry yield of German chamomile plant significantly increased when foliar sprayed by 125 mg/l chitosan compared to control.

Table 3. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on set percentage, fruit length (cm) and fruit diameter (cm) of hot pepper plant during 2019 and 2020 seasons

Phosphorus fertilization level ($kg\ P_2O_5$/fed.)	Nano-chitosan concentration (ppm)									
	0.0	25	50	100	Mean (P)	0.0	25	50	100	Mean (P)
	2019 season					2020 season				
	Set percentage									
0	46.51	47.23	47.32	47.34	47.10	42.75	44.86	45.38	45.88	44.72
16	46.23	47.30	47.97	48.35	47.46	44.20	46.17	48.63	49.04	47.01
32	47.26	48.50	50.03	52.36	49.54	47.10	49.55	50.97	51.02	49.66
48	50.13	50.88	52.99	54.65	52.16	50.02	52.07	52.67	55.85	52.65
Mean (N)	47.53	48.78	49.58	50.67		46.02	48.16	49.41	50.45	
LSD at 5%	(P)= 0.32	(N)= 0.40	(P×N)= 0.76			(P)= 0.63	(N)= 0.61	(P×N)= 1.22		
	Fruit length (cm)									
0	11.69	11.68	12.02	12.13	11.88	12.04	12.45	12.48	12.51	12.37
16	11.90	12.20	12.58	13.14	12.45	12.39	12.75	13.07	13.72	12.98
32	12.70	12.85	13.10	13.42	13.02	12.54	13.24	13.56	13.89	13.31
48	12.90	12.89	13.31	13.84	13.24	12.63	13.26	13.96	14.07	13.48
Mean (N)	12.30	12.41	12.75	13.13		12.40	12.93	13.27	13.55	
LSD at 5%	(P)= 0.41	(N)= 0.17	(P×N)= 0.51			(P)= 0.26	(N)= 0.24	(P×N)= 0.49		
	Fruit diameter (cm)									
0	1.61	1.61	1.68	1.71	1.65	1.52	1.57	1.64	1.68	1.60
16	1.63	1.64	1.68	1.71	1.67	1.59	1.64	1.67	1.70	1.64
32	1.71	1.74	1.80	1.83	1.77	1.70	1.79	1.82	1.89	1.79
48	1.73	1.78	1.86	1.94	1.83	1.75	1.83	1.89	1.98	1.86
Mean (N)	1.67	1.69	1.75	1.80		1.63	1.71	1.75	1.81	
LSD at 5%	(P)= 0.02	(N)= 0.02	(P×N)= 0.04			(P)= 0.01	(N)= 0.02	(P×N)= 0.03		

Table 4. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on fruit yield per plant (kg), early fruit yield per feddan (ton) and total fruit yield per feddan (ton) of hot pepper plant during 2019 and 2020 seasons

Phosphorus fertilization level ($kg\ P_2O_5$/fed.)	Nano-chitosan concentration (ppm)									
	0.0	25	50	100	Mean (P)	0.0	25	50	100	Mean (P)
	2019 season					2020 season				
	Fruit yield per plant (kg)									
0	1.405	1.584	1.668	1.701	1.589	1.288	1.362	1.507	1.613	1.442
16	1.532	1.631	1.670	1.820	1.663	1.325	1.435	1.577	1.663	1.500
32	1.572	1.777	1.830	1.949	1.782	1.385	1.702	1.804	1.888	1.695
48	1.667	1.873	1.975	2.239	1.938	1.506	1.904	1.994	2.092	1.874
Mean (N)	1.544	1.716	1.785	1.927		1.376	1.601	1.721	1.814	
LSD at 5%	(P)=0.231	(N)= 0.259	(P×N)= 0.492			(P)= 0.299	(N)= 0.227	(P×N)= 0.492		
	Early yield per feddan (ton)									
0	1.043	1.067	1.603	1.130	1.211	1.070	10.87	1.180	1.147	1.121
16	1.130	1.217	1.370	1.397	1.278	1.150	1.310	1.413	1.477	1.338
32	1.297	1.403	1.613	1.723	1.509	1.267	1.430	1.580	1.670	1.487
48	1.463	1.577	1.737	1.833	1.653	1.393	1.427	1.630	1.697	1.537
Mean (N)	1.233	1.316	1.581	1.521		1.220	1.313	1.451	1.498	
LSD at 5%	(P)= 0.035	(N)= 0.043	(P×N)= 0.082			(P)= 0.033	(N)= 0.037	(P×N)= 0.072		
	Total yield per feddan (ton)									
0	16.860	19.005	20.012	20.408	19.071	15.451	16.337	18.080	19.353	17.305
16	18.385	19.579	20.037	21.843	19.961	15.895	17.221	18.927	19.961	18.001
32	18.869	21.325	21.959	23.383	21.384	16.614	20.420	21.652	22.661	20.337
48	20.001	22.475	23.704	26.867	23.262	18.075	22.850	23.929	25.101	22.489
Mean (N)	18.529	20.596	21.428	23.125		16.509	19.207	20.647	21.769	
LSD at 5%	(P)= 0.277	(N)= 0.310	(P×N)= 0.603			(P)= 0.359	(N)= 0.272	(P×N)= 0.591		

Chemical constituents:

As shown in Tables 5 and 6 that, total chlorophyll content in leaves as well as total soluble solids, vitamin C content, total nitrogen, total phosphorus and potassium in fruits of hot pepper significantly increased by utilizing all phosphorus fertilization levels compared to control in both seasons. Furthermore, the best treatment in this concern was that 48 kg P_2O_5/feddan. However, total capsaicin content in hot pepper fruits recorded the highest content values with 48 kg P_2O_5/feddan level in the first season and 32 kg P_2O_5/feddan level in the second one compared to the control and the other levels under study (Fig.1). Similarly, increasing nano-chitosan concentrations from 25 to 100 ppm gradually increased chemical constituents of hot pepper leaves and fruits in both seasons. The best treatment in total chlorophyll content, total soluble solids, vitamin C content, N, P and K were that 100 ppm of nano-chitosan with significant differences with control and the other ones under study.

In addition, the chemical constituents of hot pepper plants were increased as a result of the interaction treatment between phosphorus fertilization levels and nano-chitosan at 100 ppm compared to that of phosphorus fertilization alone at any level in both seasons. In the same time, all interaction treatments between phosphorus fertilization (at 0, 16, 32 or 48 kg P_2O_5/feddan) and nano-chitosan concentrations (0, 25, 50 or 100 ppm) caused an increase in this regard compared to unfertilized plants and without nano-chitosan spraying. The best interaction treatment in increase total capsaicin content in hot pepper fruits was that of phosphorus fertilization at 48 kg/feddan + nano-chitosan at 100 ppm (Fig. 2). These results agree with those reported by Hegazi *et al.* (2017) on sweet pepper, Behboudi *et al.* (2018) on barley and Alabi and Ayodele (2019) on chilli plants.

Table 5. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on total chlorophyll content, total soluble solids and vitamin C content of hot pepper plant during 2019 and 2020 seasons

Phosphorus fertilization level (kg P_2O_5/fed.)	Nano-chitosan concentration (ppm)									
	0.0	25	50	100	Mean (P)	0.0	25	50	100	Mean (P)
	2019 season					2020 season				
	Total chlorophyll content (SPAD unit)									
0	42.70	42.93	43.10	43.78	43.13	43.33	43.86	44.36	44.53	44.02
16	43.42	43.57	43.60	44.73	43.83	43.13	44.18	44.93	46.18	44.36
32	43.28	43.50	43.77	45.54	44.02	43.81	44.67	46.02	46.45	45.24
48	44.21	44.84	46.43	47.48	45.74	44.48	45.09	46.73	48.67	46.24
Mean (N)	43.40	43.71	44.23	45.38		43.69	44.45	45.51	46.21	
LSD at 5%	(P)= 0.26		(N)= 0.32		(P×N)= 0.61	(P)= 0.42		(N)= 0.37		(P×N)= 0.73
	Total soluble solids (Brix)									
0	6.16	6.17	6.23	6.22	6.20	6.17	6.18	6.20	6.24	6.20
16	6.19	6.24	6.28	6.29	6.25	6.18	6.21	6.25	6.28	6.23
32	6.39	6.67	6.88	7.00	6.73	6.24	6.46	6.62	6.87	6.55
48	6.38	6.71	7.02	7.10	6.80	6.40	6.54	7.14	7.04	6.78
Mean (N)	6.28	6.45	6.60	6.66		6.25	6.35	6.55	6.61	
LSD at 5%	(P)= 0.03		(N)= 0.08		(P×N)= 0.14	(P)= 0.18		(N)= 0.13		(P×N)= 0.29
	Vitamin C content (mg/100mg fruit as fresh weight)									
0	180.20	181.32	181.92	182.89	181.60	181.31	182.49	185.10	184.38	183.33
16	182.89	185.35	185.80	187.75	185.45	183.41	185.02	191.83	201.60	190.47
32	187.84	190.39	192.21	194.10	191.14	185.94	191.57	194.63	169.33	192.12
48	185.47	191.30	194.35	197.71	192.21	188.30	192.80	194.26	210.48	196.46
Mean (N)	184.10	187.09	188.58	190.61		184.74	187.97	191.47	198.20	
LSD at 5%	(P)= 0.50		(N)= 0.90		(P×N)= 1.63	(P)= 1.13		(N)= 1.59		(P×N)= 2.98

Table 6. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on total nitrogen, total phosphorus and potassium percentages in fruits of hot pepper plant during 2019 and 2020 seasons

Phosphorus fertilization level (kg P_2O_5/fed.)	Nano-chitosan concentration (ppm)									
	0.0	25	50	100	Mean (P)	0.0	25	50	100	Mean (P)
	2019 season					2020 season				
	Total nitrogen (%)									
0	1.533	1.577	1.713	1.750	1.643	1.613	1.627	1.627	1.673	1.635
16	1.583	1.637	1.700	1.770	1.673	1.633	1.667	1.713	1.743	1.689
32	1.610	1.703	1.767	1.813	1.723	1.643	1.683	1.737	1.833	1.724
48	1.633	1.717	1.777	1.837	1.741	1.670	1.797	1.817	1.860	1.786
Mean (N)	1.590	1.658	1.739	1.793		1.640	1.693	1.723	1.778	
LSD at 5%	(P)= 0.025		(N)= 0.013		(P×N)= 0.033	(P)= 0.009		(N)= 0.009		(P×N)= 0.018
	Total phosphorus (%)									
0	0.523	0.532	0.533	0.540	0.532	0.540	0.543	0.550	0.580	0.553
16	0.543	0.547	0.549	0.594	0.558	0.533	0.550	0.650	0.604	0.562
32	0.543	0.577	0.623	0.643	0.597	0.553	0.603	0.617	0.657	0.608
48	0.543	0.627	0.663	0.680	0.628	0.590	0.630	0.643	0.677	0.635
Mean (N)	0.538	0.571	0.592	0.614		0.554	0.582	0.593	0.629	
LSD at 5%	(P)= 0.011		(N)= 0.013		(P×N)= 0.026	(P)= 0.008		(N)= 0.013		(P×N)= 0.023
	Potassium (%)									
0	2.467	2.467	2.493	2.520	2.487	2.472	2.483	2.500	2.533	2.497
16	2.520	2.547	2.570	2.607	2.561	2.517	2.527	2.613	2.623	2.570
32	2.567	2.620	2.690	2.703	2.645	2.550	2.560	2.690	2.710	2.528
48	2.587	2.637	2.707	2.733	2.666	2.603	2.673	2.720	2.753	2.688
Mean (N)	2.535	2.568	2.615	2.641		2.536	2.561	2.631	2.655	
LSD at 5%	(P)= 0.012		(N)= 0.012		(P×N)= 0.023	(P)= 0.016		(N)= 0.013		(P×N)= 0.027

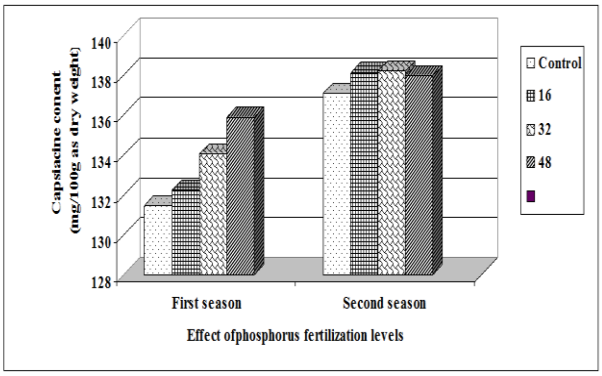

Fig. 1. Effect on phosphorus fertilization level on total capsaicin content in fruits (mg/100g as dry weight) of hot pepper plant during 2019 and 2020 seasons

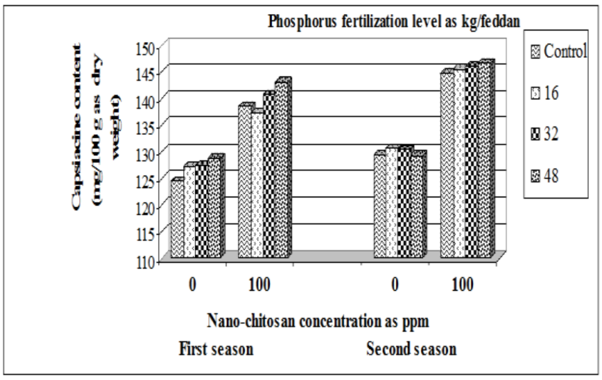

Fig. 2. Effect of interaction between phosphorus fertilization level and nano-chitosan concentrations (0.0 and 1000 ppm) on total capsaicin content in fruits (mg/100g as dry weight) of hot pepper plant during 2019 and 2020 seasons

CONCLUSION

From above mentioned results, it is preferable to spray *Capsicum annuum* cv. Hyffa plants with nano-chitosan at 100 ppm under phosphorus fertilization at 48 kg P_2O_5/feddan to enhance the plant growth, flower set percentage, fruit dimensions, yield components, total chlorophyll, and vitamin C content as well as total capsaicin content under Dakahlia Governorate conditions.

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مستوى السماد الفوسفاتي المرتبط بتركيز النانو شيتوزان وتأثيرهما على النمو والمحصول والمكونات الكيميائية للفلفل الحار

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أجريت تجربتان حقليتان في مزرعة خاصة بالمنصورة بمحافظة الدقهلية بمصر خلال موسمي الصيف المتتاليين لعامي 2019 و 2020. وكان الهدف البحثي من هذا العمل هو دراسة تأثير الرش الورقي بالنانو شيتوزان بتركيزات مختلفة (صفر، 25 ، 50 و100 جزء/المليون) تحت مستويات مختلفة من التسميد الفوسفاتي (صفر ، 16 ، 32 و48 كجم خامس أكسيد الفسفور/فدان) على إنتاجية الفلفل الحار صنف هيفاء. تم تقدير تأثير معاملات السماد الفوسفاتي والنانو شيتوزان والتفاعل بينهما على نمو النبات ومكونات المحصول وبعض المحتويات الكيميائية. أدى التسميد الفوسفاتي بمعدل 48 كجم خامس أكسيد الفسفور / فدان إلى زيادة معنوية في نمو الفلفل الحار (إرتفاع النبات، عدد الأفرع لكل نبات والوزن الجاف الكلي للنبات)، صفات المكونات المحصولية (النسبة المئوية للعقد، طول الثمرة ، قطر الثمرة ، محصول الثمار للنبات والمحصول المبكر للفدان ومحصول الفدان الكلي) والمحتوي الكيميائي (الكلوروفيل الكلي ، المواد الصلبة الذائبة الكلية ، فيتامين ج ، نسبة النيتروجين الكلي المئوية ، نسبة الفسفور الكلي المئوية ونسبة البوتاسيوم المئوية) وكذلك محتوى الثمار من الكابسيسين مقارنة بالكنترول والمستويات المنخفضة قيد الدراسة. بالإضافة إلى ذلك، أدت زيادة تركيز النانو شيتوزان إلى زيادة تدريجية في جميع الصفات المدروسة وصولاً إلى أعلى القيم مع الرش الورقي بتركيز 100 جزء في المليون مقارنة بالمعاملات الأخرى قيد الدراسة. عموماً، أظهرت نتائج هذا العمل أن الرش الورقي بالنانو شيتوزان بتركيز 100 جزء/المليون يمكن أن تساعد في تحسين نمو وإنتاجية الفلفل الحار بالإضافة إلى المحتوى القلويدي (المقدرة عي صورة كابسيسين) عند التفاعل مع التسميد الفوسفاتي بمستوى 48 كجم/فدان تحت ظروف محافظة الدقهلية.