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Influence of Potassium Fertilization and Nano-Chitosan on Growth, Yield Components and Volatile Oil Production of Chamomile (*Matricaria chamomilla*, L.) Plant

Fatma R. Ibrahim
Vegetable and Floriculture Dept., Faculty of Agric., Mansoura University, Mansoura, Egypt.

ABSTRACT

To assess the effect of potassium fertilization rates at [0.0, 50, 75 and 100 kg/fed. as potassium sulphate (48 % K_2O)], different nano-chitosan concentration (0.0, 2.5 and 5 ml/l) and their combination treatments on growth and productivity of chamomile (*Matricaria chamomilla*, L.), field experiment was conducted in private farm in Mansoura District, Dakahlia Governorate, Egypt, during the two winter consecutive seasons of 2016/2017 and 2017/2018. Treat chamomile plants with potassium fertilizer or/and nano chitosan induced significant increases in vegetative growth (plant height, number of branches/plant, fresh and dry weights of herb/plant), yield components (dry flower heads yield/plant and /feddan, yearly), volatile oil production (volatile oil percentage, volatile oil yield/plant and /feddan, yearly) and chemical constituents (K and total carbohydrates percentages in flower heads and total chlorophyll a + b content in leaves), as compared with control plants which untreated with potassium fertilization and nano-chitosan. . Generally, the obtained results indicated that growth and productivity of chamomile plants could be enhanced by the addition of potassium at 100 kg potassium sulphate /feddan in combination with the foliar application of 5 ml/l nano-chitosan grown in clay loamy soil under Dakahlia Governorate conditions.

Keywords: Chamomile, potassium, nano-chitosan, growth, yield components, volatile oil, chlorophyll

INTRODUCTION

Chamomile (*Matricaria chamomilla*, L.) is an annual plant belongs to family Asteraceae. Chamomile is the most important medicinal plant worldwide. This plant has been used for thousands of years in traditional Roman, Greek and Egyptian medicine to treat different diseases such as anxiety, chest colds, psoriasis and insomnia (Andrzejewska and Woropaj-Janczak, 2014). Later, one third of human demands for drugs are acquired from medicinal and aromatic plants (Agatonovic-Kustrin *et al*., 2015). However, increasing demand of pharmaceutical factories for primary materials and, more importantly, conservation of natural genetic resources, lay emphasis on the production as well as research on enhancing and processing of medicinal and aromatic plants.

Potassium (K) is an essential nutrient that affects most of physiological processes and the biochemical that influence plant growth and yield. It also contributes to the survival of plants exposed to various biotic and a biotic compressing. Also, potassium plays a vital role for a translocation of carbohydrates, normal cell division and reduction of nitrates. On the other hand, potassium never appears to represent a permanent structural component, but it has a metabolic role (Black, 1960). It is an important element of the many soils and is ultimately derived from the weathering of soil parent materials within the soil (Wiedenhoeft, 2006). In addition, potassium is an important element in promoting carbohydrates, plant metabolism, fats and protein synthesis, increasing crop yield and improving fresh produce quality (Hafsi *et al*., 2014). Moreover, the application of K affected plant growth and essential oil yield of dittany (*Origanum dictamnus*) and rosemary (*Rosmarinus officinalis*) plants (Economakis, 1993; Puttanna *et al*., 2010).

Chitosan is a natural polymer derived from deacetylation of chitin, which may be obtained from crustaceans, insects, fungi, etc. (Boonsongrit *et al*., 2006). A positive effect of chitosan has been observed on the growth of roots, shoots and leaves of various plants including gerbera (Wanichpongpan *et al*., 2001). Also, Abdel-Aziz *et al*. (2016) found that nano chitosan-NPK fertilizer enhances the growth and yield components of wheat plants compared to untreated plants. Chitosan and derivatives is harmless, environmentally friendly biodegradable, and have grand potential for agricultural purpose and improved yield production because of its essential plant activity (Van *et al*., 2013; Zagzog *et al*., 2017; Mahmoud *et al*., 2018) like increment chemical constituents and chlorophyll content in treated plants with chitosan.

The aim of this work was to assess the influence of potassium as a soil fertilizer in combination with nano-chitosan as foliar spray on chamomile in terms of its growth parameters, yield components, volatile oil production, potassium and total carbohydrate percentages as well as chlorophyll content under Dakahlia Governorate conditions.

MATERIALS AND METHODS

A field experiment was done during the two successive winter seasons of 2016/2017 and 2017/2018 at a private farm in Mansoura District, Dakahlia Governorate, Egypt, to study the influence of different rates of potassium sulphate, nano-chitosan concentrations and their combination treatments on the growth parameters, yield components, volatile oil production and some chemical constituents of chamomile plants. The experimental soil was clay loamy in texture; however, the physical and chemical properties were shown in Table 1. This experiment was included twelve treatments which were the combination between four levels of potassium sulphate (0.0, 50, 75 and 100 kg/fed.) as adressing application and three concentrations of nano-chitosan solution (0.0, 2.5 and 5 ml/l) as a foliar application.

These treatments were distributed in a split plot design with three replications. The rates of potassium sulphate were randomly distributed in the main plots, while nano-chitosan concentrations were randomly distributed in the sub plots.

Seeds of chamomile were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza, Egypt. The seeds were sown in the nursery on 10^{th} October, in the two seasons. Chamomile transplants (40 days old) about 10 cm lengths were transplanted on 19^{th} of November in both seasons. Seedlings were transplanted on one side of each ridge in 50 cm width and 30 cm apart. Each plot consists of five ridges; each one is 4.0 m long. The area of the experimental unit was (10 m^2).

Potassium fertilizer was applied in two splits as potassium sulphate (48% K_2O) i.e. half at after 35 days of transplanting and the remaining half after 80 days from transplanting. But, nano-chitosan was added four times as foliar application at 30, 50, 80 and 100 days after transplanting.

Table 1. Physical and chemical soil analysis during the two seasons of 2016/2017 and 2017/2018.

Seasons	Silt %	Clay %	Sand %	Texture soil	PH	E.C (dSm-1)	O.M %	$CaCO_3$ %	N ppm	P ppm	K ppm
First	42.7	35.9	21.4	Clay loamy	8.11	1.57	1.89	3.27	51.8	8.6	199
Second	42.7	35.9	21.3	Clay loamy	8.12	1.63	1.87	3.28	53.3	11.0	201

Chitosan nano crystallite powder was synthesized by high-energy ball milling. Powder mixture conducted in a 0.4 mini lab planetary ball mill (model BECO-PBM-V-0.4L, Changsha Deco Equipment Co., Ltd., China) to 40 hours using ball to powder mass ratio of 8:1 by prof. Dr. Osama M. Hemeda at Central lab., Physics Department, Faculty of Science, Tanta University, Egypt. The microstructure of the sintered samples examined using High Resolution Transmission Electron Microscope (HRTEM) model JOEL EM 2-100. The size of chitosan nano-particles, as evident from the TEM images found to be 50 nm.

Data Recorded:

A random sample of three plants from each sub plot was taken; the 1st cut at 70 days and the 2nd cut at 115 days after transplanting and the following data were recorded:

1. **Growth parameters:** Plant height (cm), number of branches/plant and herb fresh and dry weight/plant (g) were determined.
2. **Yield components:** Dry weight of yearly flower heads/ plant (g) in every plot was harvested, then total dry yield of yearly flower heads/feddan (kg) were calculated.
3. **Volatile oil production:** At harvest time (at the end of every season) about 10 g of each dried sample (flower heads) was separated triturated and steam-hydro distilled for 3 hours. The extraction of oils was carried out according to method of European Pharmacopoeia (1983). Also, yearly volatile oil yield per chamomile plant (ml) and per faddan (l) was calculated.
4. **Chemical constituents:** After every cut, 10 g of each dried flower heads were randomly taken from each treatment and oven dried at 70°C till constant weight and K and total carbohydrates percentages in flower heads according to the methods described by Jackson (1970) and AOAC (1990) respectively, as well as chlorophyll a+ b content (mg/g, fresh weight) was determined in chamomile leaves as described by Mazumder and Majumder (2003).

Statistical Analysis

Data of the present work were statically analyzed and the differences between means of the treatments (K fertilizer rates and nano-chitosan concentrations) were considered significant when they were more than the least significant differences (L.S.D) at the 5% level by using computer program of Statistix Version 9 (Analytical Software, 2008).

RESULTS AND DISCUSSION

Chamomile growth parameters:

The obtained data in Tables 2 and 3 shows that, plant height, number of branches/plant and herb fresh and dry weights/plant were significantly increased as potassium rates increase in both seasons. In addition, the highest values in this regard were recorded with the highest rate of K fertilization compared to the other three ones treatments under study. It was well known that chemical fertilizers (K) could enhance plant growth due to the role of potassium as an activator of many enzymes (Helgi and Rolfe, 2005). Moreover, Bekele (2018) reported that potassium sulphate fertilizer application at different levels showed significant effects on growth paraeters i.e. Plant height and leaf number of onion plants compared to control. In addition, significant differences were generally detected in growth parameters of chamomile plants between nano-chitosan concentrations during the two seasons. Both nano-chitosan treatments (2.5 and 5 ml/l) significantly (LSD at 5%) increased chamomile growth parameters than control in both seasons. Hasaneen *et al.* (2016) suggested that nanomaterials are leading to significant enhancement in plant through improving the growth and hence dry weight and leaf area which reflected in growth rate. Also, Anusuya and Sathiyabama (2016) found that the growth parameters of turmeric plants (shoot height, leaf number/plant and plant fresh weight) were increased with application of chitosan.

The stimulating influence of nano-chitosan on growth might be due to an increase in the availability and uptake of water and minerals through adjusting pressure of cell osmotic, and decrease the accumulation of harmtful free radicals by enhancing antioxidants and enzyme activities (Guan *et al*., 2009).

Furthermore, the combination between the different rates of potassium sulphate and nano-chitosan treatments in both seasons can be seen in Tables (2 and 3). The results indicated that the prevalence of applying the different combinations in enhancing chamomile growth parameters as plant height and number of branches per plant as well as herb fresh and dry weights per plant. Although the highest values of plant height and number of branches were obtained from both 75 and 100 Kg of K with 5 ml/l nano-chitosan , it was observed that values were significantly higher when 100 Kg K + 5 ml/l nano-chitosan was used in both seasons .

Table 2. Influence of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* plant height and number of branches/plant during 2016/2017 and 2017/2018 seasons

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	**2.5**	**5.0**	**Mean (K)**	**0.0**	**2.5**	**5.0**	**Mean (K)**
	Plant height (cm)							
	2016/2017 season							
	First cut				**Second cut**			
Control	24.33	25.33	26.33	25.33	54.33	57.00	56.33	55.89
50	25.33	26.00	26.67	26.00	56.67	57.00	61.00	58.22
75	27.33	27.67	30.33	28.44	62.00	66.00	69.00	65.67
100	27.33	29.67	31.67	29.56	64.33	68.33	71.67	68.11
Mean (C)	26.08	27.17	28.75		59.33	62.08	64.50	
L.S.D. at 5 %	(K)= 0.53	(C)= 0.64		(K×C)=1.18	(K)= 1.27	(C)= 1.18		(K×C)= 2.31
	2017/2018 season							
	First cut				Second cut			
Control	22.33	26.00	26.33	24.89	52.33	58.00	57.33	55.89
50	25.33	26.67	28.33	26.78	57.00	58.67	61.33	59.00
75	26.33	29.33	31.33	29.00	63.67	67.33	71.00	67.33
100	28.33	29.67	30.67	29.56	63.33	66.00	70.00	66.44
Mean (C)	25.58	27.92	29.17		59.08	62.50	64.92	
L.S.D. at 5 %	(K)= 0.60	(C)= 0.56		(K×C)= 1.09	(K)= 1.33	(C)= 0.91		(K×C)= 1.98
	Number of branches / plant							
	2016/2017 season							
	First cut				Second cut			
Control	9.33	10.33	10.33	10.67	13.67	14.67	19.67	16.00
50	10.00	12.33	13.00	11.78	14.67	16.67	20.33	17.22
75	11.00	12.67	13.67	12.44	15.00	18.00	22.00	18.33
100	11.67	13.33	15.33	13.44	18.33	22.00	24.67	21.67
Mean (C)	10.50	12.17	12.58		15.42	17.83	21.67	
L.S.D. at 5 %	(K)= 0.86	(C)= 0.43		(K×C)= 1.11	(K)= 0.84	(C)= 0.34		(K×C)= 1.00
	2017/2018 season							
	First cut				Second cut			
Control	9.67	10.67	12.00	10.78	14.33	16.00	19.33	16.56
50	11.00	13.33	13.33	12.56	16.00	18.67	21.67	18.78
75	11.67	13.67	15.00	13.44	16.33	19.67	23.33	19.78
100	12.33	14.33	16.33	14.33	19.00	23.00	25.33	22.44
Mean (C)	11.17	13.00	14.17		16.42	19.33	22.42	
L.S.D. at 5 %	(K)= 0.50	(C)= 0.53		(K×C)= 0.99	(K)= 0.86	(C)= 0.58		(K×C)= 1.27

Table 3. Influence of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* herb fresh and dry weights/plant (g) during 2016/2017 and 2017/2018 seasons

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	**2.5**	**5.0**	**Mean (K)**	**0.0**	**2.5**	**5.0**	**Mean (K)**
	Herb fresh weight/ plant (g)							
	2016/2017 season							
	First cut				**Second cut**			
Control	11.28	13.21	10.07	12.86	16.08	17.05	18.06	17.06
50	12.49	13.43	10.07	13.66	17.15	18.63	20.29	18.69
75	13.66	15.36	16.33	15.12	17.23	19.56	20.88	19.22
100	13.55	16.03	16.75	15.44	19.21	20.73	23.56	21.17
Mean (C)	12.75	14.51	15.55		17.41	18.99	20.70	
L.S.D. at 5 %	(K)= 0.51	(C)= 0.24		(K×C)=0.64	(K)= 0.50	(C)= 0.24		(K×C)= 0.63
	2017/2018 season							
	First cut				Second cut			
Control	12.26	13.17	14.90	13.44	16.46	17.67	18.69	17.61
50	13.07	13.79	15.40	14.09	20.27	21.64	22.84	21.58
75	14.00	15.28	17.84	15.71	21.80	23.68	25.45	23.64
100	14.56	16.63	18.56	16.58	23.09	25.56	28.05	25.57
Mean (C)	13.47	14.72	16.67		20.41	22.14	23.76	
L.S.D. at 5 %	(K)= 0.60	(C)= 0.32		(K×C)= 0.79	(K)= 0.41	(C)= 0.35		(K×C)= 0.71
	Herb dry weight/ plant (g)							
	2016/2017 season							
	First cut				Second cut			
Control	3.37	3.75	3.89	3.67	4.02	4.18	4.60	4.26
50	3.73	3.86	4.00	3.86	4.04	4.53	5.10	4.56
75	3.89	4.02	4.22	4.04	4.26	5.55	6.13	5.31
100	3.97	4.18	4.49	4.21	4.90	6.78	7.29	6.32
Mean (C)	3.74	3.95	4.15		4.30	5.26	5.78	
L.S.D. at 5 %	(K)= 0.13	(C)= 0.11		(K×C)= 0.22	(K)= 0.33	(C)= 0.15		(K×C)= 0.41
	2017/2018 season							
	First cut				Second cut			
Control	3.22	3.43	3.90	3.52	4.27	4.58	4.80	4.55
50	3.52	3.66	4.22	3.80	5.05	5.14	5.73	5.31
75	3.79	4.09	4.58	4.15	4.96	5.85	6.25	5.69
100	4.12	4.55	4.71	4.46	5.56	6.30	7.03	6.29
Mean (C)	3.66	3.93	4.35		4.96	5.47	5.95	
L.S.D. at 5 %	(K)= 0.08	(C)= 0.07		(K×C)= 0.14	(K)= 0.14	(C)= 0.10		(K×C)= 0.21

Generally, as mentioned just before, potassium fertilization rates and nano-chitosan concentrations treatments (each alone) increased plant growth of chamomile plant, in turn, they together might maximize their effects leading to better results in this concern. Likewise, Abdel-Aziz *et al*. (2016) demonstrated that treated wheat plants with nano-chitosan NPK fertilizer led to significant progressive increase in all growth variables (shoot length, fresh weight and dry weight) compared to control.

Chamomile yield components:

As shown in Table 4 that the treatment of 100 kg potassium sulphate (48 % K_2O) increased total yearly dry flower heads/plant (g) and /feddan (kg) of *Matricaria chamomilla* plant compared with the other treatments under study. Also, yield components of chamomile were increased with increasing K rates in both seasons. Generally, the two rates of 100 and 75 kg/feddan significantly increased above mentioned parameters compared to the lowest rate (50 kg/fed.) in the first and second seasons. Similar results were stated by Hussien and Wuhaib (2010) and Palizdar *et al.* (2011) observed increases in biometric characteristics and higher yields in safflower crops with greater availability of potassium. As well, Ahmed *et al*. (2018) revealed that potassium fertilization at 75 kg K_2O/ feddan significantly increased in all yield components of sunflower (weight of head/ plant, weight of seeds / head and seed yield / fed.) compared to untreated plants.

Table 4. Effect of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* dry flower heads yield / plant (g) and /feddan (kg) per year during 2016/2017 and 2017/2018 seasons

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	2.5	5.0	Mean (K)	0.0	2.5	5.0	Mean (K)
	Dry flower heads yield/plant (g) per year							
	2016/2017 season				2017/2018 season			
Control	10.70	11.25	11.73	11.23	9.27	9.51	9.91	9.56
50	11.20	12.43	13.32	12.31	10.38	10.98	11.71	11.02
75	11.45	12.86	13.98	12.76	10.41	12.29	13.64	12.11
100	12.56	14.36	15.38	14.10	11.92	13.84	15.52	13.76
Mean (C)	11.47	12.73	13.60		10.49	11.65	12.69	
L.S.D. at 5 %	(K)= 0.33	(C)= 0.28	(K×C)= 0.56		(K)= 0.41	(C)= 0.33	(K×C)= 0.67	
	Dry flower heads yield/feddan (kg) per year							
	2016/2017 season				2017/2018 season			
Control	299.51	315.09	328.53	314.38	259.47	266.19	177.57	267.74
50	313.51	347.95	372.87	344.77	290.55	307.35	327.79	308.56
75	320.60	360.17	391.35	357.37	291.57	344.21	381.83	339.20
100	351.59	402.08	430.55	394.74	333.67	387.61	434.47	385.25
Mean (C)	321.30	356.32	380.82		293.81	326.34	355.41	
L.S.D. at 5 %	(K)= 9.16	(C)= 7.75	(K×C)= 15.60		(K)= 11.47	(C)= 9.14	(K×C)=18.78	

It is quite clear from the data in Table 4 that the maximum increase in yield components [total plant fresh and dry weights / plant and fresh and dry herb yields otl [yearly dry flower heads/plant (g) and /feddan (kg)] of chamomile plant were obtained from the treatments of nano-chitosan at 5 ml/l compared to the other treatments during both seasons. Also, yield components were increased gradually with increasing nano-chitosan concentrations. The increase of yield components of chamomile was related to improve of growth with nano-chitosan because these particles enter straight into plant leaves throughout stomata (Grover *et al*., 2012), also, nano-chitosan can stimulate many biological responses in plants such as increased growth and productivity, which depend on the chemical composition of chitosan (Malerba and Cerana, 2016). These results are in accordance with those found by Choudhary *et al*. (2016), Mahmood *et al*. (2017) and Behboudi *et al*. (2018).

The best combination treatment was potassium fertilization at 100 kg/feddan combined with 5 ml/l nano-chitosan compared to the other combination treatments under study during the two tested seasons (Table 4). However, under each treatment of potassium rate yield components of chamomile plant was increased with increasing nano-chitosan concentration. Also, Abdel-Aziz *et al*. (2018) reported that as compared with control values, treatment of wheat plants with normal and nano-NPK fertilizer induced significant increases in all yield variables determined.

Chamomile volatile oil production:

The volatile oil percentage and volatile oil yield/plant (ml) and yearly/feddan (l) of chamomile plants influenced significantly among different potassium fertilization rates compared to unfertilized plants in both seasons (Table 5). The highest values in this connection were recorded by 100 kg potassium sulphate (48 % K_2O) /feddan compared to the other rates during both seasons. In *Matricaria chamomilla* L. Hendawy and Khalid (2011) found that chemical fertilization showed positive effect on the volatile oil percentage and increase in the total content of essential oil per plant.

Furthermore, volatile oil production of chamomile plants was increased gradually with increasing nano-chitosan concentration (Table 5). However, the maximum increase in those parameters (volatile oil percentage and volatile oil yield/plant and /feddan) were obtained from the treatment of nano-chitosan at (5 ml/l) compared with the other ones under study. Such increase was significant in the first and second season seasons. Similar results were found by Lei *et al.* (2011) on *Artemisia annua* and Yin *et al.* (2011) on *Oreganum vulgare* and Bistgani *et al.* (2017) on *Thymus daenensis*.

Table 5. Effect of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* volatile oil percentage (%), yield/ plant (ml) and ⁄ feddan (L) during 2016/2017 and 2017/2018 seasons

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	2.5	5.0	Mean (K)	0.0	2.5	5.0	Mean (K)
	Volatile oil percentage (%)							
	2016/2017 season				2017/2018 season			
Control	0.377	0.423	0.440	0.413	0.373	0.383	0.403	0.387
50	0.407	0.447	0.470	0.441	0.367	0.383	0.423	0.391
75	0.440	0.470	0.493	0.468	0.387	0.407	0.437	0.410
100	0.437	0.477	0.510	0.474	0.397	0.413	0.453	0.421
Mean (C)	0.415	0.454	0.478		0.381	0.397	0.429	
L.S.D. at 5 %	(K)=0.001	(C)=0.001	(K×C)= 0.002		(K)=0.004	(C)=0.007	(K×C)=0.012	
	Volatile oil yield/ plant (ml)							
	2016/2017 season				2017/2018 season			
Control	0.040	0.048	0.052	0.047	0.034	0.036	0.040	0.037
50	0.045	0.056	0.062	0.054	0.038	0.042	0.050	0.043
75	0.051	0.060	0.069	0.060	0.040	0.050	0.059	0.050
100	0.055	0.069	0.078	0.067	0.047	0.057	0.070	0.058
Mean (C)	0.048	0.058	0.065		0.040	0.046	0.055	
L.S.D. at 5 %	(K)=0.003	(C)=0.002	(K×C)= 0.004		(K)=0.002	(C)=0.002	(K×C)=0.004	
	Volatile oil yield/ feddan (l)							
	2016/2017 season				2017/2018 season			
Control	1.129	1.334	1.445	1.303	0.968	1.020	1.120	1.036
50	1.274	1.554	1.753	1.527	1.065	1.179	1.389	1.211
75	1.412	1.693	1.931	1.678	1.128	1.400	1.668	1.398
100	1.536	1.917	2.196	1.883	1.323	1.602	1.969	1.632
Mean (C)	1.337	1.624	1.831		1.121	1.300	1.536	
L.S.D. at 5 %	(K)= 0.08	(C)= 0.05	(K×C)= 0.012		(K)= 0.052	(C)= 0.052	(K×C)= 1.00	

The combination treatment between potassium fertilization at 100 kg/feddan and the highest concentration of nano-chitosan (5 ml/l) was superior in chamomile volatile oil percentage and volatile oil yield per plant and per feddan compared to the other ones under study in both seasons (Table 5). In addition, under each treatment of nano-chitosan concentration the above-mentioned parameters were increased gradually with increasing potassium fertilization rates during both seasons. Aćimović (2013) reported that chemical fertilization increased caraway, anise and coriander plants volatile oil production compared to control. Also, Aghajani *et al.* (2013) demonstrated that nano-particles (diameter ~32 nm) increased production of essential oils in *Thymus kotschyanus*.

Chamomile chemical constituents:

Tables 6 and 7 reveal that potassium and total carbohydrates percentages as well as total chlorophyll a+ b content were gradually increased by increasing K fertilization rates in both seasons. Also, the elevated values in this concern were recorded with 100 kg/feddan potassium sulphate compared to the other ones under study. Additionally, enhance translocation of sugar and carbohydrates through plant organs, increases protein synthesis and different metabolic processes by using K fertilization (Csirzinsky, 1999). Meanwhile, Abdelkader *et al.* (2018) indicated that the highest rate of potassium fertilization recorded significant increase in potassium content of caraway plants compared to control.

Results tabulated in Tables 6 and 7 show that, any nano-chitosan concentrations significantly enhanced the potassium and total carbohydrates percentages in flower heads as well as total chlorophyll a+ b content in leaves of chamomile plant compared with control during both seasons. The highest values of chemical constituents of *Matricaria chamomilla* plant were recorded with the highest concentration of nano-chitosan during the two seasons. Van *et al.* (2013) showed that the foliar application of chitosan as nano-particles to seedlings of coffee in the green house significantly improved the uptake of potassium content from 30 to 40 compared to the control.

Also, flower heads potassium and total carbohydrates percentages as well as leaves pigments of chamomile were significantly increased with all combination treatments between potassium fertilization and nano-chitosan compared with control [without potassium addition and with no nano-chitosan foliar application] in mostly during both seasons. Generally, under each treatment of potassium fertilization the above-mentioned parameters were increased gradually with increasing nano-chitosan concentration. Elfeky *et al.* (2013) found positive effects of nano-particles on total carbohydrate, chlorophyll content and essential oil content of *Ocimum basilicum*. Abdel-Aziz *et al.* (2018) suggested that K^+ element content in wheat showed an increase with nano-NPK fertilizers levels as compared with control.

Table 6. Effect of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* potassium and total carbohydrates percentages during 2016/2017 and 2017/2018 seasons

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	2.5	5.0	Mean (K)	0.0	2.5	5.0	Mean (K)
	Potassium percentage in flower heads							
	2016/2017 season							
	First cut				**Second cut**			
Control	2.32	2.38	2.45	2.38	2.12	2.26	2.30	2.23
50	2.36	2.43	2.47	2.42	2.14	2.34	2.39	2.29
75	2.40	2.46	2.50	2.45	2.19	2.42	2.50	2.37
100	2.41	2.46	2.50	2.46	2.16	2.42	2.50	2.36
Mean (C)	2.37	2.43	2.48		2.15	2.36	2.42	
L.S.D. at 5 %	(K)= 0.01	(C)= 0.01	(K×C)= 0.02		(K)= 0.03	(C)= 0.04	(K×C)= 0.07	
	2017/2018 season							
	First cut				Second cut			
Control	2.19	2.34	2.39	2.31	2.10	2.11	2.16	2.12
50	2.25	2.40	2.42	2.36	2.23	2.30	2.37	2.30
75	2.28	2.42	2.45	2.39	2.25	2.38	2.44	2.35
100	2.40	2.44	2.47	2.44	2.26	2.41	2.54	2.40
Mean (C)	2.28	2.40	2.43		2.21	2.30	2.37	
L.S.D. at 5 %	(K)= 0.02	(C)= 0.03	(K×C)= 0.05		(K)= 0.03	(C)= 0.02	(K×C)= 0.04	
	Total carbohydrates percentages in flower heads							
	2016/2017 season							
	First cut				Second cut			
Control	15.90	16.56	16.90	16.45	15.80	16.49	17.20	16.50
50	16.28	16.79	17.44	16.84	15.92	16.90	17.92	16.91
75	16.50	17.53	18.58	17.54	15.96	17.28	19.28	17.50
100	16.58	18.53	19.50	18.25	16.54	18.49	19.75	18.26
Mean (C)	16.35	17.35	18.11		16.05	17.29	18.54	
L.S.D. at 5 %	(K)= 0.23	(C)= 0.25	(K×C)= 0.47		(K)= 0.34	(C)= 0.26	(K×C)= 0.54	
	2017/2018 season							
	First cut				Second cut			
Control	15.68	16.42	17.22	16.44	16.50	16.70	17.17	16.78
50	16.07	17.14	17.63	16.95	17.20	17.64	18.20	17.68
75	16.30	16.92	18.40	17.21	17.29	18.28	19.21	18.26
100	16.49	17.34	18.87	17.57	17.54	18.49	19.39	18.47
Mean (C)	16.14	16.96	18.03		17.13	17.78	18.49	
L.S.D. at 5 %	(K)= 0.23	(C)= 0.22	(K×C)= 0.43		(K)= 0.43	(C)= 0.33	(K×C)= 0.69	

Table 7. Effect of potassium fertilization rate (K), nano-chitosan concentrations (C) and their combination (K×C) treatments on *Matricaria chamomilla* total chlorophyll content "a+b" (mg/g fresh leaves weight) during 2016/2017 and 2017/2018 seasons .

Potassium fertilization rate (kg/fed.)	Nano-chitosan concentrations (ml/l)							
	0.0	2.5	5.0	Mean (K)	0.0	2.5	5.0	Mean (K)
	Total chlorophyll content (a+b) in leaves							
	2016/2017 season							
	First cut				**Second cut**			
Control	9.71	9.93	10.22	9.95	8.94	9.51	10.22	9.56
50	9.75	10.11	11.12	10.33	9.19	9.77	10.40	9.79
75	10.22	10.66	11.03	10.64	9.18	9.80	10.78	9.92
100	10.41	10.88	12.01	11.10	9.56	10.16	11.22	10.32
Mean (C)	10.02	10.40	10.10		9.22	9.81	10.65	
L.S.D. at 5 %	(K)= 0.25	(C)= 0.21	(K×C)= 0.42		(K)= 0.13	(C)= 0.15	(K×C)= 0.27	
	2017/2018 season							
	First cut				Second cut			
Control	9.48	9.28	10.19	9.65	8.52	8.78	8.91	8.74
50	9.63	9.81	10.41	9.95	8.85	9.10	9.38	9.11
75	9.78	10.16	11.30	10.41	8.99	9.46	10.57	9.67
100	10.07	10.34	11.42	10.61	9.23	9.98	10.91	10.04
Mean (C)	9.74	9.90	10.83		8.90	9.33	9.94	
L.S.D. at 5 %	(K)= 0.08	(C)= 0.07	(K×C)= 0.14		(K)= 0.47	(C)= 0.20	(K×C)= 0.57	

CONCLUSION

In general, the results showed that potassium sulphate at 100 kg/ feddan contributed to an increase in total chamomile flower heads yield per feddan under study. Also, foliar spray with nano-chitosan at the concentration 5 ml/l led to stimulate growth, increasing yield and enhancing some biochemical constituents of chamomile plant.

From the above mentioned results it could be concluded that foliar application of nano-chitosan (5 ml/ l) could be successfully used in addition to fertilization application of potassium sulphate with rate of 100 kg/ feddan to obtain the highest vegetative growth characters, total yield, and significantly enhanced volatile oil production of chamomile plants under similar field conditions.

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تأثير التسميد البوتاسي والنانو كيتوزان على النمو والمكونات المحصولية وإنتاج الزيت العطري لنبات شيح البابونج

فاطمة رشاد إبراهيم خليل سليمان
قسم الخضر والزينة- كلية الزراعة - جامعة المنصورة

أجريت تجربة حقلية في مزرعة خاصة بمنطقة المنصورة، محافظة الدقهلية، مصر، لتقييم تأثير معدل التسميد البوتاسيوم (صفر، ٥٠، ٧٥ و١٠٠ كجم/فدان في صورة كبريتات البوتاسيوم ٤٨ % بو٢أ)، وتركيزات مختلفة من النانو كيتوزان (صفر، ٢.٥ و ٥ مللي/لتر) ومعاملات التداخل بينهما على نمو وإنتاجية شيح البابونج، خلال الموسمين الشتويين المتتاليين ٢٠١٦/٢٠١٧ و ٢٠١٧/٢٠١٨. أدت معاملة نباتات شيح البابونج بالتسميد البوتاسي و/أو النانو كيتوزان إلى زيادة معنوية في النمو الخضري (ارتفاع النبات، عدد الأفرع/النبات، الأوزان الطازجة والجافة للعشب/نبات)، مكونات المحصول (محصول رؤوس الزهور الجافة / النبات و/ الفدان، سنوياً)، إنتاج الزيت العطري (النسبة المئوية للزيت العطري ، محصول الزيت العطري/ النبات و/ الفدان، سنويًا) والمكونات الكيميائية (النسب المئوية للبوتاسيوم و الكربوهيدرات الكلية بالرؤوس الزهرية ومحتوى الكلوروفيل الكلي أ+ب بالأوراق الطازجة)، مقارنةً بمعاملة الكنترول لصفات نباتات البابونج الغير مسمد والغير مرشوشة بالنانو كيتوزان. بشكل عام ، أشارت النتائج التي تم الحصول عليها إلى أنه يمكن تحسين نمو وإنتاجية نباتات البابونج بإضافة البوتاسيوم بمعدل ١٠٠ كجم كبريتات البوتاسيوم /فدان بالتداخل مع الرش الورقي بـ ٥ مللي/لتر نانو كيتوزان المنزرع في التربة الطينية الطمية تحت ظروف محافظة الدقهلية.