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Varietal evaluation of chamomile (*Matricaria chamomilla* L.) for biometrical, yield and quality traits under the conditions of the Plovdiv region, Bulgaria

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Abstract

Chamomile (*Matricaria chamomilla* L.) is one of the most widely cultivated and used medicinal and aromatic plants worldwide. The objective of the present study was to evaluate the varietal differences in biometrical, yield, and quality traits of chamomile grown under the agroecological conditions of the Plovdiv region, Bulgaria. The investigation was conducted during the period 2023–2025 and included three chamomile varieties: Bona, Degumille, and Comune. The experiment used a randomized block design with four replications and a plot size of 15 m². The results revealed significant differences among the studied varieties with respect to the evaluated traits. The Degumille variety was characterized by the greatest plant height (59.0 cm) and the largest flower diameter (2.67 cm). The Comune variety showed superior performance in terms of stem diameter (0.71 cm), number of branches per plant (8.1), fresh flower weight per plant (5.40 g), fresh flower yield (2235 kg ha^{-1}), and essential oil yield (9.45 kg ha^{-1}). The highest essential oil content (0.54 %) and the greatest number of flowers per plant (25.2) were recorded for the Bona variety. The extraction yield varied considerably among the varieties, ranging from 190.4 kg in Bona to 229.4 kg in Comune. Varietal differences affect chamomile productivity and the oil yield. Correlation analysis found a negative relationship between essential oil content and yield components (r = –0.726 with fresh flower yield), suggesting a trade-off between biomass accumulation and oil concentration.

Keywords: chamomile, agronomy, variety, yield, essential oil

INTRODUCTION

Nowadays, the production and cultivation of plants with pharmacological significance have gained increasing importance due to the growing awareness of the adverse effects associated with synthetic medicinal products. With the expansion of their application, the need to optimize cultivation practices and enhance productivity has also increased. A representative species within this group is chamomile, widely used in pharmaceutical practice. Chamomile (*Matricaria chamomilla* L.) is a well-known medicinal plant species of the Asteraceae family, native to southern and eastern Europe (Wan et al., 2019). Due to its therapeutic, cosmetic, and nutritional properties, it is widely used in folk and traditional medicine. The chamomile drug is included in the pharmacopoeias of 26 countries and forms part of various traditional and homeopathic formulations (Das et al., 1998; Kumar et al., 2001; Mann & Staba, 1986). It is traditionally used to treat flatulence, colic, hysteria, and intermittent fever (Tyihak et al., 1962). *M. chamomilla* flowers contain blue essential oil at concentrations ranging from 0.2 to 1.9 % (Mishra et al., 1999; Šalamon, 2004). Due to its rich phytochemical composition, the blue essential oil exhibits a broad spectrum of pharmacological activities, including anti-inflammatory, antimicrobial, antiseptic, antispasmodic, sedative, immunomodulatory, antiulcerogenic, and wound-healing effects, which underpin its importance in traditional medicinal systems, as well as in contemporary pharmaceutical and cosmetic applications (Dadkhah et al., 2010; Gupta et al., 2010; Yadav et al., 2022). The dry capitula, its extracts, and blue essential oil are the plant's most economically valuable components. Chamomile capitula preparations have been used in herbal medicine for thousands of years (Singh et al., 2011). The plant is also employed in various industrial products, including herbal tea, cosmetics, food flavoring, dyes, and pest repellents.

Bulgaria possesses a rich tradition in the cultivation of medicinal and aromatic plants and is known as a producer of quality chamomile oils. Favorable environmental factors, fertile soils, and precise cultivation techniques ensure stable essential oil production of high market value (Petkova et al., 2018).

The chemical composition and yield of chamomile essential oils are affected by a complex interaction of genetic, environmental, and agronomic factors. Principal determinants comprise species, genotype, geographical origin, harvest timing, and the extraction method used (Batovska et al., 2025; El Mihyaoui et al., 2022; Höferl et al., 2020; Salehi et al., 2023).

Abiotic factors such as salinity, drought, extremes in temperature, soil type, and nutrient availability influence essential oil biosynthesis (Shakir et al., 2024; Rathore & Kumar, 2021).

Currently, there is limited information in Bulgaria regarding the varietal performance and productivity of chamomile under local growing conditions. Therefore, the objective of the present study was to evaluate the varietal differences in biometrical, yield, and quality traits of chamomile grown under the agroecological conditions of the Plovdiv region, Bulgaria.

MATERIALS AND METHODS

Field experiment

The field experiment was conducted in the experimental area of Voivodinovo village, located in the Plovdiv region of Central Bulgaria, during the period 2023–2025. The experiment was set up on alluvial-meadow soil using a randomized block design with four replications and a plot size of 15 m². Three chamomile (*Matricaria chamomilla* L.) varieties were evaluated: Bona, Degumille, and Comune.

The preceding crop was wheat. Soil preparation included plowing to a depth of 22–25 cm followed by two cultivations at a depth of 8–10 cm. These operations brought the soil to a condition suitable for high-quality sowing. Immediately prior to sowing, the soil surface was rolled to level the field. Sowing was carried out in the second decade of March at a seeding rate of 2 kg ha^{-1} and row spacing of 25 cm. All stages of the established cultivation technology for chamomile were followed. The following indices were determined: plant height, stem diameter, number of branches on the main stem, flower diameter, number of flowers per plant, fresh flower weight per plant, fresh flower yield, essential oil content, essential oil yield, and extraction yield.

Essential oil extraction method

Hydro-distillation: Employing a Clevenger extraction technology, a 30 g sample of dried flowers was subjected to each treatment in 500 mL of distilled water for 6 hours (Guenther et al., 1959). The vapor mixture of water and essential oil was condensed, and oil and bioactive components were extracted from the water using a separating funnel. The essential oil content data were examined using analysis of variance (Svab, 1981).

Data analysis

The experimental data were analyzed using analysis of variance (ANOVA) and correlation analysis, and the differences between the variants were determined by means of the Duncan’s Multiple Range Test.

RESULTS AND DISCUSSION

Weather conditions

Meteorological conditions during the experimental period are presented in Figures 1 and 2. Considerable interannual variation was observed in both mean monthly temperatures and total monthly precipitation. In 2024, the mean growing-season temperature exceeded the long-term average by 3.0–4.2 °C, except in May, when it was 1 °C lower than the long-term mean. During the same year, precipitation was unevenly distributed, and the total amount was 120.45 mm lower than the long-term average. The unfavorable weather conditions in 2024 profoundly influenced chamomile growth and morphology. As a result, plants exhibited reduced height, smaller stem diameter, fewer branches, a lower number of flowers per plant, and reduced flower diameter compared with 2023 and 2025. Despite the suppression of vegetative growth, the essential oil content (%) and essential oil yield (kg ha^{-1}) were higher in 2024. Similar reactions have been shown in medicinal and aromatic plants, where moderate water deficits and temperature stress stimulate secondary metabolite production (Bettaieb et al., 2011; Farooq et al., 2009). In chamomile specifically, drought conditions have been shown to reduce biomass while increasing essential oil concentration (Baghalian et al., 2008). This demonstrates the typical growth-quality trade-off under stress circumstances. The year 2023 provided the most favorable conditions for the development of the tested chamomile varieties. Compared with 2024 and 2025, the mean monthly temperatures were closest to the long-term averages, while total precipitation (289.10 mm) was also comparable to the long-term amount (312.48 mm). These conditions were reflected in the superior quantitative performance of all three varieties.

Plant height

Table 1 presents the data obtained regarding the differences among the examined chamomile cultivars. The Degumille cultivar had the highest record for plant height, ranging from 52.8 cm (2024) to 65.2 cm (2023), followed by the Comune cultivar, from 50.0 cm (2024) to 61.0 cm (2023). The plant height values obtained in this study fall within the range noted by Galambosi et al. (1991) for the variety Degumille (47.6–60.8 cm; mean 52.6 cm) and Bona (46.2–52.8 cm; mean 51.3 cm), further confirming the strong environmental influence on chamomile vegetative growth.

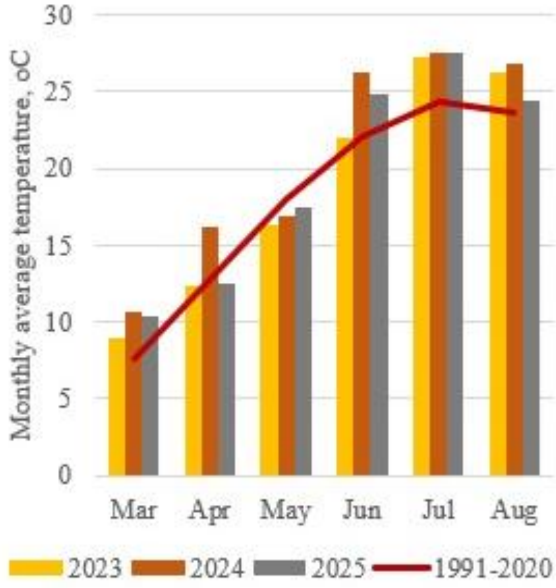

Figure 1. Mean Monthly Air Temperature,°C

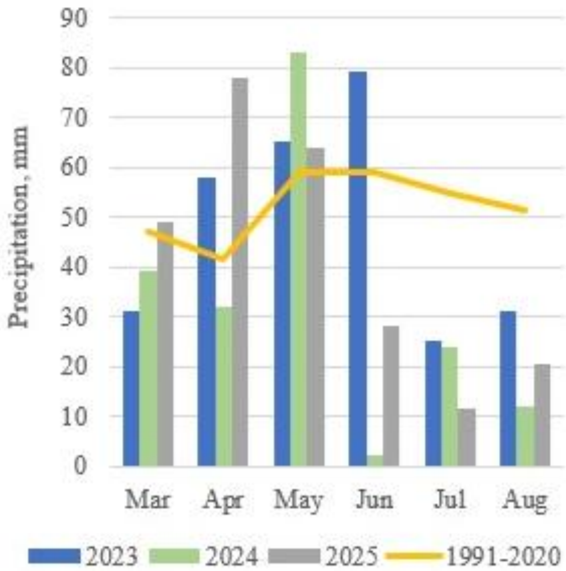

Figure 2. Monthly Precipitation, mm

Plant height varied notably over the years. The tallest plants were documented in 2023 (average 58.5 cm), while the shortest were found in 2024 (47.3 cm). The decline in plant height in 2024 can be attributed to drought stress during critical developmental stages, which is associated with higher temperatures and less precipitation. Under such hydrothermal stress-related circumstances, vegetative development is often inhibited due to limited cell expansion and reduced assimilate accumulation. In 2025, plant height displayed partial recovery (54.3 cm), indicating better growing conditions than in 2024.

The analysis of variance (ANOVA) revealed that plant height was significantly affected by year and variety, whereas their interaction was not significant.

Stem diameter

As shown in Table 1, the chamomile variety Comune exhibited the thickest stems, with stem diameters of 0.71, 0.82, and 0.60 cm in 2023, 2024, and 2025, respectively. In contrast, the variety Bona showed the thinnest stems, namely 0.45 cm (2023), 0.30 cm (2024), and 0.39 cm (2025). The observed variation in stem diameter between years and varieties reflects the sensitivity of chamomile vegetative growth to environmental factors. Across years, Comune cultivar had the highest average stem diameter (0.71 cm), followed by Degumille (0.55 cm) and Bona (0.38 cm). The average stem diameter was highest in 2023 (0.65 cm) and lowest in 2024 (0.44 cm).

Table 1. Biometrical parameters and Yield components in chamomile

		Plant height (cm)	**Stem diameter (cm)**	**Number of branches on main stem**	**Flower diameter (cm)**	**Number of flowers/ plant**	**Fresh weight of flowers per plant (g)**
Year (A)	2023	58.5 ^{a}	0.65 ^{a}	7.0 ^{a}	2.52 ^{a}	28.6 ^{a}	5.56 ^{a}
	2024	47.3 ^{c}	0.44 ^{c}	5.2 ^{c}	1.93 ^{c}	15.5 ^{c}	3.46 ^{c}
	2025	54.3 ^{b}	0.55 ^{b}	6.1 ^{b}	2.23 ^{b}	24.4 ^{b}	4.62 ^{b}
Variety (B)	Bona	44.9	0.38	5.7	2.07	25.2	3.85
	Degumille	59.0	0.55	4.5	2.67	21.9	4.40
	Comune	56.2	0.71	8.1	1.94	20.4	5.40
2023	Bona	49.3 ^{c}	0.45 ^{c}	6.8 ^{b}	2.30 ^{b}	31.6 ^{a}	4.68 ^{c}
	Degumille	65.2 ^{a}	0.68 ^{b}	5.2 ^{c}	3.11 ^{a}	25.5 ^{c}	5.21 ^{b}
	Comune	61.0 ^{b}	0.82 ^{a}	8.9 ^{a}	2.15 ^{c}	28.7 ^{b}	6.80 ^{a}
2024	Bona	39.1 ^{c}	0.30 ^{c}	4.3 ^{b}	1.90 ^{b}	15.4 ^{a}	3.07 ^{c}
	Degumille	52.8 ^{a}	0.41 ^{b}	3.8 ^{c}	2.10 ^{a}	17.2 ^{b}	3.18 ^{b}
	Comune	50.0 ^{b}	0.60 ^{a}	7.5 ^{a}	1.78 ^{c}	14.0 ^{c}	4.13 ^{a}
2025	Bona	46.2 ^{c}	0.39 ^{c}	5.9 ^{b}	2.00 ^{b}	28.7 ^{a}	3.79 ^{c}
	Degumille	59.1 ^{a}	0.55 ^{b}	4.5 ^{c}	2.80 ^{a}	23.1 ^{b}	4.81 ^{b}
	Comune	57.5 ^{b}	0.71 ^{a}	7.9 ^{a}	1.90 ^{c}	21.4 ^{c}	5.26 ^{a}
Anova	A	*	*	*	*	**	**
	B	*	*	**	*	*	*
	AB	ns	*	ns	*	*	*

*Legend: Means within columns followed by different lowercase letters are significantly different ($p < 0.05$) according to the LSD test; * F-test significant at $p < 0.05$; ** F-test significant at $p < 0.01$; ns - non-significant*

The established variance in stem diameter is consistent with prior research indicating that chamomile vegetative characteristics are highly sensitive to environmental and agronomic influences (Baghalian et al., 2008; Pirzad et al., 2006). Additionally, Karkleliene et al. (2009) found that favorable environmental conditions stimulate more vigorous plant development, which corresponds to the larger stem diameter observed in 2023. The analysis of variance demonstrates a statistically significant impact of both the examined cultivars and the years with their specific climatic conditions on the stem diameter. An interaction between cultivars and year was demonstrated.

Number of branches on main stem

The number of branches on the main stem differed greatly among varieties. The variety Comune produced the most branches on average during the experiment (8.1), followed by Bona (5.7) and Degumille (4.5). By year, branching was most intense in 2023 (7.0) and lowest in 2024 (5.2). The influence of year on morphological traits, particularly the number of branches on the main stem, was also reported by Filipović et al. (2024). Notable variations were seen across the chamomile cultivars regarding the number of branches per plant.

Flower diameter

The flower diameter exhibited considerable variation among varieties and years (Table 1). The peak values for this parameter were measured for the variety Degumille, spanning from 2.10 cm (2024) to 3.11 cm (2023). For the remaining cultivars, flower diameter varied from 1.78 to 2.30 cm.

On average for the trial period, the cultivar Degumille produced the largest flowers (2.67 cm), followed by Bona (2.07 cm) and Comune (1.94 cm). The largest mean flower diameter was reported in 2023 (2.52 cm), while the smallest occurred in 2024 (1.93 cm). Our results closely align with those of El Mihyaoui et al. (2022) and Shalaby et al. (2010) who similarly observed significant variation in flower diameter.

The observed results are statistically significant. The ANOVA revealed a substantial impact of the two factors, variety and year, on flower diameter. Their interaction has also been confirmed.

Number of flowers per plant

The more favorable climatic conditions in 2023 preconditioned the formation of a greater number of flowers per plant (28.6) compared with the other two experimental years, namely 15.5 in 2024 and 24.4 in 2025 (Table 1). On average across the study period, the highest number of flowers per plant was recorded in the variety Bona (25.2), followed by Degumille (21.9), while the lowest value was observed in Comune (20.4).

ANOVA revealed a substantial statistical effect of both parameters year and variety on number of flowers per plant, and it mathematically demonstrated their interaction.

Fresh weight of flowers per plant

The data given in Table 1 show that plants of the Comune variety achieved the highest fresh flower weight per plant—6.80 g, 4.13 g, and 5.26 g in 2023, 2024, and 2025, respectively. The cultivar Degumille followed with lower values of 5.21, 3.18, and 4.81 g over the same period.

On average by year, the fresh flower weight per plant was highest in 2023 (5.56 g), followed by 2025 (4.62 g), and lowest in 2024 (3.46 g). The depressed values in 2024 were most likely associated with insufficient and uneven precipitation during the critical moisture-sensitive period, when intensive stem elongation, branching, and flower bud formation occur in chamomile.

Analysis of variance (ANOVA) showed that both year and variety had a significant effect on the fresh weight of flowers per plant, as did their interaction.

Fresh flower yield

The highest fresh flower yield was achieved in the first harvest year (2023), with an average of 2163 kg ha^{-1}, whereas the lowest yield was recorded in 2024, averaging 1078 kg ha^{-1} (Table 2). The response of the different varieties to varying weather conditions differed considerably. Precipitation was identified as the critical factor affecting yield formation. Adequate rainfall during the vegetative growth phase, particularly during root development and rosette formation, contributed to higher yields, as observed in 2023.

In contrast, yield levels remained lower in 2024 due to soil moisture deficiency in June. Although May 2024 was characterized by above-average precipitation, the extremely low rainfall in June (2 mm compared with the long-term average of 58.96 mm) coincided with the critical flowering stage, likely restricting generative development and reducing yield components.

Among the studied varieties, Comune produced the highest fresh flower yield, ranging from 1220 kg ha^{-1} (2024) to 2850 kg ha^{-1} (2023), followed by Degumille, which varied from 1039 kg ha^{-1} (2024) to 2347 kg ha^{-1} (2023). Of the examined cultivars, Bona was the least productive, generating an average fresh flower yield of 1108 kg ha^{-1} over the trial period, with values ranging from 974 kg ha^{-1} (2024) to 1108 kg ha^{-1} (2023). These findings are in agreement with Galambosi et al. (1991), who also reported significantly lower fresh flower yield in Bona compared with Degumille.

A significant relationship between year, variety, and their interaction was observed in the fresh flower yield.

Essential oil content

The essential oil content of the studied chamomile cultivars varied from 0.38 % to 0.65 % over the trial period (Table 2). Among the cultivars, Bona exhibited the highest average essential oil content (0.54 %), whereas Comune showed the lowest (0.45 %). A statistically significant differentiation in essential oil content was observed among all studied cultivars. The highest essential oil content was recorded in 2024 (0.60 %), followed by 2023 and 2025 (0.43 % each).

The analysis of variance showed strong statistical influence on essential oil content with relation to the varieties and year as well. The interaction between both factors, variety and year, was non-significant (Table 2). A higher essential oil concentration in 2024 coincided with higher average air temperatures, with the growing season being, on average, 2.7°C above the long-term mean. Particularly pronounced deviations were observed in June (+4.2 °C) and July (+3.3°C). These conditions likely enhanced secondary metabolite accumulation as a stress-adaptive response to hydrothermal stress. This negative correlation between biomass accumulation and essential oil concentration in stressed medicinal plants validates the typical growth–quality trade-off (Baghalian et al., 2008; Selmar & Kleinwächter, 2013; Bettaieb et al., 2011).

Essential oil yield

Essential oil yield (kg ha^{-1}) varied considerably among years and cultivars (Table 2). The highest oil yield was recorded in 2023 (9.13 kg ha^{-1}), followed by 2025 (7.84 kg ha^{-1}), while the lowest value was observed in 2024 (6.42 kg ha^{-1}), despite the higher essential oil concentration during that year. This indicates that the oil yield per hectare was primarily driven by fresh flower yield rather than by the oil concentration alone. Although 2024 was characterized by the highest essential oil content (0.60 %), the markedly reduced biomass production limited the total oil yield. In contrast, the favorable weather conditions in 2023 supported higher biomass accumulation, which compensated for the lower oil concentration (0.43 %) and resulted in the greatest oil yield per hectare (Table 2).

Among the cultivars, Comune produced the highest average essential oil yield (9.45 kg ha^{-1}), followed by Degumille (8.08 kg ha^{-1}), while Bona exhibited the lowest value (5.85 kg ha^{-1}).

Table 2. Quantitative and qualitative indices

		Yield of fresh flowers (kg ha^{-1})	Essential oil content (%)	Yield of essential oil (kg ha^{-1})	Extraction yield (kg)
Year (A)	2023	2163 ^{a}	0.43 ^{b}	9.13 ^{a}	233.7 ^{a}
	2024	1078 ^{c}	0.60 ^{a}	6.42 ^{c}	167.4 ^{b}
	2025	1905 ^{b}	0.43 ^{b}	7.84 ^{b}	237.7 ^{a}
Variety (B)	Bona	1108	0.54	5.85	190.4
	Degumille	1802	0.47	8.08	219.0
	Comune	2235	0.45	9.45	229.4
2023	Bona	1291 ^{c}	0.46 ^{a}	5.94 ^{c}	217.4 ^{c}
	Degumille	2347 ^{b}	0.44 ^{b}	10.33 ^{b}	227.3 ^{b}
	Comune	2850 ^{a}	0.39 ^{c}	11.11 ^{a}	256.4 ^{a}
2024	Bona	974 ^{c}	0.65 ^{a}	6.33 ^{c}	153.8 ^{c}
	Degumille	1039 ^{b}	0.60 ^{b}	6.23 ^{b}	166.7 ^{b}
	Comune	1220 ^{a}	0.55 ^{c}	6.71 ^{a}	181.8 ^{a}
2025	Bona	1059 ^{c}	0.50 ^{a}	5.30 ^{c}	200.0 ^{c}
	Degumille	2020 ^{b}	0.38 ^{b}	7.68 ^{b}	263.0 ^{b}
	Comune	2635 ^{a}	0.40 ^{b}	10.54 ^{a}	250.0 ^{a}
Anova	A	*	*	*	*
	B	*	*	*	*
	AB	*	ns	*	ns

*Legend: Means within columns followed by different lowercase letters are significantly different ($p < 0.05$) according to the LSD test; * F-test significant at $p < 0.05$; ** F-test significant at $p < 0.01$; ns - non-significant*

The analysis of variance revealed a significant effect of year, variety, and their interaction on essential oil yield. These results demonstrate that essential oil yield per hectare is a function of both essential oil concentration and biomass production, with biomass being the dominant determinant under field conditions.

Extraction yield

The extraction yield represents the quantity of raw material required to obtain one liter of essential oil (Georgieva et al., 2021). The extraction yield (EY) was significantly affected by the year and variety, but their interaction was non-significant (Table 2). The highest EY values were recorded in 2025 (237.7 kg) and 2023 (233.7 kg), whereas the lowest value was observed in 2024 (167.4 kg). The reduced extraction yield in 2024 reflects the negative impact of meteorological stress on biomass partitioning and reproductive efficiency.

Among the cultivars, Comune exhibited the highest average EY (229.4 kg), followed by Degumille (219.0 kg), while Bona showed the lowest value (190.4 kg). The higher extraction yield of Comune indicates a more efficient allocation of assimilates toward generative organs under the given agroclimatic conditions.

The variation in extraction yield among years further confirms that precipitation distribution during critical phenological stages plays a decisive role in reproductive efficiency in chamomile.

Correlation coefficients

The correlation analysis revealed clear relationships among the studied morphological and productive traits (Table 3). The yield of fresh flowers exhibited a strong and statistically significant positive association with essential oil yield (r = 0.901), indicating that higher biomass production directly contributed to increased oil yield. Strong positive correlations (r > 0.80) were also observed between stem diameter and fresh flower weight per plant (r = 0.883), stem diameter and fresh flower yield (r = 0.887), as well as stem diameter and essential oil yield (r = 0.865). These results suggest that the stem diameter is a key morphological trait closely linked to biomass accumulation and overall productivity.

High to moderate positive correlations (r > 0.70 and r > 0.60) were found between fresh flower yield and extraction yield (r = 0.769), fresh flower weight per plant and essential oil yield (r = 0.786), extraction yield and fresh flower weight per plant (r = 0.792), stem diameter and number of branches on the main stem (r = 0.702), plant height and stem diameter (r = 0.735), plant height and fresh flower weight per plant (r = 0.635), plant height and essential oil yield (r = 0.658), plant height and extraction yield (r = 0.632), and number of branches on the main stem and fresh flower weight per plant (r = 0.683). These associations indicate that vegetative growth parameters contribute substantially to reproductive performance and yield formation.

Flower diameter showed moderate positive correlations with fresh flower yield (r = 0.314), extraction yield (r = 0.399), and essential oil yield (r = 0.337), suggesting that floral morphology also plays a role, though a less dominant one, in productivity.

A consistent negative correlation was observed between essential oil content and all other evaluated traits. In particular, strong negative associations were detected between essential oil content and extraction yield (r = –0.828), fresh flower weight per plant (r = –0.738), fresh flower yield (r = –0.726), and stem diameter (r = –0.618). This inverse relationship indicates a potential dilution effect, whereby increased biomass production may be associated with reduced concentration of essential oil in plant tissues.

Overall, the results demonstrate that biomass-related traits, especially the stem diameter and fresh flower weight per plant, are critical determinants of fresh flower yield and essential oil yield.

Table 3. Values of the coefficient of correlation

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. Plant height	1									
2. Stem diameter	0.735*	1								
3. Nr of branches on main stem	0.230	0.702*	1							
4. Flower diameter	0.588	0.236	-0.265	1						
5. Nr of flowers/plant	0.310	0.262	0.329	0.398	1					
6. Fresh weight of flowers/ plant	0.635	0.883*	0.683	0.280	0.554	1				
7. Yield of fresh flowers	0.681	0.887*	0.530	0.314	0.324	0.852*	1			
8. Essential oil content	-0.514	-0.618	-0.405	-0.334	-0.545	-0.738*	-0.726	1		
9. Yield of essential oil	0.658	0.865*	0.507	0.337	0.214	0.786*	0.901*	-0.501	1	
10. Extraction yield	0.632	0.688	0.407	0.399	0.529	0.792*	0.769*	-0.828*	0.566	1

*Legend: *significance level alpha = 0.05.*

CONCLUSIONS

Productivity of the evaluated chamomile cultivars depended on both genetic characteristics and weather conditions. Sufficient moisture during stem elongation and flower bud formation promoted higher yield, whereas drought stress during flowering reduced productivity but enhanced essential oil accumulation. Among the studied cultivars, Comune distinguished itself with the highest productivity, combining higher fresh flower yield and essential oil yield with well-developed morphological traits. The cultivar Degumille was characterized by the highest plant height and largest flower diameter, whereas Bona exhibited the highest essential oil concentration but the lowest yield performance. The fresh flower yield was strongly associated with the stem diameter and fresh flower weight per plant, while essential oil content showed a negative relationship with the biomass-related traits, indicating a trade-off between productivity and oil concentration. For the agroecological conditions of the Plovdiv region, the Comune variety can be recommended as the most suitable cultivar for high-yield production, whereas the Bona variety may be considered in systems targeting higher essential oil concentration. Successful cultivation strategies should aim at balancing biomass accumulation and essential oil concentration under variable climatic conditions.

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