Research Article

Heat Stress-Induced Changes in Growth and Essential Oil Profile of German Chamomile (*Matricaria chamomilla*)

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ABSTRACT

This study investigates the influence of different sowing times on the agro-morphological characteristics, flower productivity and essential oil content of German chamomile (*Matricaria chamomilla* L.) cultivated in the Dehradun district of Uttarakhand, India. The study employs Randomized Complete Block Design (RCBD) to investigate the effects of three different sowing times (late September, mid-October and mid-November). The second sowing time resulted in the maximum values for parameters such as plant height, number of primary branches, number of flowers, flower head diameter, stem girth and fresh flower weight. GC/MS analyses of oil samples revealed that the predominant components, including α-Bisabolol, Bisabolol oxide A, Bisabolol oxide B, Chamazulene, β-Farnesene and (Z)-en-yn-dicycloether, varied with sowing times. The findings of this research are expected to provide valuable insights to farmers in Uttarakhand regarding the optimal timing for chamomile cultivation, aiding them in enhancing the quality of chamomile flowers.

Keywords: Cultivation, Essential oil, Morphological, Productivity.

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INTRODUCTION

Matricaria chamomilla L., well known as German chamomile, is a widely cultivated medicinal plant renowned for its therapeutic properties. The plant's essential oil, extracted primarily from its flowers, contains a plethora of bioactive compounds such as chamazulene, bisabolol and apigenin, which contribute to its medicinal efficacy. Heat stress occurs when plants are exposed to temperatures beyond their optimal range, leading to physiological changes that can impact their morphological characteristics, yield and biochemical composition. Understanding the effects of heat stress on *Matricaria chamomilla* is crucial for several reasons. Firstly, as global temperatures continue to rise due to climate change, heat stress is becoming a more prevalent challenge for agricultural systems worldwide. Secondly, chamomile cultivation plays a significant role in the economy and traditional medicine practices and making it essential to assess how environmental factors like heat stress may influence its growth and quality. The objective of this study is to examine how heat stress influences the morphological features, flower yield and essential oil output of *Matricaria chamomilla* L. within the distinct environmental conditions found in the Doon Valley. By examining these aspects, we can gain insights into the adaptive responses of chamomile to heat stress and elucidate strategies for optimizing its cultivation under changing climatic conditions. Such knowledge is invaluable for sustainable agriculture, biodiversity conservation and the continued utilization of chamomile as a valuable medicinal herb. The impact of elevated temperatures on plant susceptibility varies across developmental stages, affecting both vegetative

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and reproductive phases to some degree. Aromatic and medicinal plants contain a wealth of secondary metabolites that hold significant value for humanity. The Essential Oils (EOs) derived from these plants are highly important in various domains such as enhancing natural food flavors, aromatherapy practices and pharmaceutical applications.[1] German chamomile, which belongs to the Asteraceae family, is classified among medicinal and aromatic plants. It thrives in numerous countries and is gaining popularity due to its diverse medicinal properties. Traditionally, chamomile flowers or extracts have been utilized for therapeutic purposes.[2] Environmental stressors pose challenges to plants, influencing their growth, metabolism and functions based on species sensitivity and developmental stage. The demand for chamomile's essential oil, widely used in cosmetics and aromatherapy, has been steadily rising.

The biological efficacy of chamomile is primarily attributed to phenolic compounds, flavonoids, apigenin, quercetin, patulin, luteolin, glucosides and components of essential oil like α-bisabolol, its oxides and azulenes. Many health advantages can be derived from extracts and essential oils of chamomile, such as their anti-inflammatory, depressive, antipyretic, antibacterial, antifungal, anticancer, antidiabetic and antiparasitic effects. Chamomile's qualities make it valuable in various sectors like healthcare, veterinary care, preservation of food materials, pest management in plants and as a surfactant and anti-corrosion substance.[3] Genetic background and environmental conditions affect the morphology, physiology, essential oil concentration and potency of chamomile plants. Additionally, the oil content and quality of chamomile are impacted by growing conditions. Therefore, it is essential to carefully manage and monitor the environmental and growing conditions to optimize the growth and quality of chamomile plants.[4] Despite an eightfold increase in medicinal plant cultivation globally over the past two decades, there is limited information on how sowing dates impact the morphological and phytochemical characteristics of German chamomile in India. Consequently, the research was conducted to assess the morpho-physiological impacts of different sowing dates on German chamomile within the climatic conditions of Dehradun district of Uttarakhand, India.

MATERIALS AND METHODS

The research was carried out in the Agricultural Research Field of SGRR University in Dehradun, which is situated at coordinates 30.3047550 N, 78.0328590 E and has an elevation of 640 meters above the sea level, during the Rabi seasons of 2022-2023 and 2023-2024. The subtropical climate of Dehradun is marked by hot summers, mild winters, warm springs and a strong monsoon season. The chamomile seeds used in the study were obtained from the Centre of Aromatic Plants in Dehradun. Standard soil preparation techniques, including ploughing and harrowing, were employed to ensure uniform soil conditions.

Field experiment

In August, the field underwent thorough ploughing and harrowing before commencing the experiment. The experimental plots, sized at 70 cm×50 cm with four rows of 24 plants each, were prepared using a RCBD design and replicated thrice. All plots received thorough and uniform flood irrigation. Approximately 8 irrigations were consistently administered at regular intervals. Weed management was carried out manually three times during both the vegetative and reproductive phases. The soil properties of the experimental site are detailed in Table 1.

Meteorological Condition

The long-term average weather conditions for the trial years 2022-2023 and 2023-2024 are shown in Figures 2. The data shows a gradual decrease in maximum and minimum temperatures from September to January, followed by a slight increase until May. Humidity remains consistently high, with no significant trend. Rainfall peaks in September and decreases notably in November, December and January before rising again in April and May. Wind speed remains relatively consistent throughout the year. Overall, the data suggests a transition from hot and humid conditions in September to cooler and drier weather from November to January. Meteorological data has recorded from the Weather Station located at Agricultural Research Field of SGRR University, Dehradun.

Table 1: Physical and Chemical Characteristics of the soil used in the study area.

Sl. No.	Growing Year	pH	EC (Electrical Conductivity)	Organic Carbon Content (%)	Soil Texture (%)			
					Clay	Silt	Sand	Texture
1.	2022-23	8.2	0.256	1.854	19.14	39.67	41.19	Loam
2.	2023-24	8.6	0.263	1.823	18.63	34.25	39.7	Loam

Figure 1: Chamomile field trial for the years 2022-23 and 2023-24.

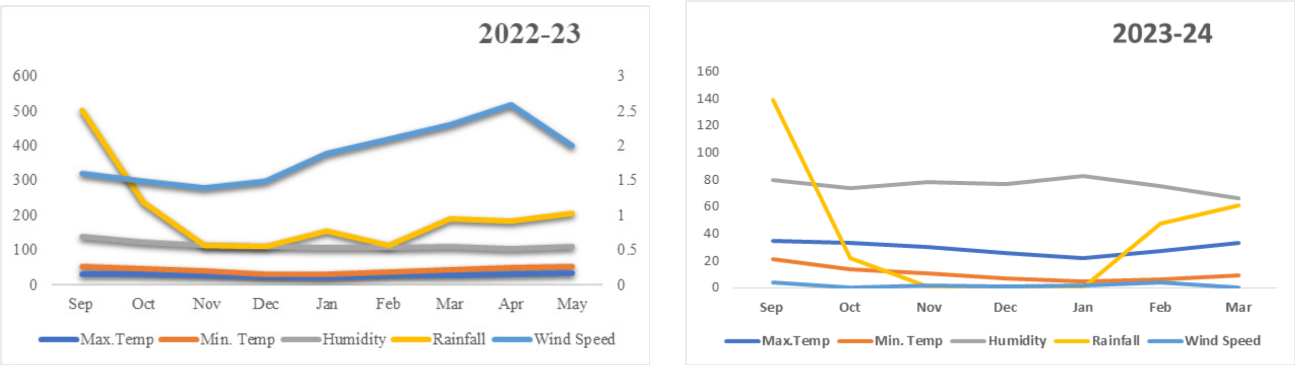

Figure 2: Mean long term values of meteorological parameters during 2022-23 and 2023-24.

Morphological Analysis

During the flowering phase, a thorough morphological analysis was carried out, covering both qualitative and quantitative aspects. These included:

- Plant height (measured in cm),
- Internodal distance (measured in cm),
- Number of primary branches (per plant),
- Stem diameter (measured in cm),
- Number of flowers per plant,
- Fresh flower yield (measured in g/plant),
- Dried flower yield (measured in g/plant),
- Flower head diameter (measured in cm),
- Peduncle length (measured in cm).

Harvesting commenced once the flowers had reached their peak blooming state. Just before the first harvesting of flower, plant height was evaluated in each plot with a ruler with an accuracy of ±0.1 cm, from the base of the plant to its tip. Twenty flowers were selected at random from every harvest and their diameters were recorded with a vernier calliper to an accuracy of ±0.01 cm. Harvesting began when 50% of the plants had flowered and was carried out weekly thereafter. Freshly harvested flowers were subjected to a drying process and the weights of both fresh and dried flowers were recorded using a digital balance.

Extraction and Profiling of Essential Oil Constituents

Employing a Clevenger apparatus, 30 g of dried flowers underwent heating with 500 mL of water for six hours, repeated thrice until oil condensation occurred. Preceding GC/MS analysis, the oil, enriched with biological compounds, underwent separation from water via a funnel and drying with anhydrous magnesium sulphate.

Statistical analysis

IBM SPSS Statistics 20 was used for statistical analysis to assess the results of various quantitative characteristics from both years.

RESULTS

Morphological studies

There is significant variation in the morphological characteristics of *Matricaria chamomilla* cultivated at various sowing times (Table 2). For the year 2022-23, the highest values for plant height (93±1.732 cm), flower head diameter (3.83±0.166 cm), number of primary branches (18±1.33), peduncle length (8.16±0.16), thickest stems (2.83±0.44 cm) and essential oil (0.59±0.02) observed in second sowing times (Mid-October). These findings may indicate a more branched growth pattern and stronger structural support, potentially higher yield or floral abundance compared to other sowing times. While in the growing season 2023-24, the maximum values for plant height (86±1.76), Flower head diameter (3.16±0.16), stem girth (3±0.28), peduncle length (8.06±0.06) and essential oil (0.57±0.02) are also observed from second time of sowing (Mid Oct).

Floral Characteristics

The dried flower yield (g/plant), fresh flower yield (g/plant) and number of flowers per plant in chamomile crops were notably influenced by different sowing times (as shown in Figure 3). The highest values for dried flower yield (8.54± 0.43 g/plant), fresh flower yield (43.93±3.0 g/plant) and number of flowers (386.33±2.33 per plant) in chamomile crops were observed during the second sowing time (Mid Oct) in the 2022-2023. Similar patterns were noted in the growing season 2023-2024

Essential oil content

The comparison of the attained essential oil contents (%) of German Chamomile at different sowing times is presented in Figure 4. Results indicate that the total 6 major components Chamazulene, β-farnesene, α-Bisabolol, α-Bisabolol oxide A, α- Bisabolol Oxide B, Z (en) yn dicycloether were identified from the Chamomile oil. The maximum values of the main essential oil compounds belong to α-Bisabolol, Bisabolol Oxide B, while the minimum amount which was identified between main compounds were β-farnesene, Z (en)-yn-dicycloether. GC-FID analyses revealed that the maximum amount of Chamazulene which gives blue colour to oil and Bisabolol Oxide B was found with the second sowing time. The highest values for α-Bisabolol, Bisabolol oxide A were obtained from the second sowing time while β-farnesene, Z (en) yn dicycloether were obtained with the maximum amount from the first sowing time. The identified essential oil compounds at the different treatments are depicted in Figure 4.

Table 2: Mean comparison of sowing times on morphological traits of *Matricaria chamomilla* L. (Values are mean±standard error of the mean (*n*=3).

Growing Year	Sowing Time	Plant Height (cm)	Internodal distance (cm)	Flower head diameter (cm)	No. of primary branches (per plant)	Stem Girth (cm)	Peduncle length	Essential Oil (%)
2022-23	Late Sep	91±0.57	3.8±0.16	2.33±0.333	16±0.88	1.93±0.06	7.6±0.37	0.37±0.03
	Mid Oct	93±1.73	3.5±0.5	3.16±0.166	18±1.33	2.83±0.44	8.16±0.16	0.59±0.02
	Mid Nov	73±1.52	4.6±0.33	2.66±0.33	13±1	1.66±0.16	7.16±0.16	0.28±0.03
2023-24	Late Sep	75±1.85	3.8±0.16	2.3±0.33	16±0.33	2.1±0.2	7.5±0.23	0.39±0.04
	Mid Oct	86±1.76	3.8±0.44	3.16±0.16	15+0.57	3±0.28	8.06±0.06	0.57±0.02
	Mid Nov	61±1.45	4.6±0.33	2.5±0.28	13±0.88	1.83±0.16	7.2+0.14	0.30±0.03

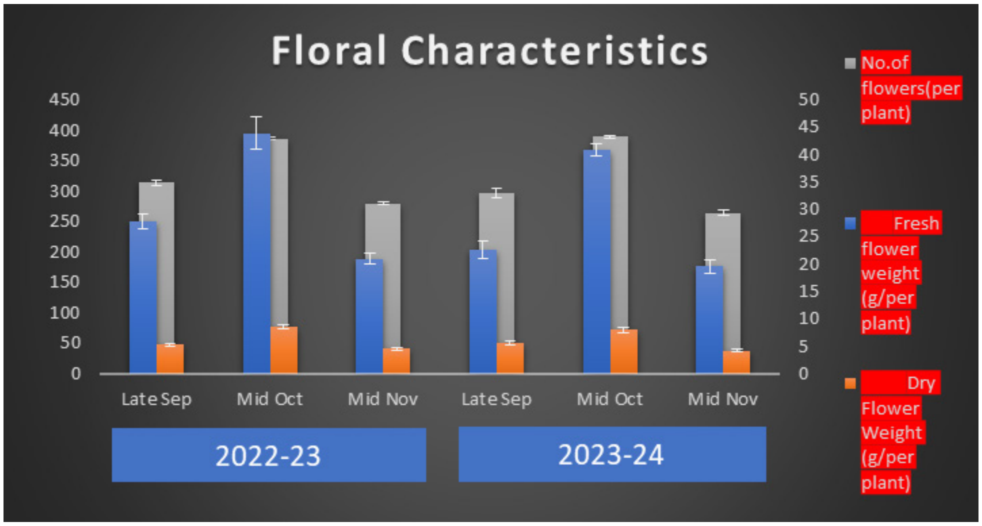

Figure 3: Effect of date of sowing on the Floral characteristics (No. of flowers, fresh flower yield and dry flower yield) during the experimental year 2022-23 and 2023-24.

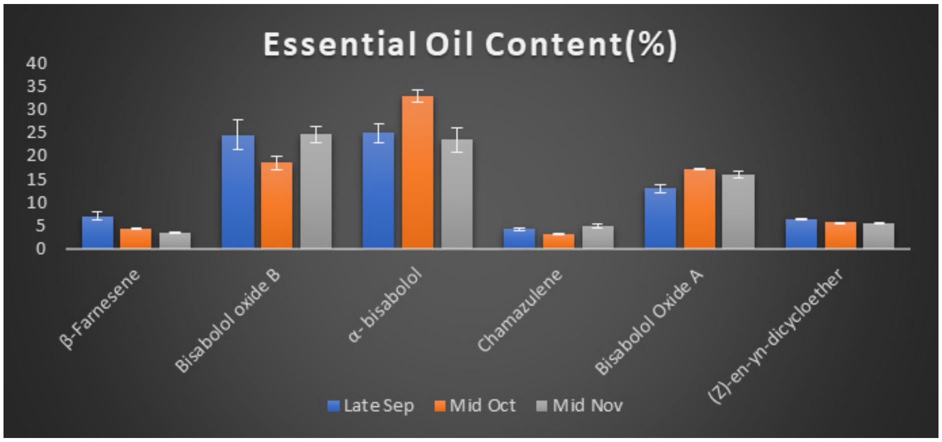

Figure 4: Effect of date of sowing on the essential chamomile oil (percentage of essential oil) in GC/MS in the experimental year 2022-23.

DISCUSSION

Chamomile, which is sensitive to temperature changes, utilizes various adaptive strategies to manage increased temperatures.[4] The research on the effects of heat stress on morphological traits and essential oil yield in *Matricaria chamomila* L. in doon valley of Uttarakhand, India, yielded valuable insights. The study revealed that heat stress significantly impacted morphological characteristics of *Matricaria chamomilla* L., leading to notable changes in essential oil yield. These findings are consistent with previous research that has demonstrated the influence of heat stress, on the essential oil yield and composition of chamomile plants. Additionally, the study contributes to the growing body of knowledge on the impact of different sowing time on the growth, yield and essential oil composition of chamomile, providing important considerations for the cultivation and management of this valuable plant species in the face of changing climate patterns and environmental stressors. The second sowing period, occurring around mid-October, resulted in the highest observed values for the measured traits. In contrast, other sowing times showed decreasing trends. Delayed sowing reduced the time taken to reach each phenological stage in German chamomile, primarily by shortening the growing season, especially the reproductive phase. Our findings align with Mehriya *et al.*[5], who also noted that October sowing yielded the best results for these traits. Rathore and Kumar [1] similarly noted the impact of different planting times on the agro-morphological and yield characteristics of German Chamomile. Mohammad *et al.*[6] emphasized the significant influence of sowing dates on chamomile crop growth and yield. Additionally, Da Silva *et al.*[7] highlighted how sowing dates affect chamomile's flower yield and essential oil content due to thermal time interference with plastochron and flower buds. Ebadi *et al*.[8] also discovered a notable effect of sowing date and seedling levels on flower yields, essential oil content and composition.

The current study's results indicated that major essential oil constituents in German chamomile include α-bisabolol oxide A, α-bisabolol oxide B, bisabolone oxide A, β-farnesene and chamazulene, consistent with earlier research findings.[6,9,10] Several researchers discovered that α-bisabolol ranged from 1.11% to 50.58%, while chamazulene ranged from 1.22% to 29.8%.[11-14] In Europe, a study conducted on wild populations found that the α-bisabolol content varied from 24% to 41.54%.[15] The study is conducted in a specific region (Dehradun district, Uttarakhand), so the findings might not be directly applicable to other regions with different climatic and soil conditions. This research provides practical insights for farmers on the optimal sowing time for German chamomile in Dehradun, resulting in improved plant height, number of primary branches, number of flowers, flower head diameter, stem girth and fresh flower weight. This can enhance both the quantity and quality of chamomile production. The study's insights into the variations in essential oil components with different sowing times can guide breeding programs aimed at developing chamomile varieties with enhanced oil quality and yield. The findings are specific to the Dehradun district of Uttarakhand and their applicability to other regions with different climatic and soil conditions may be limited. Further studies in diverse geographic locations are needed to validate the generalizability of these results.

CONCLUSION

The research on the morphological traits and essential oil yield under heat stress in *Matricaria chamomila* L. cultivated in Doon Valley of Uttarakhand, India, revealed significant impacts. The findings underscore the vulnerability of *Matricaria chamomila* L. to heat stress, leading to notable changes in its essential oil content and composition. The study offers relevant information to lessen the adverse impacts of heat stress on the development and oil yield of *Matricaria chamomilla* L., thereby contributing to the sustainable cultivation of this important plant species.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

None

CONFLICT OF INTEREST

The Authors declare no conflict of interest.

AUTHOR'S CONTRIBUTION

The conceptualization, methodology, investigation, allocation of resources, data curation by Subhdara and KDJ manuscript review and editing by SK and GT. All the authors have reviewed and consented to the final version of the manuscript for publication.

ABBREVIATIONS

RCBD: Randomized Complete Block Design; **GC-MS:** Gas Chromatography; **GC-FID:** Gas Chromatography-Flame ionization detector.

SUMMARY

Summary is included in Discussion and abstract portion.

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