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Original Article

Evaluation of biomass formation, essential oil yield and composition of four different *Matricaria recutita* L. cultivars grown in Egypt

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ABSTRACT

A field experiment was carried out during two successive seasons (2011 and 2012) to evaluate the growth, yield and oil quality of four different *Matricaria recutita* L. cultivars. Three of them were introduced from Germany, namely, Luta, Bona and Goral and one was a local Egyptian cultivar, belonging to the bisabolol-oxide chemotype. The comparison between the four chamomile cultivars was done based on 35 components of the essential oils. Bisabolol oxide was shown to be the major component in all four cultivars. Data clearly showed significant differences between the four cultivars, regarding their growth parameters and essential oil productivity. Thus, the Goral cultivar was shown to be superior in terms of growth followed by the Luta cultivar in both seasons, On the other hand Luta was superior regarding its essential oil content (0.41 and 0.54 %, for the two harvesting seasons, respectively) followed by the Goral cultivar (0.40 and 0.48 %), while the Local cultivar gave the lowest value in essential oil content (0.30 % and 0.36 % in both seasons).
The obtained results revealed that the oil composition of the four chamomile cultivars is stable and characteristic for each type.

Keywords: *Matricaria recutita* L., essential oil, cultivation, medicinal plant, Bisabolol oxidide A, chemotype

INTRODUCTION

Chamomile (*Matricaria recutita* L., *Matricaria chamomilla* L. or *Chamomilla recutita* (L.), Asteraceae) is one of the most widely studied medicinal plants in the world. Chamomile is a well-known medicinal plant species often referred to as "the star" among medicinal species. The species is native to Asia, Northern Africa, Southern and Eastern Europe [1].The worldwide cultivation areas of chamomile lie in Argentina, Egypt, Germany, Hungary, Poland, Spain, Belorussia, Russia, Czech Republic, Slovakia, countries of the Balkan peninsula (Bulgaria, Serbia, Macedonia, Turkey) Ukraine and also in Bolivia and Brasil [2]. Over 120 constituents have been identified in chamomile [3]. Chamomile history tracks as far as the Ancient Egyptians (over 2500 years), Greek and Roman and still has great importance as a medicinal plant in Egypt and other countries now-a-days [4]. In 500 B.C., Hippocrates, the founder of modern medicine in ancient Greece, recognized the therapeutic properties of chamomile. Pharmacological properties include anti-inflammatory, antiseptic, carminative, healing, sedative and spasmolytic activity [5]. Accordingly, it has been included in the Pharmacopoeias of many countries**.** Recently, it was reported that chamomile can be successfully employed for soil reclamation [6].
Due to both its medicinal and industrial importance, chamomile is mass produced in many countries, including Egypt. Moreover, it is one of the most important medicinal and aromatic plants produced in Egypt. The area cultivated with chamomile in 2005 reached about 9500 acres and came in the second rank among the cultivated medicinal plants in Egypt. The production reached about 8000 tons of which 3000 tons were exported amounting for about 5 million dollars. The Egyptian chamomile was categorized under the α-bisabololoxide A group [7, 8, 9].
Chemical constituents identified in chamomile as secondary metabolites, include 28 terpenoids, 36 flavonoids and 52 additional compounds with

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potential pharmacological activity [10]. In addition to pharmaceutical uses, the oil is extensively used in perfumery, cosmetics, and aromatherapy, and in food industry [1] Because of its various pharmacological and pharmaceutical properties, the plant possesses great economic value and is in great demand in the European countries.

The yield of essential oil of *Matricaria recutita* depends on the plant genotype as well as the environmental conditions under which the plants are grown [11, 12, 5, 9, 13, 14]. The Egyptian chamomile has a good reputation in the export markets due to hand pick of the flower heads and application of organic farming system [9] Although Egyptian chamomile cultivars are valued on international markets due to their quality, in the last decade exports of chamomile faced some problems due to inconsistency with the required oil characteristics [9]. This motivated our work to select improvement of the yield and quality of this species in order to meet the higher demand of its raw material and products. Therefore, the aim of the present work was to evaluate the growth, yield, qualitative and quantitative characteristics of the essential oil of four different chamomile cultivars, and introduce novel sources of chamomile raw material to support and improve chamomile cultivation practices in Egypt.

MATERIALS AND METHODS

Field site description: This investigation was carried out during two successive seasons (2011 and 2012), at the Adlya farm of the SEKEM Company, Sharkiya Governorate, Egypt (80 km to the East of Cairo). The physical and chemical properties of the soil samples and analyses of the irrigation water samples were determined according to Jackson [15] and Cottenie et al. [16] and are shown in Table (1 a, b). Air temperature and relative humidity during the investigation period are presented in Table (1 c).

Plant material: Four different *Matricaria recutita* L were compared. One of them was Local (the chamomile locally grown in Egypt). Three cultivars were introduced from Jellitto staudensamen Gmbh, Germany, namely Luta, Bona and Goral.

Cultivation and harvesting: The seeds of chamomile were sown in the nursery on 15st September of both seasons (2011 and 2012)) at Elmizan Company of SEKEM, Sharkiya Governorate, Egypt. Two months after sowing, the uniform seedlings were transplanted into plots 10.5 m^2 on rows, with 60 cm a part and 20 cm between the seedlings. In all cases the plants were grown under an organic farming system. The experimental soils were supplied with 20 m^3/faddan (Faddan = 4200 m^2) of mature compost. Irrigation was supplied through drip irrigation system. Routine agricultural practices were carried out as usually practiced in chamomile cultivation. Data for growth characters, yield, essential oil and its chemical constituents for all species were obtained during three harvests as follows: the first harvest in January, the second harvest in February and the third harvest in March. The data measurements included plant height (cm), number of branches/plant, fresh and dry weights of flowers (g/m^2).

Essential oil production: Essential oil percentage of each replicate at the three harvests was determined in the air dried flowers according to Guenther [17] and expressed as ml/100g, while essential oil yield was expressed as ml / plant and L /feddan. The extracted essential oil was dehydrated over anhydrous sodium sulphate and stored at freezer till used for gas chromatography-mass spectrometry (GC - MS)

Qualitative and quantitative characterization of essential oils: Chamomile essential oils of the studied cultivars were characterized by gas chromatography mass spectrometry. The GC-MS analyses of the essential oil samples were carried out in the first season using gas chromatography – mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Center with the following specifications. Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TG-WAX MS column (30 m x 0.25 mm i.d., 0.25 μm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10 using the following temperature program: 40 °C for 1 min; rising at 4.0 C/min to 160 C and held for 6 min; rising at 6 C/min to 210 C and held for 1min. The injector and detector were held at 210 ^{o}C. Diluted samples (1:10 hexane, v/v) of 1 μL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Most of the compounds were identified using two different analytical methods: (a) KI, Kovats indices in reference to n-alkanes (C_9-C_{22}) (National Institute of Standards and Technology [18]; and (b) mass spectra (authentic chemicals, Wiley spectral library collection and NSIT library).

Statistical analysis: Data of the present study were statistically analyzed according to Cochran and Cox [19]. Data was analysed separately for each

respective season. The differences between the means of the treatments were considered significant when they were more than least significant differences (LSD) at 5%. The data were subjected to ANOVA test (MS DOS/ Costat Exe Program).

RESULTS AND DISCUSSION

Growth and yield parameters: The data of the growth and yield parameters (plant height in cm), number of branches per plant, fresh flowers (g/plant and kg/fed) and dry flowers (g/plant and kg/fed) of the four *Matricaria recutita* L. cultivars at the three harvests in the two successive seasons (2011 and 2012) are presented in Tables 2 to 6. The data clearly indicated that, there are high significant differences between the four cultivars, harvesting time and the interaction. Thus, the Luta cultivar showed the best values in plant height (75 and 85 cm) followed by Goral cultivar where plant height was shown to be 69 and 83 cm/plant in both seasons, respectively. On the other hand, the Local cultivar had the lowest value for plant height (60.60 and 62.80 cm) in both seasons. Moreover, *Matricaria recutita* L cultivar Goral was the most branching type (17.20 and 16.40 in the two seasons, respectively) and the cv. Luta was the least in this regard.

It is clear from the data presented in Table 3 that plants of the Goral cultivar produced the highest weight of fresh flower heads; 155.60 and 154.0 g/plant of total three harvesting in the two seasons, respectively where it is the best in the first and second cut, followed by the Luta cultivar (109 and 130.20 g/plant) in the two seasons, respectively where it is the best in its third cut. The Bona cultivar gave the lowest yield of fresh flowers followed by the Local one.

On the other hand, the data showed that the second harvesting time in February gave the best value better than the other harvesting times and this trend was observed in all growth and yield parameters.
Obviously, the yield of dry flower heads/ plant followed the same trend of the fresh flower yield, meaning that the cv. Goral produced the highest yield of 31.12 and 30.70 g/plant in the two seasons, respectively followed by the Luta cultivar (21.80 and 26.80 g/plant), while the Bona cultivar produced the lowest yield of dry flowers (17.64 and 17.96 g/plant) as shown in Table 3.

It was shown that that Goral cultivar was most productive among the investigated types yielding in average 3423.2 and 3410 kg/fed in the two seasons, respectively followed by the Luta cultivar (2398 and 2864.4 kg/fed). On the other hand, the Bona cultivar gave the lowest yield of dry flower per fed; 1940.4 and 1975.6 kg/fed respectively.

The obtained results revealed that the Goral cultivar was superior regarding its productivity per unit area in comparison with the other cultivars of chamomile. Such productivity is the net accumulation of the growth traits; number of branches per plant, fresh and dry weight of flowers per plant. The Local type came in the third rank after Luta cultivar.

Qualitative and quantitative characteristics of the essential oils: The flowers of the Luta cultivar contained the highest content of essential oil 0.41 % and 0.51 % as a mean of three harvested in the two seasons, respectively, followed by the Goral cultivar (0.40 and 0.48%) in the both seasons, respectively, while the Local cultivar gave the lowest value in essential oil content (0.30 and 0.36 %) in the both seasons, respectively, on the other hand data revealed that the essential oil percentage in third cut was the heights than the first and second cuts (0.40 and 0.50) in first and second season, respectively (Tables 7 to 9).

The best interaction between the cultivar and time of cutting was in case of Luta cultivar in third cutting (0.43 and 0.61%) flowed by second cutting (0.43 and 0.55%) in first and second season, respectively. Many studies revealed that the essential oil content differed significantly between examined chamomile populations, ranging from 0.25 to 0.55% [20], 0.2% up to 0.93% [21, 0.90% up to 3.21% [9] and from 0.78 % up to 2.69% by [14].

The yield of essential oil of *Matricaria recutita* depends on the plant genotype as well as the environmental conditions under which the plants are grown [11, 12, 5, 9, 14]. The result of the present study differ from some previous works, where the essential oil yields were shown to be higher than in the present study, and this may be due to many factors e.g. different types of cultivars [9, 22], different locations, growing conditions (soil and climate) [23, 24]. Some authors have also reported variability of the oil content under the influence of different factors as soil type [24], soil pH [25]**,** day light and irradiance [26], and nitrogen supply [2]**,** time of cutting of flower heads. Thus in the present study cutting was performed three times (December to February) and in other studies the flower harvest was done in February and March [9] and in full-bloom stage, on 5th July [14]. These observations come in agreement with [27], who report that the essential oil yields increased with the increasing of temperature.

The Goral chamomile cultivar gave significantly higher yield of oil (0.124 and 0.147 ml/plant and 2.72 and 3.27 l/fed in two seasons, respectively, compared with the other cultivars (Table 4.). The cv. Luta came in the second place (0.091 and 0.140 ml/plant and 2.00 and 3.07 l/fed in first and second seasons respectively, while the Local one was the lowest in this regard.

The results of the GC/MS analysis of the essential oils of the *Matricaria recutita* cultivars are shown in Table 10. *Matricaria recutita* cultivars were compared based on 35 compounds identified in their essential oils. . The total identified compounds ranged from 95.68% in *M. recutita* Bona cultivar to 98.85 % in *M. recutita* Local cultivar. The majorities of compounds (6 compounds) are oxygenated sesquiterpenes and ranged from 64.30 % in the *Matricaria recutita* var. Luta to 69.68% in *M. recutita* Bona cultivar. And six compounds were identified as sesquiterpene hydrocarbons and ranged from 15.59 in Bona cultivar to 18.30 % in Goral cultivar. Fourteen compounds (7 oxygenated and 7 hydrocarbons) were identified as monoterpenes and ranged from 9.80 % in Bona cultivar to 13.18% in Luta cultivar.

Matricaria recutita cultivars differed in the content of monoterpenes and sesquiterpenes. The oils were characterized by high contents of oxygenated sesquiterpenes. The compound Bisabolol oxidide A was the major dominant compound in all varieties and ranged from 46.83 % in the Goral cultivar up to 53.93 % in the Local cultivar followed by (E)-β-Farnesene (oxygenated monoterpene), ranging from 11.34 % in the Bona cultivar up to 13.29 % in the Local cultivar. Then, the third main compound was α-Bisabolol oxide B (oxygenated sesquiterpene compound) which ranged from 8.25 % in the Local cultivar up to 13.22 % in the Goral cultivar. They were followed by p-Menth-1(7)-en-9-ol (oxygenated monoterpene compound) which ranged from 8.15 % in the Bona cultivar up to 12.26 % in the Local cultivar. The fourth main compound in all cultivars was *α*-Bisabolol ranging from 2.65 % in Goral up to 3.55 % in Local cultivar, and the sixth main compound was Chamazulene ranging from 1.08 % in Local up to 2.20 % in the Goral cultivar.

Chamomile oil is produced conventionally by steam distillation as endorsed in many pharmacopoeias. It incorporates several chemical class entities including sesquiterpenes (α-(-)-bisabolol known as levomenol, and bisabolol oxides A & B (≤78%), farnesene (12-28%) and chamazulene (1-15%)); and polyacetylene derivatives, e.g. spiroethers (cis/trans-en-yne-dicycloethers (8–20%)) (McKay and Blumberg, 2006). The qualitative and quantitative chemical characteristics of chamomile oil have revealed the existence of four different chamomile chemotypes, in terms of their essential oil composition [28, 29].
Salamon and Abou Zeid [8] compared the oils of chamomile grown in different locations in Egypt and they reported a chamazulene content of 1.7- 2.6 %, bisabolol-oxide B (1.6-4.9 %), with the lowest content in Giza location, and the highest in Fayoum. Bisabolol-oxide A followed the opposite trend reaching the maximum (68.2 %) in Giza and the minimum in Fayoum. Chamazulene content ranged between 1.7 and 2.6 %, while bisabolol between 2.4 and 11.2 % in the different locations. They reported that the Egyptian chamomile belongs to the bisabolol-oxide chemotype A.

Weglarz and Roslon, [20] reported that, Bisabolol oxide B and chamazulene was the main component in 9 lines of *Matricaria recutita* (30.42%) in one. Also Baghalian *et al.*[30] on *Matricaria recutita*, observed that, the main essential oil constituents (*α*-bisabololoxide B, *α*-bisabolonoxide A, chamazulene, *α*-bisabolol oxide A, *α*-bisabolol, trans-*β* farnesene).

Mayra et al., [7] compared five commercial samples of chamomile grown in Brazil and one from Egypt as control. The major compound in Brazilian chamomile samples were *α*-bisabolol oxide B (25.31 - 32.99 %) while it constituted (9.87 %) of the Egyptian sample. On the contrary, the Egyptian sample contained (46.55 %) of *α*-Bisabolol oxide A, while it ranged between 11.61 and 16.57 % in the Brazilian samples.

CONCLUSIONS

Matricaria recutita Luta cultivar followed by *Matricaria recutita* Goral cultivar, recorded higher values of growth parameters and oil production compared to those of the other chamomile cultivars studied in the present work. The obtained results indicate the potential of the newly introduced *Matricaria recutita* cultivars as prospective novel source of the improvement of agronomical practices of chamomile production in Egypt.

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Table 1: a: Physical and chemical properties of the studied soils and water irrigation.

Mechanical analysis	Crouse sand %	Fine sand %	Silt %	Clay %	texture	O.M %	$Caco_3$ %
	15.45	61.17	7.96	15.42	Sandy loam	0.75	2.34

Chemical analysis	EC (1:5)	TSS %	pH (1:2.5)	Cations meq/L				Anions meq/L			
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
	8.30	2.66	7.70	6.9	3.7	71.1	1.3	-	2	79.4	1.6

	Available macronutrients (mg/kg)			Available micronutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
	65.45	6.15	225	3.20	4.10	1.75	0.085

Table 1b: chemical properties of the studied water irrigation

	EC	TSS ppm	pH	Cations meq/L				Anions meq/L			
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
Adlea	1.59	1017.6	7.77	1.0	1.0	15	0.144	-	2.8	6.5	7.8

Table 1c: Environmental data for the studied location.

Date	2011				2012			
	HC Air temperature[°C]			HC Relative humidity [%]	HC Air temperature[°C]			HC Relative humidity [%]
	Max	Min	Aver	Aver	Max	Min	Aver	Aver
January	21.47	4.44	12.29	73.00	17.19	9.10	12.87	55.77
February	21.90	2.39	11.77	78.00	18.69	9.72	14.00	49.21
March	24.69	5.47	15.22	75.00	21.19	11.42	16.19	53.26
April	38.31	7.09	18.87	66.00	29.77	16.57	23.07	39.87
May	37.16	2.09	22.79	58.00	32.35	20.00	26.16	42.84
June	39.06	16.51	25.87	61.00	35.00	22.53	28.83	49.57
July	35.80	18.63	27.26	72.00	35.55	24.52	30.00	54.68
August	34.29	18.01	26.45	77.00	35.32	24.74	29.97	52.65
September	33.77	0.59	25.10	77.00	32.57	22.27	27.47	57.10
October	38.44	12.48	21.77	69.00	28.82	15.15	21.71	69.30
November	25.55	8.12	16.55	76.00	22.38	11.31	16.69	75.67
December	21.78	5.32	13.83	79.00	19.73	8.55	13.90	80.13

Table (2): Variation in plant height (cm) and No of Branches/ plant of chamomile types cultivated during two successive seasons

	Cultivars	Plant height (cm)			No of Branches/ plant		
				SD			SD
1st season	Luta	75.00[a]	±	4.74	11.20	±	1.64
	Bona	67.60[b]	±	3.56	14.20	±	1.48
	local	60.60 [c]	±	6.31	13.80	±	2.95
	Goral	69.20[ab]	±	7.57	17.20	±	2.77
LSD 0.05 (cultivars)		6.19***			2.48***		
2nd season	Luta	85.40	±	8.20	9.80	±	1.64
	Bona	70.60	±	8.80	14.00	±	1.87
	local	62.80	±	7.12	11.60	±	2.30
	Goral	83.20	±	8.44	16.40	±	1.82
LSD 0.05 (cultivars)		9.76***			2.07***		

Table (3): Variation in Fresh flowers (g/plant) in three harvest times of chamomile cultivars during two successive seasons

Title		fresh flowers (g/plant)										
	Cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
1st season	Luta	26.60	±	4.98	49.20	±	4.09	33.20	±	1.30	109.00	36.33
	Bona	31.60	±	8.62	35.80	±	2.59	20.80	±	3.11	88.20	29.40
	local	29.80	±	5.02	43.60	±	10.12	20.80	±	2.59	94.20	31.40
	Goral	61.40	±	7.96	76.20	±	11.77	18.00	±	1.22	155.60	51.87
Mean		37.35			51.20			23.20				
LSD 0.05	Cultivars				4.59 ***							
	Harvest				3.97 ***							
	Cx H				42.74***							
2nd season	Luta	36.00	±	3.94	63.60	±	9.24	30.60	±	4.93	130.20	43.40
	Bona	26.40	±	6.11	41.20	±	5.02	22.20	±	5.07	89.80	29.93
	local	28.20	±	5.63	68.00	±	6.27	27.20	±	6.91	123.40	41.13
	Goral	45.00	±	2.24	83.40	±	9.87	25.60	±	5.94	154.00	51.66
Mean		33.90			64.30			26.40				
LSD 0.05	Cultivars				3.73***							
	Harvest				3.23***							
	C x H				35.96***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (4): Variation in Dry flowers (g/plant) in three harvest times of chamomile cultivars during two successive seasons

Title		dry flowers (g/plant)										
	Cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
1st season	Luta	5.32	±	1.00	9.84	±	0.82	6.64	±	0.26	21.80	7.27
	Bona	6.32	±	1.72	7.16	±	0.52	4.16	±	0.62	17.64	5.88
	local	5.96	±	1.00	8.72	±	2.82	4.16	±	0.52	18.84	6.28
	Goral	12.28	±	1.59	15.24	±	3.35	3.60	±	0.24	31.12	10.37
Mean		7.47			10.24			4.64				
LSD 0.05	Cultivars					0.918***						
	Harvest					0.795***						
	C x H					8.55***						
2nd season	Luta	7.20	±	0.79	12.72	±	1.85	6.12	±	0.99	26.04	8.68
	Bona	5.28	±	1.22	8.24	±	1.00	4.44	±	1.01	17.96	5.99
	local	5.64	±	1.13	13.60	±	1.25	5.44	±	1.38	24.68	8.23
	Goral	9.00	±	0.45	16.58	±	1.97	5.12	±	1.19	30.70	10.23
Mean		6.78			12.79			5.28				
LSD 0.05	Cultivars				0.73***							
	Harvest				0.633***							
	C x H				6.01***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (5): Variation in Fresh flowers (Kg/fed) in three harvest times of chamomile cultivars during two successive seasons

	Title	fresh flowers (Kg/fed)										
	Cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
	Luta	585.20	±		1082.40	±	89.90	730.40	±	28.68	2398.00	799.33
	Bona	695.20	±	189.63	787.60	±	56.95	457.60	±	68.52	1940.40	646.80
	local	655.60	±	110.44	959.20	±	310.58	457.60	±	56.95	2072.40	690.80
	Goral	1350.80	±	175.03	1676.40	±	368.92	396.00	±	26.94	3423.20	1141.07
Mean		821.70			1126.40			510.40				
LSD 0.05	Cultivars				100.99***							
	Harvest				87.46***							
	C x H				940.43***							
2nd season	Luta	792.00	±	86.61	1399.20	±	203.19	673.20	±	108.45	2864.40	954.80
	Bona	580.80	±	134.36	906.40	±	110.44	488.40	±	111.53	1975.60	658.53
	local	620.40	±	123.87	1496.00	±	137.92	598.40	±	151.94	2714.80	904.93
	Goral	990.00	±	49.19	1856.80	±	217.23	563.20	±	130.71	3410.00	1136.67
Mean		745.80			1414.60			580.80				
LSD 0.05	Cultivars				82.09***							
	Harvest				71.09***							
	C x H				682.41***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (6): Variation in Dry flowers (g/plant) in three harvest times of chamomile cultivars during two successive seasons

	Title	dry flowers (Kg/fed)										
	cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
1st season	Luta	117.04	±	21.91	216.48	±	17.98	146.08	±	5.74	479.60	159.87
	Bona	139.04	±	37.93	157.52	±	11.39	91.52	±	13.70	388.08	129.36
	local	131.12	±	22.09	191.84	±	62.12	91.52	±	11.39	414.48	138.16
	Goral	270.16	±	35.01	335.28	±	73.78	79.20	±	5.39	684.64	228.21
Mean		164.34			225.28			102.08				
LSD 0.05	Cultivars				20.19***							
	Harvest				17.49***							
	C x H				188.09***							
2nd season	Luta	158.40	±	17.32	279.84	±	40.64	134.64	±	21.69	572.88	190.96
	Bona	116.16	±	26.87	181.28	±	22.09	97.68	±	22.31	395.12	131.71
	local	124.08	±	24.77	299.20	±	27.58	119.68	±	30.39	542.96	180.99
	Goral	198.00	±	9.84	371.36	±	43.45	112.64	±	26.14	682.00	227.33
Mean		149.16			282.92			116.16				
LSD 0.05	Cultivars				16.41***							
	Harvest				14.21***							
	C x H				136.48***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (7): Variation in Essential oil % in three harvest times of chamomile cultivars during two successive seasons

Title		Essential oil %									
	Cultivars	H1		SD	H2		SD	H3		SD	Mean
1st season	Luta	0.37	±	0.07	0.43	±	0.03	0.43	±	0.02	0.41
	Bona	0.27	±	0.07	0.33	±	0.02	0.38	±	0.06	0.33
	local	0.28	±	0.05	0.28	±	0.09	0.34	±	0.04	0.30
	Goral	0.37	±	0.05	0.41	±	0.09	0.43	±	0.03	0.40
Mean		0.32			0.36			0.40			
LSD 0.05	Cultivars				0.030***						
	Harvest				0.026***						
	C x H				NS						
2nd season	Luta	0.45	±	0.05	0.55	±	0.08	0.61	±	0.10	0.54
	Bona	0.35	±	0.08	0.42	±	0.05	0.49	±	0.11	0.42
	local	0.33	±	0.07	0.35	±	0.03	0.40	±	0.10	0.36
	Goral	0.44	±	0.02	0.49	±	0.07	0.51	±	0.12	0.48
Mean		0.39			0.45			0.50			
LSD 0.05	Cultivars				0.047***						
	Harvest				0.041***						
	C x H				NS						

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (8): Variation in Essential oil yield (ml/plant) in three harvest times of chamomile cultivars during two successive seasons

Title		Essential oil ml/plant										
	Cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
1st season	Luta	0.020	±	0.01	0.042	±	0.01	0.029	±	0.002	0.091	0.030
	Bona	0.017	±	0.01	0.024	±	0.00	0.016	±	0.001	0.056	0.019
	Local	0.017	±	0.01	0.024	±	0.02	0.014	±	0.004	0.055	0.019
	Goral	0.045	±	0.01	0.063	±	0.03	0.015	±	0.002	0.124	0.042
Mean		0.025			0.039			0.019				
LSD	Cultivars				0.006***							
	Harvest				0.005***							
	C x H				0.037***							
2nd season	Luta	0.032	±	0.01	0.070	±	0.02	0.037	±	0.013	0.140	0.047
	Bona	0.018	±	0.01	0.035	±	0.01	0.022	±	0.011	0.075	0.025
	Local	0.019	±	0.01	0.048	±	0.01	0.022	±	0.009	0.088	0.029
	Goral	0.040	±	0.00	0.081	±	0.02	0.026	±	0.012	0.147	0.049
Mean		0.027			0.058			0.027				
LSD 0.05	Cultivars				0.007***							
	Harvest				0.006***							
	C x H				0.032***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (9): Variation in Essential oil yield (L/fed) in three harvest times of chamomile cultivars during two successive seasons

Title		Essential oil yield l/fed									
	Cultivars	H1		SD	H2		SD	H3		SD	Total	Mean
	Luta	0.433	±	0.18	0.931	±	0.15	0.633	±	0.05	2.00	0.669
	Bona	0.371	±	0.21	0.520	±	0.08	0.348	±	0.10	1.24	0.421
	Local	0.367	±	0.12	0.537	±	0.40	0.311	±	0.08	1.22	0.421
1st season	Goral	1.000	±	0.27	1.378	±	0.63	0.341	±	0.05	2.72	0.920
Mean		0.554			0.86			0.410				
	Cultivars				0.124***							
	Harvest				0.107***							
LSD	C x H				0.819***							
	Luta	0.713	±	0.16	1.539	±	0.47	0.822	±	0.28	3.07	1.038
2nd season	Bona	0.407	±	0.21	0.761	±	0.19	0.479	±	0.25	1.65	0.561
	Local	0.409	±	0.17	1.047	±	0.19	0.479	±	0.20	1.94	0.656
	Goral	0.871	±	0.09	1.820	±	0.42	0.574	±	0.27	3.27	1.096
Mean		0.608			1.292			0.606				
	Cultivars				0.147***							
	Harvest				0.127***							
LSD 0.05	C x H				0.730***							

Mean ±Sd (standard deviation) and H = Time of harvesting after sowing, i. e. H1= first harvest (January month), H2= second harvest (February month) and H3= third harvest (March month)

Table (10): Variation in chemical composition of Essential oil of chamomile cultivars plants.

Name	KI**	RT*	Luta	Bona	Local	Goral
α-Phellandrene	1138	6.51	0.79	t	0.14	t
β-Pinene	1142	6.60	0.16	t	t	t
4-Terpinenyl acetate	1152	6.85	0.18	t	t	t
D-Limonene	1171	7.32	1.44	0.22	0.3	0.17
β-Phellandrene	1180	7.55	0.2	t	t	t
γ-Terpinene	1218	8.56	0.65	t	0.16	0.17
β-Ocimene	1228	8.88	t	t	t	0.26
o-Cymene	1252	9.34	0.47	t	t	t
Artemisia ketone	1327	11.84	0.58	0.6	0.11	0.96
Yomogi alcohol	1388	13.75		0.24		0.24
cis-3-Hexenyl isovalerate	1468	16.26	0.48	t	t	t
Artemisia alcohol	1486	16.89	t	0.21	t	0.37
β-Caryophyllene	1555	18.94	t	t	t	0.14
(E)-β-Famesene	1639	21.46	12.03	11.34	13.29	12.23
Estragole	1647	21.63	0.44	t	0.13	t
Germacrene D	1667	22.28	1.32	1.34	0.93	1.76
endo-Borneol	1673	22.50	0.21	0.25	0.12	0.38
(E)-p-2,8-Menthadien-1-ol	1681	22.70	0.53	0.35	0.31	0.24
γ-Elemene	1690	22.97	0.65	0.71	0.52	1.05
(+)-δ-Cadinene	1711	23.61	0.19	t	0.14	0.16
α-Farnesene	1716	23.72	0.52	0.45	0.62	0.76
Farnesene epoxide, E-	1907	28.95	0.15	0.18	0.13	0.18
(±)-trans-Nuciferol	1998	31.33	0.49	0.61	0.4	0.48
Santalol, cis,α-	2171	34.05	0.86	2.51	0.32	0.82
(-)-Spathulenol	2184	34.28	0.8	1.75	1.21	1.21
α-Bisabolol oxide B	2201	34.57	9.35	10.17	8.52	13.22
Limonen-6-ol, pivalate	2268	35.59	0.16	0.24	t	0.17

p-Menth-1(7)-en-9-ol	2297	36.08	10.76	8.15	12.26	9.36
α-Bisabolol	2416	37.90	2.98	3.46	3.55	2.65
α-Cadinol	2446	38.38	0.28	0.38	0.22	0.55
Bergamotol, Z-α-trans-	2513	39.42	t	0.29	0.12	0.18
n-Decanoic acid	2581	40.46	0.33	t	0.17	0.4
Heptacosane	2648	41.55	0.21	0.39	0.17	0.23
Chamazulene	2780	43.62	1.59	1.75	1.08	2.2
Bisabolol oxide A	2848	44.68	49.23	50.09	53.93	46.83
Monoterpene hydrocarbons			3.71	0.22	0.6	0.60
Oxyg. Monoterpenes			13.18	9.8	12.93	11.55
Sesquiterpene Hydroc.			16.3	15.59	16.58	18.3
Oxig. Sesquiterpenes			64.3	69.68	68.4	66.29
Others			0.54	0.39	0.34	0.63
Total			98.03	95.68	98.85	97.37

*Rt= Retention time (TGWAX MS column), **KI= kovets Index (TGWAX MS column)

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