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Investigation of Yield and Quality Characteristics of Local and Foreign Origin Yarrow (*Achillea millefolium* L.) Genotypes in Culture Conditions

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Abstract: This study was conducted in 2023 to evaluate the yield and quality characteristics of 3 local and 60 foreign Achillea millefolium L. genotypes under the ecological conditions of Isparta. All genotypes were planted in 3 rows with a block length of 3 m, using a planting norm of 100 × 30 cm. The results revealed considerable variation among the genotypes. Flowering duration ranged from 10 to 41 days, plant height from 21.8 to 72.0 cm, flower head diameter from 4.3 to 15.5 cm, and the number of florets per capitulum from 26.0 to 419.0. Fresh flower yield exhibited substantial variation, ranging from 246.9 to 2829.7 kg/da, while dry flower yield ranged between 82.6 and 1017.7 kg/da. Among all genotypes, PI 439888, PI 661151 and PI 439892 were identified as having the highest yield potential. Essential oil content varied between 0.05-0.50%. In 10 genotypes and local genotypes selected according to fresh herb and oil yield, essential oil content and color, 1,8-cineole (3.1–22.4%), borneol (2.5–18.3%), camphene (1.8–12.7%), α-pinene (4.2–28.9%) and β-pinene (3.7–19.5%) were determined as the main components. Overall, the findings demonstrate that A. millefolium genotypes can be successfully cultivated under field conditions and that materials collected from natural populations possess strong potential for sustainable and economically viable production. The Yalvaç-Kozluçay showed higher performance in terms of fresh flower yield than 30 genotypes and in terms of essential oil content than 28 genotypes. This study provides a scientific foundation for the industrial utilization, quality standardization, future adaptation studies, and breeding programs of yarrow.

Yerli ve Yabancı Orijinli Civanperçemi (*Achillea millefolium* L.) Genotiplerinin Kültür Koşulları Ortamında Verim ve Kalite Özelliklerinin İncelenmesi

Anahtar Kelimeler
Civanperçemi,
Achillea millefolium,
Genotip,
Verim,
Kalite,
Kamazulen

Öz: Bu araştırma, 3 adet yerli ve 60 adet yabancı orijinli *Achillea millefolium* L. genotiplerinin Isparta ekolojik koşullarında verim ve kalite özelliklerini belirlemek amacıyla 2023 yılında yürütülmüştür. Tüm genotipler, 100 × 30 cm'lik bir dikim normunda, 3 m'lik blok uzunluğunda ve 3 sıra halinde dikilmiştir. Çalışmada çiçeklenme süresi 10–41 gün, bitki boyu 21.8–72.0 cm, çiçek çapı 4.3–15.5 cm ve çiçekçik sayısı 26.0–419.0 adet/kapitulum arasındadır. Taze çiçek verimi 246.9–2829.7 kg/da, kuru çiçek verimi ise 82.6–1017.7 kg/da aralığında ölçülmüş ve PI 439888, PI 661151 ve PI 439892 genotipleri yüksek verim potansiyeliyle dikkat çekmiştir. Uçucu yağ oranları %0.05-0.50 arasında değişmiştir. Taze herba ve uçucu yağ verimi ile uçucu yağ oranı ve rengine göre seçilen 10 genotip ve yerli genotiplerde; 1,8-sineol (%3.1–22.4), borneol (%2.5–18.3), kamfen (%1.8–12.7), α-pinen (%4.2–28.9) ve β-pinen (%3.7–19.5) ana bileşenler olarak belirlenmiştir. Sonuçlar, *A. millefolium* genotiplerinin kültür koşullarında başarıyla yetiştirilebildiğini ve doğal popülasyonlardan kültüre alınan materyalin sürdürülebilir ve ekonomik bir üretim potansiyeline sahip olduğunu göstermektedir. Yalvaç-Kozluçay taze çiçek verimi bakımından 30 genotipten ve uçucu

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yağ oranı bakımından 28 genotipten daha yüksek bir performans gösterdi. Bu çalışma, civanperçeminin endüstriyel kullanımı, kalite standardizasyonu ve gelecekte yürütülecek adaptasyon ve ıslah çalışmalarına bilimsel temel oluşturmaktadır.

1. Introduction

The genus *Achillea* (2n=2x=18) belongs to the family Asteraceae and comprises over 130 species of perennial herbaceous plants native to the Northern Hemisphere, from Europe to Asia, growing in temperate, dry, or semi-arid environments [1]. The best-known and most widespread species is *A. millefolium* L. The flowers and leaves of yarrow are used, but the active compounds are mostly found in the flowers. The essential oils and secondary metabolites such as phenolic compounds obtained from the flowers exhibit various pharmacological effects. These effects include spasmolytic, antidiabetic, cholagogue, antitumor, antioxidant, antifungal, anti-inflammatory, analgesic, hemostatic, antiseptic, and hepatoprotective activities [2-8]. Yarrow essential oil can be found in herbal pharmacies as tinctures and capsules containing dried flowers or aerial plants [9]. Yarrow essential oil can be used as an infusion or alcoholic extract, decoction, hydroalcoholic, methanol, and aqueous extract [10].

Yarrow exhibits a complex structure as a result of evolutionary processes associated with cross-pollination, polyploidy, and different habitat types [11]. The presence of autopolyploids and allopolyploids representing four different ploidy levels (2x, 4x, 6x, and 8x) is common, and genetic diversity analyses have revealed significantly higher polymorphism in polyploid species compared to diploid species [12, 13]. Gene flow with other yarrow species (*A. crithmifolia, A. nobilis, A. clypeolata, A. coarctata*) can also result in a wide range of morphologically and chemically heterogeneous hybrid individuals [14-16]. Since different species and plants with and without proazulene can grow side by side in the same habitat and considering their pollination potential, the raw drug source plants of *herba millefolii* will be quite heterogeneous in many respects.

Yarrow flowers contain 0.1-3.5% essential oil. The components of yarrow essential oil consist of 90% monoterpene molecules. However, the chemical composition of the oil depends on the chromosome number. Diploid and tetraploid plants contain proazulene sesquiterpenes, which are mostly converted to chamazulene (up to 25%) upon distillation. The main compounds found in hexaploidy plants are camphor (18%), sabinene (12%), 1,8-cineole (10%), etc. The main component found in octoploid plants is linalool [17]. Furthermore, phytochemical analysis of essential oil is an important characterization tool. It has been proven that focusing on specific mono- and sesquiterpenes alone is sufficient to distinguish between species [18].

Chamazulene ($C_{14}H_{16}$), a bicyclic sesquiterpenoid polyalkene compound, is found in a limited number of plant structures worldwide. Chamazulene is not a natural product derived from plants; after formation in the plant matrix in the presence of water and acetic acid under heat, it is decarboxylated to form chamazulene carboxylic acid (CCA), the direct precursor of chamazulene. Chamazulene imparts a blue color to the essential oil, depending on its concentration. At low concentrations, the essential oil produces a light blue color, while at high concentrations, it produces a dark blue color [19]. The most widely produced plant worldwide as a source of chamazulene is German chamomile (*Matricaria chamomile* L.). On the other hand, other plants containing camomile include Roman chamomile (*Chamaemelum nobile* L.), blue tansy (*Tanacetum annuum* L.), Scots pine (*Pinus sylvestris* L.), wormwood (*Artemisia arborescens* L.), and Northern Cyprus pine (*Callitris intratropica* L.). Chamazulene can be used in cosmetics such as skin and hair care products due to its anti-inflammatory and antioxidant properties; in aromatherapy mixtures due to its stress-reducing and soothing properties; as a flavoring and colorant in food products; in medicine for the treatment of respiratory disorders such as asthma, bronchitis, and allergic reactions; and in agricultural products as a natural pesticide [19].

Genetic diversity is crucial for the sustainability of plant populations. Understanding the genetic diversity within yarrow species requires genetic conservation programs aimed at preventing the extinction of some species, genetic improvement studies, improvement of germplasm collections, and evaluation of the evolutionary processes of endangered species [20]. In a study conducted in Bulgaria, chemical analyses of yarrow plant samples grown in culture and collected from the wild revealed very similar content values, suggesting that culturing the plant is an important step for producing high-quality drugs [21]. However, as with many aromatic plant species, variation in essential oil composition can vary depending on environmental conditions such as chemotype, ecotype, altitude and temperature, photoperiod, relative humidity, and radiation [22]. In this study, it was aimed to investigate the adaptation abilities of 60 foreign yarrow (*A. millefolium*) genotypes collected by USDA from different countries and 3 local (*A. millefolium*) genotypes collected from Isparta region in terms of yield and quality traits as well as environmental conditions in Isparta.

2. Material and Method

2.1. Climate and soil characteristics of the research area

Some climate data for the year 2023, when the trial was conducted, are given in Table 1. According to climate data for 2023, no adverse temperature events affecting plant growth and development were observed (especially during the March-August period). On the other hand, from 2021, when the seedlings were planted, until 2023, when the trial was conducted, no adverse climate was experienced for the plants. In 2023, when the trial was conducted, a total of 131.1 mm of precipitation fell in January and February, when the plants were in the dormant period, 302.0 mm from the vegetative period to the flowering time (early March-end of June), and 55.3 mm in June and July, when the flowering time was. On the other hand, the average monthly temperatures during the flowering time (June-July) were measured as 20.1 °C and 25.8 °C, respectively (Table 1) [23]. The soil properties of the research area were determined according to the method recommended by [24]. The soil texture was determined to be clayey-loam, the organic matter content was 1.1% by the Walkley-Black method, the lime content was 7.20% by the Schiebler calcimeter, the salt content was 0.38%, the available phosphorus was 3.9 mg/kg, and the available potassium was 119.0 mg/kg in 1N NH_4OAc. On the other hand, the soil pH was determined to be slightly acidic (pH 6.5). The soil of the trial area, although slightly acidic and low in organic matter, was suitable for yarrow.

Table 1. Climate values of Isparta province for 2023 and many years

Months	Precipitation, L m²		Temperature, °C		Humidity, %	
	1950–2023	2023	1950–2023	2023	1950–2023	2023
January	81.4	125.3	1.8	5.4	75.2	73.3
February	67.5	5.8	3.0	3.6	71.5	59.3
March	59.0	73.8	6.0	9.1	65.8	67.1
April	51.4	69.9	10.8	10.8	61.1	65.0
May	56.5	111.0	15.5	15.5	59.9	71.7
June	35.7	47.3	19.9	20.1	52.9	65.8
July	15.5	8.0	23.5	25.8	45.4	40.2
August	14.0	3.1	23.4	27.3	46.2	43.1
September	18.6	29.1	18.9	21.7	52.0	47.0
October	37.5	9.7	13.4	16.7	62.1	56.5
November	44.4	53.3	7.9	11.9	69.8	73.8
December	86.0	46.3	3.7	7.7	76.0	79.0
Sum	**567.5**	**582.6**	**-**	**-**	**-**	**-**
Average	**-**	**-**	**12.3**	**14.6**	**61.4**	**61.8**

2.2. Material

Field trials (37°45’ N and 30°33’ E, 997 m) and laboratory analyses of the study were carried out in 2023 at the Department of Field Crops of the Faculty of Agriculture of Isparta University of Applied Sciences. The study used three yarrow genotypes distributed in the flora of Isparta (Kozluçay-Yalvaç, Akpınar-Aksu, Diktaş-Yenişarbademli) and 60 yarrow genotypes provided by the USDA Regional Plant Identification Station (Pulman, WA) as material. The identification of the collected plants was made by Prof. Dr. Hüseyin FAKİR, a faculty member of the Faculty of Forestry of Isparta University of Applied Sciences.

2.3. Method

Yarrow seeds obtained from the USDA (United States Department of Agriculture) gene bank were sown in seedling trays in March 2022 and germinated under greenhouse conditions to produce seedlings. In addition, semi-hardwood cuttings collected from natural populations in the flora of Isparta in April 2022 were rooted under greenhouse conditions (70% relative humidity and 30 °C temperature). For rooting, 1000 ppm indole-3-butyric acid (IBA) was applied, and the cuttings were planted in a peat–perlite medium.

Seedlings obtained from seeds and rooted cuttings collected from natural populations were transplanted at the end of May 2022 into the experimental area of the Field Crops Department, Faculty of Agriculture, Isparta University of Applied Sciences. The experimental plots were established with a spacing of 100 × 30 cm, consisting of three rows per plot and a plot length of 3 m. All genotypes were cultivated under field conditions for one year, during which routine agronomic practices such as weed control, fertilization, and irrigation were applied. Weed control was performed mechanically.

A drip irrigation system was installed during planting, and irrigation was applied for 2 hours every 20 days during the summer period to reduce heat stress. In the first year, 5 kg P_2O_5 per decare was applied as

diammonium phosphate (DAP), and 5 kg N per decare was applied as ammonium sulfate (AS). In 2023, DAP fertilizer was applied in February, while AS fertilizer was applied at the beginning of the bolting stage (late April–early May).

In 2023, the genotypes were harvested at the mid-flowering stage. The plants were evaluated for flowering time (days), plant height (cm), flower diameter (cm), number of florets (number per capitulum), fresh flower yield (kg/da), dry flower yield (kg/da), essential oil content (%), essential oil yield (kg/da), and essential oil composition (%).

For the determination of essential oil content, 200 g of fresh yarrow flowers were placed in a 5 L round-bottom flask connected to a Clevenger-type hydrodistillation apparatus. Subsequently, 1.5 L of distilled water was added, and the samples were subjected to hydrodistillation for 3 h. The essential oil content was calculated as % (w/v) [25].

The essential oil composition was analyzed using a GC–MS system (Shimadzu 2010 coupled with a QP-5050 quadrupole detector) at the Süleyman Demirel University Innovative Technologies Research and Application Center Laboratory. GC–MS analyses were performed using a CP-Wax 52 CB capillary column (50 m × 0.32 mm × 0.25 µm). The oven temperature program was set from 60 °C to 220 °C at a rate of 10 °C/min and held at 220 °C for 10 min. The total analysis time was 60 min. The injector temperature was set at 240 °C and the detector temperature at 250 °C. Helium was used as the carrier gas at a flow rate of 2 mL/min with a split ratio of 1:20. Identification of essential oil components was carried out by comparing mass spectra with those in the Wiley, NIST, Tutor, and FFNSC libraries. The mean values and standard errors of the obtained data were calculated using the SAS® statistical software [26].

3. Results and Discussion

The average agronomic and quality traits of yarrow genotypes of domestic and foreign origin are presented in Table 2. Among the genotypes, the shortest flowering time was recorded as 10 days for the genotype coded W6 36805, while the longest flowering time was recorded as 41 days for the genotype coded W6 50082. When the flowering times of the genotypes were evaluated, it was determined that 19 genotypes had a flowering time of 10–20 days, 5 genotypes had a flowering time of 20–30 days, and 4 genotypes had a flowering time of 30–41 days. While the genotypes numbered W6 32806 (30.04.2023), W6 48672 (13.05.2023) and W6 50041 (17.05.2023) were the earliest flowering genotypes, the genotypes numbered W6 49102, (04.07.2023), PI 439889 (22.06.2023) and PI 439892 (22.06.2023) were determined to be the latest flowering genotypes. On the other hand, it was determined that the cultivated Kozluçay-Yalvaç genotype had a flowering period of 15 days (22.05.2023-07.07.2023), the Akpınar-Aksu genotype had a flowering period of 19 days (18.06.2023-06.07.2023), and the Diktaş-Yenişarbademli genotype had a flowering period of 18 days (18.05.2023-05.06.2023) (Table 2). The flowering period (the time from the beginning of inflorescence formation to seed shed) of yarrow was reported to be relatively long. This period was determined to be approximately 165 days in central mountainous regions and approximately 140 days in high subalpine areas. It was reported that seed formation, where it begins at full bloom, lasted 50 days in low subalpine areas and 20 days in high subalpine areas. Yarrow exhibits a high degree of polymorphism due to high rates of cross-pollination, which allows for the emergence of plants with different ploidy levels [13]. Therefore, the heterogeneity in flowering times of the *A. millefolium* genotypes used in our study is thought to be due to different ploidy levels. On the other hand, when the flowering dates of native genotypes are examined, it is generally observed that they begin flowering in mid-May. This indicates that the native populations are well adapted to the climatic conditions of the region.

The average plant height distribution across genotypes was mostly concentrated between 41.0 and 80.0 cm. Six genotypes had plant heights between 20 and 40 cm, 29 genotypes between 41 and 60 cm, and 16 genotypes between 61 and 80 cm. The local genotypes Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli had average plant heights of 42.5, 48.3 and 44.7 cm, respectively. In studies conducted with yarrow species, different results were obtained from different locations (Table 2). Nadim et al. [27] reported the plant height of yarrow plant as 82.30±1.53 cm under tropical climate conditions, Baczek et al. [28] reported the plant height of 20 different yarrow genotypes collected from eastern Poland to be between 65.2-93.2 cm and Giorgi et al. [29] reported that the plant height of yarrow plant varied between 54.0-77.0 cm at different altitudes in the Central Italian Alps. On the other hand, Pouyanfar et al. [30] investigated the plant height of yarrow at four different planting times (March 6, March 26, April 14, and May 5) and different planting norms (30 x 30 cm, 20 x 20 cm, and 15 x 15 cm). They reported that plant height decreased with delay in planting time, with the maximum plant height (139.3 cm) being obtained at the 20 x 20 cm planting norm. The shortest plant height was observed at the 30 x 30 cm planting norm (66.8 cm). The fact that local genotypes have shorter plant heights compared to some foreign genotypes can be considered an advantageous trait, especially in agricultural production, in terms of lodging resistance and ease of harvesting. Our findings are similar to the plant height variations reported by the above researchers. The differences are thought to be due to differences in climate, soil, genetic material, and harvest time.

The smallest flower diameter was determined as 4.3 cm in the genotype coded W6 36884 and the highest as 15.5 cm in the genotype coded PI 439892. The local genotypes Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli had average flower diameters of 9.9, 7.9 and 11.7 cm, respectively (Table 2). Flower diameter in yarrow may vary throughout the phenological development stage. In previous studies, the flower diameter of yarrow, which began bud formation on March 20, was determined to be 7.0 cm in June, 8.1 cm in July, 8.5 cm in August, 9.0 cm in September, 9.4 cm in October, 10.0 cm in November, 7.0 cm in December, and 5.0 cm in January [31]. Furthermore, they reported that flower diameters varied between 4.0 and 4.8 cm at different planting times and planting standards. In our study, a wide variation was detected among yarrow genotypes, with some genotypes having higher flower diameters than those reported in the studies mentioned above.

The number of florets per capitulum of the genotypes ranged from 26.0 to 419.0 florets per capitulum (W6 36884-W6 47355). The local genotypes Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli had average number of florets per capitulum of 157.4, 162.4 and 167.8, respectively (Table 2). The inflorescence of yarrow consists of small capitulums in dense corymbous clusters, an involucre consisting of phyllaries, flower buds surrounding each capitulum, and receptacles. The capitulums are numerous and arranged in unequal compound panicles, and their diameters are reported to range from 2 to 15 cm [32, 33]. Bostock and Benton [34] reported that the number of florets per capitulum in yarrow was 149.4/capitulum. These findings indicate that yarrow genotypes exhibit a wide morphological diversity in terms of floret number. In our study, a relatively wide variation was obtained among the yarrow genotypes. The number of florets per capitulum in local genotypes is higher than in many foreign genotypes, which can be considered a significant advantage in terms of floral biomass and potential essential oil production.

Average fresh flower yield of local and foreign yarrow genotypes varied between 246.9 kg/da and 2829.7 kg/da (W6 37296-PI 439888). 16 genotypes with yields ranging from 200-500 kg/da, 15 genotypes with yields ranging from 500-1000 kg/da, 9 genotypes with yields ranging from 1000-1500 kg/da, 6 genotypes with yields ranging from 1500-2000 kg/da and 5 genotypes with yields ranging from 2000-2500 kg/da were identified. The local genotypes Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli had average fresh flower yield of 915.4, 812.4 and 760.5 kg/da, respectively (Table 2). In medicinal and aromatic plants, the highest active substance yield is achieved by harvesting the drug containing the active substance. Furthermore, a high concentration of the drug ensures a higher active substance harvest. The organs of yarrow containing the highest active substance concentration are the flowers. It has been reported that higher active substance yields can be achieved as flower yield increases [29]. A study conducted in Italy found fresh flower yields ranging from 536.0 to 1044.0 kg/da at five different locations. On the other hand, Aziz et al. [35] reported that the fresh herb yield of yarrow, harvested four times a year in Egypt, was 40.00 g/plant in the first harvest, 47.53 g/plant in the second harvest, 83.73 g/plant in the third harvest, and 79.30 g/plant in the final harvest in the first year. In the second year, the fresh herb yield was 40 g/plant in the first harvest, 114.20 g/plant in the second harvest, 58.77 g/plant in the third harvest, and 32.10 g/plant in the final harvest. Nadim et al. [27] reported the fresh flower weight of yarrow plants under tropical climate conditions as 312.55 g/plant. A wider variation in fresh flower yield was observed in our study. Although the yield values of local genotypes were lower than some high-yielding foreign genotypes, they were found to be stable and acceptable for commercial production. This indicates that local genotypes have a high level of adaptation to regional ecological conditions.

Dried flower yields of local and foreign yarrow genotypes varied between 82.6-1017.7 kg/da (W6 50082-PI 661151). When the dry flower yields were classified numerically, 13 genotypes ranged between 80-150 kg/da, 6 genotypes ranged between 250-350 kg/da, 2 genotypes ranged between 350-450 kg/da, 5 genotypes ranged between 450-550 kg/da, and 7 genotypes with yields of 550 kg/da and above. The local genotypes Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli had average dry flower yields of 235.8, 191.6 and 209.5 kg/da, respectively. In general, dry flower yields are concentrated below 350 kg/da (Table 2). A wide variation in dry flower yields has been observed in studies on yarrow worldwide. Tatar et al. [36] reported that the dry matter content in populations originating from Turkey was between 26.9 and 39.2%. Aziz et al. [35] reported that the dry herb yield of yarrow harvested four times a year in Egypt was 10.50 g/plant in the first harvest, 15.10 g/plant in the second harvest, 35.33 g/plant in the third harvest, and 28.20 g/plant in the last harvest in the first year. In the second year, 10.93 g/plant in the first harvest, 35.20 g/plant in the second harvest, 18.77 g/plant in the third harvest, and 11.10 g/plant in the last harvest. Scheffer et al. [37] reported that organic fertilizer applications to Yarrow significantly increased the plant's biomass production, from 46.94 kg/da to 133.60 kg/da. A wider variation in dried flower yield was observed in our study. The higher dried flower yields among genotypes are thought to be due to differences in climate, soil, and genetics.

The lowest essential oil content of local and foreign yarrow genotypes was determined as 0.05% in W6 49102, W6 38959, PI 439889 and PI 439892, and the highest oil content as 0.50% in genotype W6 46211. Of the local genotypes, the Kozluçay-Yalvaç was

determined to have essential oil content of 0.21%, the Akpınar-Aksu as 0.22%, and the Diktaş-Yenişarbademli as 0.21% (Table 2). The European Pharmacopoeia prescribes *millefolii herba* as having an essential oil content of at least 0.2% [38]. In our study, the essential oil content of 27 genotypes was determined to be below 0.2%, while the other genotypes met the European Pharmacopoeia standard. On the other hand, the local genotypes also exhibited values above the European Pharmacopoeia standard. Numerous studies have been conducted on the essential oil content of yarrow in both natural flora and cultivated media worldwide. In a study comparing seven different subspecies of yarrow collected from the natural flora in the Czech Republic, reported that dry samples contained essential oil between 0.05-0.88% [38]. Gudaityt and Rimantas [39] reported that yarrow flowers collected from 14 locations in the Lithuanian flora contained 0.15-0.55% essential oil, and leaves contained 0.06-0.19%. Rahimmaleka et al. [40] reported that the essential oil content in yarrow samples collected from 10 provinces of Iran varied between 0.15-0.63%. Nadim et al. [27] detected 0.70% essential oil in fresh flowers of yarrow plant under tropical climate conditions. Baczek et al. [28] detected the essential oil content of β-pinene type genotypes between 0.30-1.00%, β-pinene+chamazulene type genotypes between 0.37-0.60%, 1,8-cineole type genotypes between 0.30-1.00% and other genotypes between 0.10-0.43% in 20 different yarrow varieties collected from eastern Poland. The essential oil content of *A. millefolium* subsp. *millefolium*, which is distributed in Turkey was determined as 0.60-0.80% [41, 42]. Bayram et al. [41] reported that the essential oil content varied between 0.15% and 0.78% over two years, and Aziz et al. [35] found the lowest at the first harvest (0.67%) and the highest at the third harvest (0.86%). The essential oil content obtained in our study falls within the variation range of the above studies. Yarrow exhibits high polymorphism due to cross-pollination and polyploidy, and therefore its essential oil content is reported to vary depending on chromosome folding [11-13].

The essential oil yields of the foreign genotypes ranged from 0.21 to 12.12 kg/da (W6 50096, PI 439889, PI 439892- PI 661151). A total of 20 genotypes were found to have oil yields below 1.00 kg/da. The PI 661151 (2678.1 kg/da and 0.45%, respectively), W6 48203 (1905.7 kg/da and 0.37%, respectively) and W6 41862 (1589.2 kg/da and 0.46%, respectively) had high fresh flower yield and essential oil yield (12.14, 7.11 and 7.26 kg/da, respectively). Essential oil yields of the PI 439888 (2829.7 kg/da), W6 38958 (2634.2 kg/da), W6 37298 (2346.4 kg/da), W6 32806 (2188.1 kg/da), W6 49101 (1848.1 kg/da), W6 49330 (1763.6 kg/da), W6 37295 (1767.2 kg/da) and W6 26974 (1615.5 kg/da) were found to be high due to their high fresh flower yields. In addition, it was observed that the essential oil yield of the W6 48672 (0.34%) was high due to its high essential oil content. However, the W6 41863 (0.51%), W6 46211 (0.50%), W6 44271 (0.43%), W6 37202 (0.35%), and W6 46469 (0.35%), which have high essential oil content, yielded lower essential oil due to lower fresh flower yields. The essential oil yield of Kozluçay-Yalvaç was determined as 1.92 kg/da, in Akpınar-Aksu as 1.79 kg/da, and in Diktaş-Yenişarbademli as 1.60 kg/da. High essential oil content and fresh flower yield are required for yarrow oil production. Research has yielded the following results regarding oil yield. Aziz et al. [35] reported that the essential oil yield from yarrow flowers harvested in four harvests in Egypt between 2007 and 2009 was 0.741, 1.894, 4.308, and 4.014 L/ha in the first year, giving a total of 10.957 L/ha, and 0.906, 4.011, 2.406, and 1.571 L/ha in the second year, giving a total of 8.894 L/ha. On the other hand, Nadim et al. [27] reported that 2.18 g of essential oil per plant was obtained from yarrow plants under tropical climate conditions. In our study, it was observed that some genotypes yielded higher essential oil than the studies conducted above. These differences are thought to be due to differences in climate, soil, and genetics.

Essential oil components of yarrow genotypes are presented in Table 3. In our study, essential oil components of 10 genotypes (W6 38957, W6 49101, W6 37202, W6 46211, W6 44271, W6 46469, W6 41863, W6 38959, PI 439895 and PI 371687) and local genotypes were analysed, especially by selection based on fresh flower yield, essential oil content and color and essential oil yield. Of these genotypes, W6 37202, W6 46211, W6 44271, W6 46469 and W6 41863 have high essential oil content, W6 49101 has high fresh flower yield and essential oil yield, and the other genotypes have dark blue oil color. The main essential oil components of the genotypes were sabinene, camphene, 1,8-cineole, yomogi alcohol, artemisia alcohol, camphor and chamazulene. Sabinene contents varied between 0.00-11.23% and the highest were determined in genotypes W6 46469 (11.23%), W6 49111 (11.03%) and PI 439895 (6.64%). While the highest camphene content was determined in genotype W6 46469 (14.61%), it varied between 0.00-4.28% in other genotypes. The highest 1,8-cineole content was determined in W6 46469 with 24.04% and this was followed by PI 439895 with 17.63%, W6 41863 with 16.96% and W6 38957 with 14.07%. While yomogi alcohol was not determined in W6 38957, W6 46469 and PI 371687, it was determined as 26.68% in W6 49101, 10.14% in W6 46211 and 9.90% in W6 41863. Camphor content showed a wide variation and was not detected at all in PI 371687, while the highest was found at 36.53% in W6 38957. This genotype was followed by W6 37202 with 25.66% and W6 38959 with 16.68%.

Among the genotypes, chamazulene was detected in all except W6 49101. The highest chamazulene content was determined in PI 371687 with 53.42%, while it varied between 0.59-7.41% in other

genotypes. The main component in W6 46211, W6 44271 and W6 41863 was determined as terpinene 4-ol (24.20, 25.70 and 24.60%, respectively). Apart from the above components, the W6 38957 contained 6.29% nerolidol, the W6 49101 contained 12.03% 1-(1-methoxyethyl)-6-oxabicyclohexane and 21.05% artemisia alcohol, the W6 37202 contained 8.09% terpinen 4-ol, the W6 46211 contained 6.82% *trans*-sabinene hydrate and 6.42% γ-terpinene, the W6 44271 contained 8.80% *trans*-sabinene hydrate and 5.69% γ-terpinene, the W6 46469 contained 5.77% γ-terpinene, the W6 38959 contained 6.59% germacrene D, 5.65% bornyl acetate and 4.29% borneol, In the PI 439895, 5.06% α-terpineol and 5.23% germacrene D and finally in the PI 371687, 23.09% guaiole, 7.99% 10-epi-γ-eudesmol, 7.97% germacrene D and 5.60% δ-guanine compounds were found. The essential oil components of the domestic genotypes were similar. The main component of the essential oils was determined as 1,8-cineole (47.89%, 50.28% and 48.95%, respectively). The other main component of the essential oils is camphor (11.29%, 11.85% and 12.45%, respectively). Other high-concentration compounds were identified as α-terpineol, lavandulyl acetate, p-cymene, benzaldehyde, sabinene, and β-pinene (Table 3).

Among the genotypes, chamazulene was detected in all except W6 49101. The highest chamazulene content was determined in PI 371687 with 53.42%, while it varied between 0.59-7.41% in other genotypes. The main component in W6 46211, W6 44271 and W6 41863 was determined as terpinene 4-ol (24.20, 25.70 and 24.60%, respectively). Apart from the above components, the W6 38957 contained 6.29% nerolidol, the W6 49101 contained 12.03% 1-(1-methoxyethyl)-6-oxabicyclohexane and 21.05% artemisia alcohol, the W6 37202 contained 8.09% terpinen 4-ol, the W6 46211 contained 6.82% *trans*-sabinene hydrate and 6.42% γ-terpinene, the W6 44271 contained 8.80% *trans*-sabinene hydrate and 5.69% γ-terpinene, the W6 46469 contained 5.77% γ-terpinene, the W6 38959 contained 6.59% germacrene D, 5.65% bornyl acetate and 4.29% borneol, the PI 439895, 5.06% α-terpineol and 5.23% germacrene D and finally in the PI 371687, 23.09% guaiole, 7.99% 10-epi-γ-eudesmol, 7.97% germacrene D and 5.60% δ-guanine compounds were found. The essential oil components of the genotypes collected from Kozluçay-Yalvaç, Akpınar-Aksu and Diktaş-Yenişarbademli locations were similar. The main component of the essential oils was determined as 1,8-cineole and was found at the contents of 47.89%, 50.28% and 48.95%, respectively. The other main component of the essential oils is camphor and was determined at the contents of 11.29%, 11.85% and 12.45% in the genotypes, respectively. Other high-concentration compounds were identified as α-terpineol, lavandulyl acetate, p-cymene, benzaldehyde, sabinene, and β-pinene (Table 3).

Yarrow species exhibit high polymorphism due to cross-pollination and polyploidy, and there are autopolyploid and allopolyploid species representing four different ploidy levels (2x, 4x, 6x, and 8x) [11-13]. The chemical composition of the essential oil varies with variation in ploidy levels. The essential oils of diploid and tetraploid plants contain mostly proazulene sesquiterpenes, which are converted to chamazulene (up to 25%), while hexaploid plants contain camphor (18%), sabinene (12%), and 1,8-cineole (10%). compounds, and octaploid plants contain linalool [17]. In addition, it is reported that the main terpenes of proazulene-positive species (*A. aspleniifolia, A. roseo-alba, A. ceretanica, A. collina*) are sabinene, β-pinene and β-caryophyllene, while for species that do not contain proazulene, it is especially 1,8-cineole and camphor, followed by compounds such as α-pinene, camphene, p-cymene, γ-terpinene, α- and β-thuone, borneol, α-terpineol, bornyl acetate, eudesmol and elemol [42-44].

In genotypes containing high camphor and 1,8-cineole (W6 38957, W6 37202, W6 46211, W6 46469 and W6 41863), chamazulene was found at very low or absent levels. However, no chamazulene was detected in species containing yomogi alcohol and artemisia alcohol. On the other hand, only 7 compounds were identified in the high chamazulene containing PI 371687 (53.42%) and as mentioned above, this genotype contains high levels of 10-epi-γ-eudesmol. It was determined that local genotypes are quite rich in 1,8-cineole. The 1,8-cineole content was determined as 47.89% in Kozluçay-Yalvaç, 50.28% in Akpınar-Aksu, and 48.95% in Diktaş-Yenişarbademli. These values are significantly higher than many foreign genotypes. This indicates that local populations form a 1,8-cineole chemotype. Similar or different results were obtained with yarrow essential oil in our study. Anne et al. [1] determined that the main components in the oil obtained from dry yarrow flowers were β-pinene (14.0-29.2%), sabinene (2.9-17.6%), 1,8-cineole (6.9-18.3%), β-caryophyllene (3.3-6.2%) and chamazulene (0.1-13.3%). Shawl et al. (2002) determined camphor with 28%, germacrene-D with 12% and 1,8-cineole with 2% in yarrow oil. Mockute and Judzentiene [45] classified 40 yarrow oils collected from 21 locations in Lithuania into four groups and reported that group 1 contained borneol and camphor, group 2 chamazulene and β-pinene, group 3 trans-nerolidol and β-pinene, and group 4 β-pinene and 1,8-cineole. Gudaityt and Rimantas [39] reported the presence of β-pinene (0.33-62.29%), β-myrcene (0.05-69.76%), α-phellandrene (0.13-29.96%), 1,8-cineole (2.30-21.57%), and chamazulene (0.08-30.70%) in yarrow flowers collected from 14 locations in the Lithuanian flora. In studies conducted in our country, Karamenderes et al. [2] reported that there was no chamazulene molecule in the essential oils obtained from *A. millefolium* spp. *pannonica* and *A. millefolium* spp. *millefolium* species in their natural distribution areas in Turkey.

Table 2. Agronomic and quality characteristics of yarrow genotypes of domestic and foreign origin

Genotype	Flowering			Plant height (cm)	Flower diameter (cm)	Number of florets per capitulum	Fresh flower yield (kg/da)	Dry flower yield (kg/da)	Essential oil content (%)	Essential oil yield (kg/da)
	Duration (days)	Beginning	Ending							
W6 45879	17	05.06.2023	22.06.2023	53.1±7.2	7.0±1.1	152.0±6.6	1061.7±28.3	307.7±14.2	0.13±0.02	1.39±0.27
W6 37299	19	04.06.2023	23.06.2023	62.4±3.1	8.3±0.6	148.3±15.6	1367.0±36.8	533.1±24.9	0.08±0.02	1.04±0.24
W6 48671	20	04.06.2023	24.06.2023	56.8±8.1	10.2±1.3	198.0±0.9	1007.4±21.6	224.7±8.4	0.19±0.03	1.92±0.34
W6 45618	21	04.06.2023	25.06.2023	55.1±4.3	8.0±0.8	124.0±6.1	1246.5±33.2	320.7±14.8	0.13±0.02	1.62±0.26
W6 26974	13	30.05.2023	12.06.2023	64.2±3.3	11.6±1.1	121.7±2.4	1615.5±45.5	417.3±20.3	0.25±0.00	4.09±0.25
W6 46747	13	30.05.2023	12.06.2023	51.8±2.3	7.7±1.0	85.3±5.6	400.5±12.4	96.1±5.2	0.26±0.04	1.03±0.16
W6 50041	16	17.05.2023	02.06.2023	57.7±3.2	7.5±1.2	80.3±2.1	440.5±6.7	161.7±4.3	0.10±0.02	0.44±0.01
W6 40363	20	04.06.2023	24.06.2023	70.1±4.5	9.5±0.2	189.0±13.4	1049.0±28.0	466.2±21.5	0.25±0.04	2.61±0.37
W6 47357	16	24.05.2023	09.06.2023	51.6±6.8	8.1±0.8	87.3±3.5	408.5±10.9	89.9±4.2	0.06±0.02	0.25±0.10
W6 37296	14	01.06.2023	15.06.2023	54.7±5.3	8.0±1.2	44.7±0.7	246.9±6.6	110.0±5.1	0.18±0.02	0.44±0.02
W6 38957	14	01.06.2023	15.06.2023	51.2±3.2	7.8±1.1	107.3±2.6	343.1±10.0	104.3±5.3	0.20±0.01	0.68±0.08
W6 47561	20	04.06.2023	24.06.2023	56.7±3.8	8.3±0.2	90.7±8.1	432.4±12.5	169.9±8.5	0.06±0.00	0.25±0.03
W6 48672	17	13.05.2023	30.05.2023	54.6±5.1	13.2±2.2	199.0±17.0	1264.0±28.6	480.3±18.8	0.34±0.03	4.27±0.49
W6 52709	34	04.06.2023	08.07.2023	54.6±4.3	7.7±0.5	88.3±4.0	611.4±14.8	228.9±9.6	0.12±0.02	0.76±0.15
W6 37295	11	22.05.2023	02.06.2023	69.5±4.7	9.9±0.8	123.3±1.7	1767.2±47.1	648.4±30.0	0.25±0.04	4.34±0.60
W6 49101	40	21.05.2023	30.06.2023	61.3±5.1	8.6±0.6	82.0±0.5	1848.1±49.3	739.2±34.1	0.29±0.06	5.34±1.32
W6 46213	13	02.06.2023	15.06.2023	58.6±3.9	10.3±1.2	150.0±6.1	512.8±16.5	194.6±10.8	0.25±0.01	1.28±0.04
W6 37202	11	22.05.2023	02.06.2023	48.2±3.5	11.1±1.0	108.0±8.5	593.5±6.9	258.7±5.2	0.35±0.04	2.08±0.23
W6 50073	13	18.05.2023	31.05.2023	43.9±5.9	8.0±0.1	75.7±3.8	532.7±14.2	122.5±5.7	0.17±0.01	0.91±0.07
W6 32806	38	30.04.2023	07.06.2023	63.9±3.1	9.8±0.9	154.3±9.7	2188.1±61.6	634.6±30.9	0.12±0.02	2.63±0.41
W6 41861	33	05.06.2023	08.07.2023	63.8±3.9	6.7±0.3	81.3±2.6	629.7±16.8	226.7±10.5	0.21±0.01	1.30±0.12
W6 49330	13	20.06.2023	03.07.2023	67.7±10.9	11.4±2.0	153.3±1.0	1763.6±39.9	529.1±20.7	0.21±0.02	3.77±0.46
W6 48485	13	24.05.2023	06.06.2023	47.5±3.5	6.9±1.9	127.0±8.2	505.5±10.5	131.4±4.7	0.25±0.00	1.28±0.02
W6 50080	15	23.05.2023	07.06.2023	67.0±2.9	7.8±0.8	99.3±0.7	1144.7±30.5	222.9±10.3	0.11±0.01	1.26±0.08
W6 46211	12	23.05.2023	04.06.2023	51.8±5.7	8.4±1.3	97.7±10.9	1258.4±36.8	371.0±18.8	0.50±0.04	6.31±0.35
W6 38958	13	18.05.2023	31.05.2023	63.1±3.9	9.9±0.6	233.3±6.4	2634.2±89.1	226.6±20.23	0.28±0.02	7.29±0.67
W6 44271	13	24.05.2023	06.06.2023	49.8±6.2	8.9±0.3	114.0±5.2	711.3±10.8	270.3±7.1	0.43±0.02	3.03±0.08
W6 36805	10	28.05.2023	07.06.2023	68.6±9.9	8.7±0.5	130.0±6.8	543.4±15.3	163.0±7.9	0.12±0.02	0.65±0.10
W6 47560	21	01.06.2023	22.06.2023	54.4±11.4	5.8±0.2	54.3±10.2	432.5±11.5	144.2±6.7	0.06±0.02	0.26±0.04
W6 49100	16	28.05.2023	13.06.2023	58.9±2.8	7.5±0.5	75.0±2.8	526.7±14.0	179.1±8.3	0.15±0.01	0.79±0.08
W6 48203	15	07.06.2023	22.06.2023	46.2±1.1	7.8±0.6	117.3±6.7	1905.7±50.8	552.4±25.5	0.37±0.02	7.10±0.10
PI 661151	14	18.05.2023	01.06.2023	70.0±12.2	11.4±0.2	132.0±5.7	2678.1±60.6	1017.7±39.9	0.45±0.04	12.12±0.04
W6 36884	13	22.05.2023	04.06.2023	40.0±6.5	4.3±0.1	26.0±6.0	383.9±10.0	128.0±5.8	0.06±0.01	0.22±0.08
PI 678924	26	02.06.2023	28.06.2023	34.9±0.7	8.0±0.8	68.3±5.0	994.8±28.8	314.8±15.8	0.14±0.01	1.43±0.31
W6 37298	13	25.05.2023	07.06.2023	72.0±8.4	10.2±0.6	93.3±0.5	2346.4±62.6	797.8±36.9	0.22±0.01	5.09±0.93

Genotype	Flowering			Plant height (cm)	Flower diameter (cm)	Number of florets per capitulum	Fresh flower yield (kg/da)	Dry flower yield (kg/da)	Essential oil content (%)	Essential oil yield (kg/da)
	Duration (days)	Beginning	Ending							
W6 50096	19	06.06.2023	25.06.2023	44.3±5.8	7.4±0.3	75.3±4.5	346.3±10.9	107.4±5.8	0.06±0.02	0.21±0.04
W6 49102	17	04.07.2023	21.07.2023	39.6±5.3	8.2±0.8	57.7±7.3	504.9±7.7	201.5±5.3	0.05±0.00	0.24±0.01
W6 46469	13	24.05.2023	06.06.2023	53.9±2.8	7.8±0.4	105.0±2.8	701.1±18.7	285.2±13.2	0.35±0.04	2.44±0.34
W6 50082	41	18.05.2023	28.06.2023	48.1±1.5	7.6±0.5	81.7±0.3	344.2±9.2	82.6±3.8	0.12±0.02	0.41±0.07
W6 41862	18	18.06.2023	06.07.2023	61.8±6.4	10.4±0.2	151.3±13.7	1589.2±46.5	473.6±24.0	0.46±0.03	7.28±0.82
W6 35210	12	26.05.2023	07.06.2023	49.2±4.2	9.2±0.3	84.0±6.1	481.6±13.9	110.8±5.5	0.26±0.01	1.27±0.12
W6 41863	18	30.05.2023	17.06.2023	60.3±13.2	6.4±0.5	113.0±4.2	466.1±12.4	167.1±7.7	0.51±0.02	2.38±0.16
W6 38959	24	06.06.2023	30.06.2023	33.8±4.0	7.3±0.5	379.0±17.4	618.6±15.7	224.2±9.9	0.05±0.01	0.31±0.06
W6 47355	18	03.06.2023	21.06.2023	21.8±4.5	7.7±0.6	419.0±9.0	1072.4±22.3	249.4±9.0	0.10±0.01	1.11±0.17
PI 439888	22	15.06.2023	07.07.2023	68.0±3.2	10.4±0.6	85.0±0.9	2829.7±75.5	764.0±35.3	0.16±0.02	4.51±0.25
PI 439896	12	03.06.2023	15.06.2023	47.0±2.9	8.0±0.5	368.0±8.5	462.4±13.5	127.8±6.5	0.11±0.01	0.52±0.04
PI 439889	15	22.06.2023	07.07.2023	46.3±2.6	8.3±0.5	272.3±1.2	383.3±12.3	92.0±5.1	0.05±0.02	0.21±0.06
PI 439891	17	03.06.2023	20.06.2023	63.6±2.4	6.7±0.3	121.0±6.2	603.3±7.0	161.4±3.2	0.12±0.00	0.73±0.11
PI 439892	20	22.06.2023	12.07.2023	49.7±7.5	15.5±0.7	86.7±3.6	457.9±12.2	100.7±4.7	0.05±0.01	0.21±0.02
PI 439895	13	06.06.2023	19.06.2023	44.7±3.8	12.5±0.5	286.3±13.4	439.4±12.4	114.2±5.6	0.22±0.01	0.95±0.04
PI371687	15	06.06.2023	21.06.2023	39.4±3.5	10.3±0.5	287.3±13.4	793.1±21.2	215.7±10.0	0.20±0.01	1.56±0.17
Kozluçay-Yalvaç	15	22.05.2023	07.07.2023	42.5±2.9	9.9±1.1	157.4±9.1	915.4±42.7	235.8±22.7	0.21±0.02	1.92±0.32
Diktaş-Yenişarbademli	18	18.05.2023	05.06.2023	44.7±2.7	11.7±0.9	167.8±8.9	760.5±19.3	209.5±13.9	0.21±0.03	1.60±0.23
Akpınar-Aksu	19	18.05.2023	06.06.2023	48.3±3.7	9.7±0.4	162.4±7.4	812.4±38.2	212.3±18.8	0.22±0.01	1.79±0.31

Table 3. Essential oil components of yarrow genotypes of domestic and foreign origin

RT	Bileşenler	1	2	3	4	5	6	7	8	9	10	11	12	13
7.78	α-Pinene	1.92	0.79	0.92	1.47	0.72	5.53	1.30	0.21	0.83		2.45	2.21	1.99
8.22	Camphene	4.28	0.77	1.71	1.21	0.45	14.61	0.84	0.59	0.70		1.71	1.80	2.12
8.67	β-Pinene	1.51		2.61	0.57	0.35	3.50	0.60	0.89	2.49		2.99	2.84	2.98
8.73	Sabinene	4.85	11.03		3.31	2.50	11.23	4.97	0.89	6.64				
9.03	β-Myrcene	0.22					0.44		1.89	1.93			0.19	0.25
9.46	α-Terpinene		0.50	1.26	2.78	2.33	1.05	2.86	0.47			0.41		
9.73	*dl*-Limonene	0.99		0.43	0.32	0.32	1.94	0.32	0.65					
9.88	Benzaldehyde											3.33	3.50	3.67
10.02	1,8-Cineole	14.07	4.66	11.87	10.63	10.74	24.02	16.96	10.48	17.63		47.89	50.28	48.95
10.29	Sabinene											3.49	3.14	2.98
10.37	γ-Terpinene	3.33	2.24	3.14	6.42	5.69	5.77	6.39	0.63	0.59				
10.75	*p*-Cymene	2.18	1.45	1.91	1.86	1.42	4.92	2.92	0.26	0.38		3.43	3.09	3.24
10.83	2-Methylbutyl 2-methylbutanoate	0.69		0.70	0.53	0.60		0.84	0.46					
10.98	α-Terpinolene			0.40	1.06	1.01	0.57							
11.92	β-Artemisia			4.82	2.35	3.73		0.59	5.56					
12.50	Yomogi alcohol		26.68	8.54	10.14	8.88		9.90	2.18	0.48				
13.05	1-(1-methoxyethyl)-6-oxabicyclohekzane		12.03	2.52		4.14		2.15						
13.62	γ-Terpinene											0.75	0.71	0.95
13.97	α-Thujone	2.34		4.47	5.26			2.59	0.44	1.71		1.58	1.50	1.58
13.97	β-Thujone	0.71		0.66	0.16			0.49	1.14					
14.07	*trans*-sabinene hydrate	1.28	2.60	3.11	6.82	8.80		5.53	4.57	2.64		0.97	0.87	0.79
14.60	Artemisia alcohol	1.96	21.05	5.70	2.82	2.11		2.75	4.84	3.93				
14.67	α-Terpinolene											0.19		
15.31	Linalool						0.92		2.90	0.25				
15.31	*cis*-Sabinene hydrate											0.82	0.86	0.97
16.55	Lavandulyl acetate		0.78						0.45	1.31				
15.56	Camphor	36.53	1.34	25.66	7.38	5.49	11.79	2.44	16.68	9.49		11.29	11.85	12.45
16.48	Endobornyl acetate	0.77	1.34				1.59		0.59	2.39				
16.73	Terpinen 4-ol	1.35	4.55	8.09	24.20	25.70	1.64	24.60	6.49	2.78				
17.00	*trans*-caryophyllene	0.54	0.21	0.40	0.60	0.30	0.65	0.80	0.49	1.02				
17.45	Sabinaketone											0.19	0.18	
17.49	Pinocarvone								0.37			0.62	0.56	0.62
17.79	Lavandulol									0.67		0.79	0.71	0.68
18.11	Borneol								4.29					
18.12	*trans*-carveol									1.44		0.14	0.15	
18.30	α-Selinene						0.93							
18.36	4-Terpineol											0.58	0.55	0.75
18.37	α-Terpineol	2.73	1.35	1.92	1.62	2.14	0.71	2.31	2.69	5.06		4.36	4.14	4.35
18.44	α-Thujenal											0.11		
18.53	Endoborneol	1.24	1.81	1.51	0.52	1.02	0.45			1.38				
19.00	Germacrene-D	0.57					1.36	0.32	6.59	5.23	7.97			
19.21	*trans*-p-Mentha-2,8-dienol									1.56				
19.42	γ-Elemene									0.80				
20.13	Myrtenol									1.48				
21.31	α-cedrol		0.43											
20.33	*cis*-Carveol												0.16	
20.95	*trans*-Verbenol											0.31	0.28	0.25
21.33	(E)-3(10)-Caren-2-ol									1.66				
21.66	*4*-Thujenyl acetate											0.41	0.43	0.45
22.24	Lavandulyl acetate											5.99	5.69	5.98
23.91	Caryophyllene oxide								1.09	0.60				
24.01	Nerolidol	6.29		1.05	0.48	0.59		0.65		0.50				
24.60	Globulol									0.55				
24.74	Longipinocarvone									1.48				
24.92	Elemol		1.14											
25.12	Guaiol										23.09			
25.34	Bornyl acetate								5.65					
25.65	α-Copaene						1.26		1.37					
25.79	Rosifoliol										1.93			

RT	Bileşenler	1	2	3	4	5	6	7	8	9	10	11	12	13
26.41	10-Epi-γ-eudesmol		0.52				2.16			0.89	7.99			
26.69	Bornyl isobutyrate											0.35	0.32	
26.74	Caryophyllene								1.12			0.19		
26.76	Neryl isobutyrate											0.24		
27.01	α-Muurolene								0.13					
27.29	α-Eudesmol									1.40				
27.35	δ-Cadinene								0.32					
27.41	δ-Guanine										5.60			
27.47	β-Eudesmol								0.93	2.57				
27.55	β-Cedrene											0.67	0.64	0.67
28.77	β-Himachalene												0.09	
28.87	*ar*-Curcumene											0.74	0.70	0.74
29.39	Longipinocarveol									1.48				
29.70	Bornyl isovalerate												0.17	
30.12	Chamazulene	2.43		0.59	1.12	4.37	0.38	0.29	7.41	5.74	53.42			
32.07	Caryophyllene oxide											0.45	0.41	
Tespit edilemeyen		7.22	2.73	6.01	6.37	6.60	2.58	6.59	3.20	6.79		2.56	1.77	1.07

1: W6 38957, **2:** W6 49101, **3:** W6 37202, **4:** W6 46211, **5:** W6 44271, **6:** W6 46469, **7:** W6 41863, **8:** W6 38959, **9:** PI 439895, **10:** PI 371687, **11:** Kozluçay-Yalvaç, **12:** Akpınar-Aksu, **13:** Diktaş-Yenişarbademli

Koçak et al. [46] detected 19% γ-cadinene, 10.13% limonene oxide, 6.37% alloaromadendrene, 5.71% caryophyllene oxide and 4.89% *trans*-caryophyllene in *A. millefolium* subsp. *millefolium* naturally distributed in Elazığ. Başer [47] reported that *A. millefolium* subsp. *millefolium* species were reported as 1,8-cineole, camphor, α-terpineol, γ-cadinene, limonene oxide, alloaromadendrene, caryophyllene oxide, β-caryophyllene, α-bisabolol, muurolo-4,10(14)-dien-1-ol. Our study showed similar characteristics to the studies above and no chamazulene compound was found in the genotypes obtained from three locations. The European Pharmacopoeia prescribes the proazulene amount of the essential oil of *millefolii herba* as at least 0.02% [37]. In our study, it was observed that the high genotypes of W6 38959, PI 439895, PI 371687 had high chamazulene content and met the proazulene standards recommended by the European Pharmacopoeia.

4. Conclusion

This study revealed that yarrow (*Achillea millefolium* L.) genotypes exhibit significant genetic variation in terms of agronomic performance and essential oil characteristics under the ecological conditions of Isparta. Among the evaluated genotypes, flowering duration ranged from 10 to 41 days, plant height from 21.8 to 72.0 cm, fresh flower yield from 246.9 to 2829.7 kg/da, and essential oil content from 0.05% to 0.51%. This wide variation indicates that yarrow genetic resources possess considerable potential in terms of both yield and quality traits.

According to the results, the highest fresh flower yield was recorded in genotype PI 439888 (2829.7 kg/da). In terms of essential oil content, genotype W6 46211 exhibited the highest value with 0.50%. Examination of the essential oil composition showed that some genotypes were distinguished by specific compounds. In particular, the high chamazulene content detected in genotype PI 371687 (53.42%) indicates that this material has significant potential for pharmaceutical and cosmetic applications. Chamazulene is known as a valuable compound in medicinal and aromatherapy products due to its strong anti-inflammatory and antioxidant properties.

The results also showed that some genotypes met the pharmacopoeial standards in terms of essential oil composition, suggesting that these materials may be directly utilized in medicinal and aromatic plant production. Furthermore, the findings demonstrate that yarrow can be successfully cultivated under agricultural conditions and that superior genotypes selected from natural populations can be used for sustainable production systems.

Based on the obtained results, PI 439888 stands out due to its high yield potential, W6 46211 due to its high essential oil content, and PI 371687 due to its high chamazulene content, making them promising genetic materials for yarrow cultivation and breeding programs. Evaluation of these genotypes under different ecological conditions and long-term monitoring of their chemical characteristics will contribute significantly to the industrial cultivation of yarrow and the development of new medicinal and aromatic plant varieties in Türkiye.

Etik Beyanı/Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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