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(Original Article)

Response of Growth, Flowering, Nutrient Uptake and Essential Oil of German Chamomile to Organic Nutrition

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Abstract

An experimental field was conducted during 2019/2020 and 2021/2021 seasons to evaluate the effects of different rates of humic acid (H.A) and liquid compost (L.C) on quantitative and qualitative yield of German chamomile (*Matericaria recutita L.*). Rates of both organic materials were 2000 and 4000 ppm, beside control were applied as a soil drench method and performed five times, two weeks intervals through growing seasons starting 45 days from sowing. Vegetative growth, flowering characters, nutritional state, physiological traits, and essential oil yield and its components were studied. Results indicated that all H.A and L.C treatments improved growth parameters (plant height, number of branches per plant, fresh and dry weights of herb and roots), flowering characteristics (number of flower-heads per plant, flower diameter, and fresh and dry weights of flower yield) as compared to control. However, L.C at 4000 ppm was the most effective treatment resulting in significant increases as compared to other treatments. The vigorous growth of superior treatment was closely associated with higher uptake of nutrient elements (N, P, K, Ca and Mg) than control which produced the worst growth with the lowest uptake of minerals. A positive relationship was found between the adequate nutrients uptake and the highest leaf contents of chlorophyll "a", carotenoids, carbohydrates and protein. Treatment of L.C at 4000 ppm showed considerable increases in essential oil percentage, oil yield and the major constituent in chamomile oil of chamazulene. So, we can recommend to apply this best treatment for organic German chamomile with clearly, safety, health quality and free contaminate chemicals.

Key words: *Chamomile yield, Humic acid, Liquid compost, Essential oil, Chamazulene.*

Introduction

German chamomile (*Matericaria recutita L.*) belongs to the Asteraceae family. It is considered as one of the most common cultivated medicinal crops in the world and it listed in major pharmacopeia such as B.P.C. (2002) and U.S.P.C. (2004). It is an annual herb varies in height from 20-60 cm depending on soil fertility and climatic conditions. The flower-heads mainly used which contain an essential oil about 1.2 - 1.9 % by steam distillation (Weiss, 1997). The major essential oil components include chamazulene, bisabolone-oxide A and bisablolol-

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oxide B (Guenther, 1972). Pharmacological properties involve anti-inflammatory, antiseptic, carminative, healing, sedative and spasmolytic activity (Salamon, 1992).

It is well known that the management practices with organic substances influence agricultural sustainability by improving physical, chemical and biological properties of soil (Abbott and Murphy, 2007). Addition of organic amendments to the soil surface is widely used in order to ameliorate soil physical conditions such as temperature, evaporation and have positive effects on soil nutrient availability, improve soil water storage and produce the maximum yield of chamomile (Kisic *et al*., 2019).The use of organic fertilizers are recommended by many researchers to substitute the chemical fertilizers. Organic materials have long been recognized as an effective means of clean agriculture with minimum pollution effects and reduce agriculture cost (Arun, 2002 and Panda, 2006). Since, organically grown crops are believed to provide more healthy and nutritionally superior food for human than those grown with chemical fertilizers. There is an increasing consumer demand for agricultural products which are free for toxic chemical residues (Bohn *et al*., 2001 and Nardi *et al*., 2002). In addition, organic farming helps to prevent environmental pollution and the management of nutritional aspects of chamomile is very important in agro-ecosystems (Hadi *et al*., 2011).

Studies along these lines have emphasized that the improvement of chamomile yield quality and quantity are the major objectives in nutritional programs, especially for the organic fertilization. Ahmadian *et al*. (2011) reported that compost application enhanced fresh and dry weights of chamomile flower yield, increased essential oil content and chamazulene yield. Hadi *et al*. (2011) demonstrated that the best quantitative and qualitative flower yield, and essential oil and its components of chamomile were obtained by using vermicompost addition (20 ton/ha). Hendawy and Khalid (2011) supplied chamomile plants with different rates of liquid compost and found that all treatments improved flower-head characteristics, increased essential oil content and had a positive effect on oil constituents as compared to chemical fertilizers. Singh *et al*. (2011) cleared that humic substances and composts had favorable influences on growth, flowering, essential oil percentage and oil yield of chamomile. They added that chamomile plants are rich in secondary metabolites which greatly affected by organic fertilization that led to some beneficial changes in concentration and quality of their ingredients such as essential oil, alkaloids, glycosides and steroids. Juárez *et al*. (2012) stated that humic substances stimulated the vegetative growth characteristics, as well as flowers and essential oil production of chamomile. Jimayu (2017) revealed that the application of compost enhanced plant growth, development, and consequently chamomile flower productivity, as well as the percentage of oil production and quality. He, also found that compost had pronounced effect on chlorophyll synthesis, carbohydrates accumulation and leaf minerals content.

Khoshghalb *et al*. (2017) pointed out that humic acid (5 g/l) applied as foliar sprays improved the vegetative growth parameters of German chamomile, increased flower fresh and dry weights, essential oil content and the major component in essential oil of chamazulene. Hassan and Fahmy (2020) concluded that the application of humic acid at 150 ppm as foliar spray resulted in the highest values of vegetative growth measurements, yield of chamomile flower-heads per plant and per feddan, oil percentage and yield, and the main constituents of chamazulene; bisabolone-oxide A and bisabolol-oxide B in essential oil, as well as, leaf nutrients content of N, P and K.

Furthermore, Sardoei (2014) reported that vermicompost application at 30 % had positive effects on the vegetative and root growth, flowering characters, leaf pigments of chlorophyll (a & b) and carotenoids content in pot marigold. Omar (2020) found that humic acid at 400 ppm as foliar sprays was superior treatment for improving growth characteristics of caraway plant. He added that the optimum growth was closely associated with the adequate nutrient's uptake of N, P, K and Mg, the formation of leaf pigments, carbohydrates accumulation and protein synthesis in the herb.

The aim of this investigation was to evaluate the effects of different rates of humic acid and liquid compost on growth, flowering, yield and constituents of essential oil of German chamomile. Sufficient information concerning these aspects and their relationships with plant physiology and metabolic processes are necessary.

Materials and Methods

An open field experiment was carried out at the Floriculture Nursery, Faculty of Agriculture, Assiut University during 2019/2020 and 2020/2021 seasons. Chamomile seeds were obtained from Germany (Enza Zadden Co.). Before sowing immediately, seeds were treated with fungicide (Rizolex T 50% W.P.) at the rate of 3 g/kg.

On November 3rd 2019 and 2020, seeds were sown in plots each was 2x1 m including terrace divided into four rows with 20 cm distance and each row contained 20 hills at 10 cm distance. A total of chamomile plants was approximately 96000 per feddan. Some physic-chemical properties of field soil are shown in Table 1. The ambient temperatures in the location of study during the period of experimentation ranged from 11 to 32°C and the relative humidity 27-50 %. All horticultural practices as irrigation, weeding and fungicides treatment were similarly done whenever needed.

The experimental design was complete randomized blocks with four replicates, in each one five treatments; humic acid and liquid compost, each at 2000 and 4000 ppm, beside control (only water). The potassium humate was used in this study, produced in China and imported by Art. Chem. Co., Egypt and has a physical data as follows: appearance (black powder), pH (9-10) and water solubility (>98%). The quarated analysis was humic acid 90 % and K_2O 10 %. The liquid compost is prepared by Soil and Water Laboratory, Faculty of Agriculture, Assiut University, Egypt. The chemical analysis is presented in Table 2.

Table 1. Physico-chemical properties of the experimental soil

Particle size distribution (%)								Soluble ions (meq/l, soil paste)										
								Anions				Cations						
Sand	Silt	Clay	Texture grade	pH (1.:2.5) soil suspension	EC DS/m (1.5 oil extract)	Total $CaCO_3$ (%)	Organic matter (%)	Cl^-	CO_3^-	HCO_3^-	SO_4^-	Ca^{++}	Mg^{++}	Na^+	K^+	Total N (%)	Total P (%)	Total K (%)
22.3	26.2	51.5	Clay	8.71	1.03	1.07	0.57	3.32	-	4.94	3.63	5.40	0.52	1.30	3.89	0.70	0.21	0.41

Each value represents the mean of three replicates.

Table 2. Chemical properties of liquid compost used to amend the soil

Organic matter %	N %	P %	K %	Fe ppm	Zn ppm	Mn ppm	Cu ppm	Amino acids %
50	10	15	30	200	100	150	20	5

Four doses of both organic substances were applied as soil drenches; the first was applied after 45 days from sowing, followed by three doses at the same levels, two weeks intervals through the growing season. The solution of each treatment was added at the rate of 2 l/plot on soil surface for each and addition.

The yield of chamomile flower-heads was collected periodically at full opening stage; once or twice weekly depending on the acceleration of flowering that was started from the first of February to the end of April, during both seasons.

Data were recorded on the vegetative growth and flowering parameters, nutrients uptake, some biochemical compounds in leaves and oil characteristics (percentage, yield and chemical constituents). Determination of nutrient elements of N, P, K, Ca and Mg were done in wet digested solution of dried leaves according to Baruah and Barthakur (1997). Calculations of nutrients uptake are based on the dry weight of herb. Nitrogen was estimated by using the modified micro kjeldahl method (Black *et al*., 1965). Protein content in leaves were quantified and calculated using the conversion factor of 6.25 based on the assumption that the protein contains 16 % nitrogen according to Ranganna (1978). Phosphorus was determined colorimetrically at 660 nm wavelength using stannous chloride phosphomolibdic-sulphuric acid system according to Jackson (1978). Potassium was determined in the digested solution using Flame-photometer model 52 with acetylene burner according to Jackson (1978). Calcium and magnesium were measured volumetrically in the sample extract by titration with versene according to Helrich (1990). Photosynthetic pigments were estimated and calculated according to Vernon (1960). Total soluble carbohydrates in leaves were measured colorimetrically by anthrone sulphuric acid method at 630 nm wavelength according to Hansen and Moller (1975).

Essential oil of the air-dried flower-heads of German chamomile was extracted by the hydro-distillation method till a complete separation according to

U.S.P.C. (2004). Essential oil percentage (ml/100 g), oil yield was calculated by multiplying the oil % in flower-heads yield per plant (ml/plant) and per feddan (l/fed). Gas liquid chromatography (GLC) analysis of chamomile essential oil samples was measured by the methods outlined by Singh *et al*. (2006).

Data were statistically analyzed using Statistics 8.1 analytical software, and the means were compared using a least significant difference (L.S.D.) test according to Dowdy and Wearden (1983).

Results and Discussion

Vegetative growth

It is quite clear that the treatments of humic acid (H.A) and liquid compost (L.C) significantly increased the vegetative growth characteristics expressed as plant height, branch number and weight of herb and roots (fresh & dry) except for 2000 ppm H.A for plant height in the first season, as compared to control in both seasons (Table 3). Whilst L.C at 4000 ppm concentration was the most effective treatment, mostly, accompanied by significant increases in comparison with the other treatments. These results are in conformity with those reported on chamomile by Hadi *et al*. (2011), Khoshghalb *et al*. (2017), and Hassan and Fahmy (2020).

Table 3. Vegetative growth characteristics of German chamomile as affected by humic acid and liquid compost treatments during 2019/2020 and 2020/2021 seasons

Treatments (ppm)	2019/2020						2020/2021					
	Plant height (cm)	Branch No./plant	Herb weight (g/plant)		Root weight (g/plant)		Plant height (cm)	Branch No./plant	Herb weight (g/plant)		Root weight (g/plant)	
			Fresh	Dry	Fresh	Dry			Fresh	Dry	Fresh	Dry
Control	114.0	19.34	141.0	70.50	8.54	1.11	113.5	20.00	156.8	78.32	11.15	1.45
Humic acid 2000	116.4	20.88	165.8	82.88	10.07	1.31	115.0	22.00	163.1	81.55	12.28	1.60
Humic acid 4000	119.0	22.43	176.3	88.13	11.53	1.50	115.8	22.75	167.8	83.88	12.94	1.68
Liquid compost 2000	123.6	24.00	187.9	93.94	12.55	1.63	116.5	23.75	169.0	84.50	13.10	1.70
Liquid compost 4000	129.0	27.25	195.3	97.63	13.59	1.77	117.5	24.00	172.8	86.38	13.58	1.76
L.S.D. 0.05	2.9	1.24	7.5	3.75	0.50	0.07	1.3	1.33	2.7	1.35	0.33	0.04

A positive relationship was found in weight of herb and root system in the best treatment (L.C at 4000 ppm). This observation could be attributed to the large size of roots which was improved its capacity to extract more water and nutrients by exploring larger volumes of soil that metabolized and translocated toward the growing tip for the photosynthetic apparatus. Products of photosynthesis are largely used in the vegetative growth, a considerable amount of carbohydrates translocated to root that control mechanisms to regulate the use of energy absorbed by the reflecting on more vegetative growth led to increase the photosynthetic capacity cause large export to roots as explained by Wilkins (1989), and Taiz and Zeiger (2010).

On the other hand, the favorable growth obtained from the best treatment may be due to plays vital roles in several process of the soil ecosystem including nutrients cycling since increase them in plant-available forms, soil structure formation, carbon sequestration, water retention and energy supply to microorganisms reported by Bohn *et al*. (2001) and Nardi *et al*. (2002). It is rich in microbial population and diversity, particularly, fungi, bacteria and actinomycetes (Arun, 2002 and Abbott and Murphy, 2007). It contains plant growth regulators and other growth stimulant materials produced by microorganisms (Olivares, 2017). Also, contains large amounts of humic substances which can be improve plant growth directly by their effects on protein synthesis, increasing water, nutrient uptake and growth regulators or hormones which in turn reflects into crop yield (Panda, 2006). Liquid compost is applied to support biologically diverse and metabolically dynamic process during the plant growth. It can increase the chlorophyll content in plant and improve photosynthesis (Nardie *et al*., 2002). It contains plant nutrients essential for improving soil fertility and productivity so can be considered to be a store-house of minerals (Arun, 2002). It can provide protection against growth inhibiting (toxic) substances introduced in the soil, and disease suppressors (Singh *et al*., 2011).

Flowering characters

Data cleared that number of flower-heads, flower diameter, fresh and dry weights of flower per plant and per feddan were considerably responded to both organic substances treatment resulting in significant increases compared to control (Table 4). As a general rule, the obtained results from L.C was markedly high than those of H.A, also the high level was more pronounced than low one in both seasons. Accordingly, the highest values of those parameters were resulted from L.C at 4000 ppm which was recorded the most apparent increase in flower yield per plant reached 28.7 and 18.4 % over controls in the first and second seasons, respectively. Obviously, such increases in flower number were corresponded to heavier fresh and dry yield of flower per feddan evaluated by 73.4 and 40.6 % higher than controls in the first and second seasons, respectively. These results are in harmony with those obtained on chamomile by Hendawy and Khalid (2011), Khoshghalb *et al*. (2017), Kisić *et al*. (2019), Mashayekhi *et al*. (2019), and Hassan and Fahmy (2020).

Table 4. Flower-head characteristics of German chamomile as affected by humic acid and liquid compost treatments during 2019/2020 and 2020/2021 seasons

Treatments (ppm)	2019/2020						2020/2021					
	Flower-heads No./plant	Flower-head diameter (cm)	fresh weight of flower-heads		Dry weight of flower-heads		Flower-heads No./plant	Flower-head diameter (cm)	fresh weight of flower-heads		Dry weight of flower-heads	
			g/plant	kg/fed.	g/plant	kg/fed.			g/plant	kg/fed.	g/plant	kg/fed.
Control	263.1	1.44	31.25	1750	10.94	612	184.8	1.98	45.00	2520	15.75	882
Humic acid 2000	265.7	2.25	39.45	2209	13.81	773	193.0	2.33	50.75	2842	17.76	994
Humic acid 4000	289.0	2.38	43.10	2413	15.09	844	199.0	2.48	55.25	3094	19.34	1082
Liquid compost 2000	308.0	2.38	48.75	2730	17.06	955	208.5	2.53	57.25	3206	20.04	1122
Liquid compost 4000	338.6	2.43	54.20	3035	18.97	1062	218.8	2.53	63.25	3542	22.14	1239
L.S.D. 0.05	12.1	0.16	2.32	130	0.81	46	4.7	0.15	3.50	196	1.22	69

It is interesting to note that the vigorous growth occurred by the treatment of L.C at 4000 ppm showed positive relationships with flower yield and high quality.

This stimulative effect could be explained on the basis of encouraging the growth and increased the plant capacity for building metabolites which have been given a particular attention on the physiological dynamics and biochemical processes within the plant controlling carbohydrates synthesis, which is necessary for flower initiation and blooming, similarly an increase in product of photosynthesis will positively associated with an increase in flower formation. This explanation was supported by Wilkins (1989), Raghavan (2000) and Öpik *et al*. (2005).

Nutrients uptake

Some authors found a direct relationship between the physiological processes and growth stimulation is found which seem to require metabolic action clearly needed specialized for nutrient elements absorption. Most of the essential elements seem to have a close relation to the rate and total growth of chamomile plants (Singh *et al*., 2011; Juárez *et al*., 2012; Jimayu, 2017 and Kisić *et al*., 2019).

Therefore, the uptake of nutrients is one of the most important factors controlling the growth, development and flowering. In this concern, Pearcy *et al*. (1989) reported that the essential functions of mineral elements vary depending on the level of the particular one has attained.

Results clearly indicated that the uptake of N, P, K, Ca and Mg showed noticeable responses to H.A and L.C (Table 5). Obviously, both organic substances treatment appeared to be significantly higher than control in the two seasons. These findings explained that H.A and L.C proved to be more sufficiently active to absorb more amount of such macronutrients. These results are in accordance with the findings of Kisić *et al*. (2019), Hassan and Fahmy (2020) on chamomile and Omar (2020) on caraway.

A great interest of the data on the treatment of L.C at 4000 ppm which showed drastically enhanced more uptake of N, P and Mg than the other treatments, but this behavior is in direct contrast to K and Ca uptake. These findings indicated that a good correlation between phosphorus and magnesium absorptions was found as a result of positive interaction (synergistic effect) between each other of one nutrient increased and the other also was increased. On the contrary, antagonistic effect was observed among Mg and both of K and Ca, since excess Mg in plant appears led to decrease in K and Ca uptakes. These results are parallel to the results of Fageria (2001) and Marschener (2012).

It is worth paying attention to the organic matter which is a reservoir of chemical elements essential to the growth and flowering of plants. This is especially true of carbon and nitrogen, phosphorus, sulfur and other elements. Hence, H.A and L.C are chemically active (Stevenson, 1994 and Lobartini *et al*., 1997).

Table 5. Nutrients uptake and biochemical contents in leaves of German chamomile as affected by humic acid and liquid compost treatments during 2019/2020 and 2020/2021 seasons

Treatments (ppm)	2019/2020										2020/2021									
	Nutrient uptake (mg/plant)					Leaf contents					Nutrient uptake (mg/plant)					Leaf contents				
						Pigment										Pigment				
	N	P	K	Ca	Mg	Cl.a	Cl.b	Caro-tenoids	Carbo-hydrates %	Protein %	N	P	K	Ca	Mg	Cl.a	Cl.b	Caro-tenoids	Carbo-hydrates %	Protein %
Control	2066	370	3612	106	265	1.77	0.50	0.54	6.06	18.31	2195	425	3087	119	272	3.92	1.15	1.20	5.07	17.50
Humic acid 2000	3134	471	4580	141	385	1.63	0.61	0.65	7.42	25.31	3074	510	5003	204	351	4.52	1.27	1.47	6.45	23.56
Humic acid 4000	3129	619	6151	141	571	1.80	0.51	0.51	8.53	22.19	3045	625	6395	188	503	4.55	1.27	1.40	7.55	22.69
Liquid compost 2000	3194	851	5459	148	432	1.77	0.51	0.51	9.25	21.25	2873	816	5157	169	304	4.38	1.25	1.30	8.65	23.25
Liquid compost 4000	3357	914	3671	127	885	2.23	0.51	0.48	9.63	24.06	3375	884	3664	143	744	5.09	1.51	1.52	9.20	24.19
L.S.D. 0.05	145	56	248	13	68	0.28	N.S	0.08	0.45	1.12	162	64	262	21	64	0.58	N.S	0.14	0.48	1.07

Table 6. Essential oil yield and its constituents as affected by humic acid and compost treatments

Treatments (ppm)	2019/2020			2020/2021			Oil constituents %											
	Oil %	Essential oil yield		Oil %	Essential oil yield		Chamozulene		Bisabolone-oxide A	Bisabolol-oxide B	E.a. Farnesene	Germa-crene D	Bicyclog-ermacron	Caryophy-llene oxide	Spatulenol	Tau-Cadinol	Other components
		ml/ plant	l/fed		ml/ plant	l/fed	%	l/fed									
Control	1.81	0.19	10.89	2.25	0.35	19.76	39.62	4.31	15.23	10.27	7.77	1.73	1.18	0.90	4.18	2.26	16.86
Humic acid 2000	2.72	0.38	21.07	2.97	0.53	29.48	44.56	9.39	10.96	10.36	8.79	2.54	2.06	0.39	5.10	3.13	12.11
Humic acid 4000	3.03	0.46	25.69	3.25	0.63	35.12	47.38	12.17	10.11	8.88	7.04	1.73	1.12	0.81	4.96	2.83	15.14
Liquid compost 2000	3.38	0.58	32.29	3.79	0.76	42.39	42.18	13.62	14.63	12.99	9.10	2.08	1.79	2.22	5.88	2.71	6.42
Liquid compost 4000	3.74	0.71	39.73	3.88	0.86	48.02	45.18	17.95	14.09	12.20	8.43	2.41	1.61	2.26	5.98	2.73	5.11
L.S.D. 0.05	0.26	0.04	1.97	0.19	0.05	2.68	-	-	-	-	-	-	-	-	-	-	-

Active biochemical constituents

Photosynthetic pigments

As evident from Table 5, H.A and L.C showed different influences in leaf pigments. As for chlorophyll “a”, the treatment of L.C at 4000 ppm was significantly higher than other treatments or control during both seasons. However, significant increases were resulted from the most treatments as compared to control in the second season only. Neither H.A nor L.C treatments had pronounced effect on chlorophyll “b” in both seasons. Respecting carotenoids content, the most treatments cleared inconsiderable effect in the first season, in contrast to this was noticed in the second one since L.C at 4000 ppm recorded the highest value. These results are in partial agreement with those obtained by Sardoei (2014) on marigold and Omar (2020) on caraway.

A direct relationship between chlorophyll “a” and the uptake of Mg and N were apparently found in treatment of L.C at 4000 ppm since the elevated amounts in Mg and N associated with high chlorophyll content due to the beneficial effects of this treatment. Magnesium and nitrogen are constituents of the chlorophyll molecule, without one of them photosynthesis would not occur. The role of Mg at adequate level is closely correlated with chlorophyll synthesis also the production of leaf pigments was reduced when nitrogen is lacking (Taiz and Zeiger, 2010).

Total carbohydrates content

It is quite clear that all organic substance treatments significantly increased leaf carbohydrates content compared to control in both seasons (Table 5). Whilst L.C at 4000 ppm was the most effective treatment resulting in the highest content with significant increase in comparison with the other treatments. These results are in coordination with the findings of El-Shayeb *et al*. (2015) on sage and Omar (2020) on caraway.

A close relationship between K-uptake and carbohydrates was observed. Potassium has a function in carbohydrate synthesis (Gibson, 2005), it plays a direct role in rapid export of photosynthate from the leaf which important for maintenance of a high net photosynthetic rate (Pessarakli, 2001).

In view of the close carbohydrates control in flowering, which is known to occur, it is sufficient to attribute favorable responses in flowering which demand for the carbohydrate synthesis. In fact, this close correlation was found in the best treatment (L.C at 4000 ppm) which produced the maximum yield of flower-heads also accumulate the highest carbohydrates content resulting in the optimum relationship by adapting interference among them under appropriate nutrition to induce a suitable link to regulation of flowering process. These observations were supported by earlier reports, the adaptation of flowering dependent on maintaining high carbohydrates in leaf tissues (Raghavan, 2000). The initiation, development of flower and formation are associated with an accumulation of carbohydrates in the regions where flower buds can be formed (Öpik *et al*., 2005).

Total protein content

It was observed that total protein content in the leaves of German chamomile cleared noticeable responses to both organic amendments (Table 5). Obviously, all H.A and L.C treatments significantly increases protein content compared to controls in the two seasons. However, the highest value was induced by L.C at 4000 ppm resulting in significant increases when compared with some other treatments. These results are in accordance with the findings of Omar (2020) on caraway with humic acid, as well as Hassan *et al*. (2012) on coriander with compost.

Apparently, a good coordination between leaf nitrogen and protein content was observed in the treatment of L.C at 4000 ppm. Nitrogen is to be expected from its major role as a constituent of protein and may coenzymes and interference with protein synthesis and hence with growth. Rajan (2003) demonstrated that the resulting slow-down of photosynthesis causes a nitrogen deficient to lake not only essential amino acids, but also the machinery for synthesis of necessary carbohydrates. Gibson (2005) stated that a reduction of N in the leaves causes photosynthesis fails to keep pace and a depletion of carbohydrates. Taiz and Zeiger (2010) reported that the accumulation of carbohydrate and soluble nitrogen compounds point to diminish protein synthesis under potassium deficiency.

Essential oil characteristics

The data pertaining to essential oil characteristics revealed that the oil percentage, oil yield per plant and per feddan appeared considerable responses to both organic materials (Table 6). Clearly, all H.A and L.C treatments significantly increased oil % compared to control in both seasons. Since L.C at 4000 ppm resulted in the highest oil content showing significant increases compared to the rest of treatments in most cases. These results are in agreement with those obtained on chamomile by Ahmadian *et al*. (2011), Juárez *et al*. (2012) and Khoshghalb *et al*. (2017).

It was observed that the oil yield also followed a similar trend to that of oil % under various treatments. Since L.C at 4000 ppm gave the highest oil yield per plant or per feddan achieving increases reached 3.7 and 2.5-fold higher than controls in the first and second seasons, respectively. These results are in accordance with the findings of Hendawy and Khalid (2011), Juárez *et al*. (2012), Khoshghalb *et al*. (2017), and Hassan and Fahmy (2020) on chamomile.

The GLC analysis of German chamomile volatile oil identified more than 30 essential oil components, but for easier comparison the different chemotypes of oil were selected nine principal constituents (Table 6). Clearly, the total nine compounds representing 83.14-94.89 % of total detected constituents with different treatments. The other components representing 5.11-16.86% of total detected constituents. The major constituents were chamazulene (39.62-47.38%), bisabolone-oxide A (10.11-15.23%) and bisabolol-oxide B (10.27-12.99%). Within, the essential oil, the relative level for various constituents were increased, decreased, or did not change in oil under H.A and L.C treatments as compared to control.

Although chamazulene percentage in oil showed some increments among treatments, its production was the highest in L.C at 4000 ppm treatment (17.95 l/fed) that related to produce the maximum yield of flower-heads. These results are in harmony with those reported by Ahmadian *et al*. (2011), Khoshghalb *et al*. (2017), and Hassan and Fahmy (2020).

Finally, it could be noticed that the nutritional quality has a strong bearing on plant's performance, more so with respect to physiological mechanism of essential oil production. These opinions were supported by Sangwan *et al.* (2001).

Conclusion

The results of the present experiment show that liquid compost at 4000 ppm treatment has stimulative effects on growth, flowering, essential oil content, the main active constituent of chamomile oil (chamozulene), metabolic processes and has thus considerable potential for providing nutritional elements in chamomile production. Hence, making it sustainable for organic medicinal plants production systems.

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استجابة النمو، الإزهار، امتصاص المغذيات والزيت الطيار في البابونج الألماني للتغذية العضوية

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الملخص

أجريت تجربة حقلية خلال موسمى 2020/2019 و2021/2020 لدراسة تأثير حامض الهيوميك والكمبوست السائل كمحلول للتربة بتركيزي 2000، 4000 جزء في المليون لكل منهما بالإضافة إلى الكنترول على نمو البابونج الألماني ومحصول النورات والزيت الطيار ومكوناته الأساسية، وبعض المحتويات الغذائية والبيوكيميائية بالأوراق. زرعت بذور البابونج في 3 نوفمبر لكل موسم، وتم إضافة أربع جرعات من المادتين العضويتين، حيث أضيفت الأولي منها بعد 45 يوماً من الزراعة يعقبها ثلاث جرعات بنفس التركيزات بفاصل أسبوعين خلال موسم النمو. وقد سجلت البيانات على مواصفات النمو الخضرية والجذرية، وأيضاً محصول النورات المجموعة على فترات من أول فبراير وحتى آخر أبريل. أظهرت معاملات التسميد العضوي تأثيراً منشطاً في قياسات النمو (ارتفاع النبات، عدد الفروع، الوزن الطازج والجاف للعشب والجذور) وأيضاً زيادة عدد الأزهار بالنبات وأقطارها، وزيادة الوزن الطازج والجاف لمحصول النورات حيث كانت الزيادة جوهرية بمقارنتها بالكنترول، بينما كانت معاملة الكمبوست السائل بتركيز 4000 جزء في المليون الأكثر تفوقاً في تنشيط النمو وإنتاج الأزهار. ارتبطت بشدة المعاملات التي نشطت وحسنت نمو وتطور النبات بزيادة امتصاصها الكلي المتوازن للعناصر الغذائية (نيتروجين، فوسفور، بوتاسيوم، كالسيوم، مغنسيوم)، على العكس، ارتبط ضعف نمو الكنترول بأدنى قيم الامتصاص لهذه المغذيات. كان هناك علاقة وثيقة بين امتصاص العناصر لمعاملة الكمبوست السائل بتركيز 4000 جزء في المليون وزيادة تخليق كلوروفيل أو الكاروتينويدات، ومحتوى الأوراق من الكربوهيدرات الكلية والبروتين. حسنت المادتين العضويتين مواصفات الزيت الطيار مقارنة بالكنترول. أظهرت معاملة الكمبوست السائل بتركيز 4000 جزء في المليون تفوقاً ملحوظاً في إنتاج الزيت الطيار وارتفاع نسبة الكامازيولين والتي ارتبطت بتحسن المواصفات الكيميائية للزيت الطيار. ولذا يوصي بتطبيق هذه المعاملة لإنتاج بابونج ألماني عضوي نظيف وآمن صحياً من الملوثات الكيماوية.