Microhabitat-driven Variation in Fruit Yield of Cornelian Cherry (*Cornus mas* L.) in a Mediterranean Ecosystem

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Effects of microhabitat were studied relative to the growth and fruit yield of *Cornus mas* L. (Cornelian cherry) populations in a Mediterranean ecosystem. Two contrasting natural habitats were compared: rocky slopes and streamside environments in southwestern Türkiye. A total of 60 mature trees (30 per habitat) were sampled during the 2025 growing season. Tree height, basal diameter, diameter at breast height (DBH), crown diameter, age, fruit number, and total fruit weight were measured to assess growth and yield responses.The results revealed pronounced habitat-related differences in reproductive performance. Trees growing in rocky habitats produced approximately 60% more fruits and 85% higher total fruit yield compared with those in streamside habitats. Analysis of variance indicated that habitat effects were statistically significant ($p < 0.05$) for most growth and yield traits, except for tree height and crown diameter. Correlation analyses demonstrated strong positive relationships between growth parameters and fruit yield, with basal diameter emerging as the most reliable predictor of reproductive output. Rocky habitats appeared to provide more favorable conditions for fruit production, likely due to improved drainage, enhanced light availability, and reduced interspecific competition. The study provides valuable insights for the sustainable management, conservation, and potential cultivation of *C. mas.*

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INTRODUCTION

Cornelian cherry (*Cornus mas* L.) is a woody species of considerable ecological, economic, and cultural significance. It typically grows as a small tree or shrub and produces edible fruits that are widely utilized in the food, nutraceutical, and pharmaceutical industries (Aykut and Konuklugil 2018; Szczepaniak *et al.* 2019). Beyond its commercial value, *C. mas* plays an important role in supporting wildlife, facilitating landscape rehabilitation, sustaining rural livelihoods, and maintaining biodiversity in both natural and semi-natural ecosystems.

The fruits of *C. mas* are characterized by a rich phytochemical composition, including anthocyanins, flavonoids, iridoids, vitamin C, and essential minerals (Cumhur 2022). These bioactive compounds underpin the species' strong antioxidant, anti-inflammatory, and antimicrobial properties. Consequently, various plant parts have been traditionally employed in folk medicine across Europe and Asia for the prevention and treatment of ailments such as diabetes, gastrointestinal disorders, rheumatic conditions, kidney and liver diseases, and sunstroke (Cumhur 2022). In recent years, growing scientific interest has further highlighted *C. mas* as a promising natural source of health-promoting compounds with potential applications in functional food development (Klimenko and Łojewska 2022).

From an ecological perspective, *C. mas* exhibits a broad adaptive capacity. The species is naturally distributed across temperate regions of Central and Southern Europe as well as Southwest Asia (EUFORGEN, 2024). It commonly inhabits mountain slopes, forest edges, valleys, and streamside environments, typically under well-drained soil conditions and moderate climatic regimes (Ercisli 2004; Dokoupil and Reznicek 2012). In Türkiye, *C. mas* is widely distributed in the Mediterranean, Aegean, Marmara, and Black Sea regions, where it may attain heights of 7 to 8 m under favorable environmental conditions (Szczepaniak *et al.* 2019). Its tolerance to diverse soil types and environmental stressors, including drought and frost, underscores its potential utility in ecological restoration and sustainable cultivation initiatives (EUFORGEN, 2024).

Drought stress is known to exert pronounced negative effects on vegetative growth and photosynthetic performance, as widely documented in plant physiological studies. Under water-limited conditions, reductions in stomatal conductance lead to decreased CO_2 uptake and lower net photosynthetic rates. Concurrently, alterations in chlorophyll fluorescence parameters reflect impairments in photosystem II (PSII) efficiency (Ödemiş *et al.* 2022). In woody species, such drought-induced responses are generally attributed to physiological mechanisms including reduced root water uptake, stomatal closure, and declines in photosynthesis resulting from both stomatal and non-stomatal limitations (Kamanga *et al.* 2018). These processes collectively reduce the plant carbon budget, thereby constraining vegetative growth, flower bud differentiation, and ultimately fruit yield. During stress periods, diminished photosynthetic activity and carbon assimilation limit the availability of carbon resources and hormonal signals essential for bud development (Ödemiş *et al.* 2022). In *C. mas,* drought stress has been shown to induce marked physiological responses, such as reductions in leaf area and vegetative growth, stomatal closure, decreased net photosynthetic rates, and disruptions in chlorophyll fluorescence, which together restrict carbon gain and result in reduced fruit set and overall yield (Šajbidorová and Lichtnerová 2018).

Although *C. mas* is naturally adapted to variable environmental conditions, climatic stressors can substantially influence its physiological performance and productivity. Owing to its early spring flowering, the species is particularly susceptible to frost damage, which may cause severe losses in fruit set. Flowering phenology in *C. mas* is closely regulated by air temperature, and fluctuations in thermal conditions can modify flowering duration and subsequent yield (Ocokoljić *et al.* 2025). Thus, both low-temperature frost events and drought stress are associated with physiological responses such as stomatal closure, reductions in net photosynthesis, and disruptions in chlorophyll fluorescence, ultimately culminating in yield losses in *C. mas* and many other plant species.

Despite being predominantly harvested from natural populations, interest in the cultivation of *C. mas* has increased in recent decades due to its ecological resilience and high-value fruits. Global annual fruit production has been estimated at approximately 875,000 tonnes (Yalım Kaya and Canlı 2019). Nevertheless, productivity remains highly variable and is strongly influenced by a combination of biotic and abiotic factors, including genotype, site conditions, and tree morphological traits (Mert and Soylu 2006; Karadeniz 2019). Although numerous studies have addressed fruit quality, propagation techniques, and genetic variation, the interactive effects of habitat type and tree growth characteristics on fruit yield in natural *C. mas* populations remain insufficiently understood (Klymenko *et* *al.* 2017; Grygorieva *et al.* 2023).

In recent years, *C. mas* has attracted increasing attention as an alternative fruit species due to its broad ecological tolerance, relative resistance to low temperatures, and high concentrations of bioactive compounds in its fruits. Nevertheless, despite these advantageous traits, *C. mas* has not yet been successfully incorporated into modern, large-scale, and intensive cultivation systems. This limitation is largely attributed to structural and technical constraints stemming from the species' biological and ecological characteristics. In particular, the pronounced phenological and morphological heterogeneity of genetic material derived from natural populations complicates synchronization of flowering and fruit ripening, resulting in marked interannual variability in yield and fruit quality (Ercisli 2004).

Early spring flowering further increases the vulnerability of *C. mas* to late frost events, which can severely damage generative organs and lead to substantial yield losses, thereby elevating economic risks in large-scale production systems. Moreover, low success rates in vegetative propagation, genotype–rootstock incompatibilities, and micropropagation protocols that have yet to be fully optimized or validated at an industrial scale constrain the production of uniform, high-quality planting material. The lack of long-term, standardized agronomic data related to irrigation, fertilization, pruning, and high-density planting systems further hampers the development of reliable cultivation practices for *C. mas*.

Beyond these biological and technical limitations, the current marketing structure of *C. mas* is predominantly oriented toward processed and functional products, which does not fully align with industrial production models requiring a consistent and high-volume supply of raw material. Consequently, the obstacles to large-scale artificial cultivation of *C. mas* should be viewed as a multidimensional challenge shaped by the interplay of genetic, physiological, agronomic, and economic factors (Dzydzan *et al.* 2022).

In this context, the present study aimed to (i) evaluate the effects of two contrasting natural habitats (rocky and streamside) on the growth and fruit production traits of *C. mas*, and (ii) examine the relationships between growth characteristics—such as tree height, basal diameter, diameter at breast height (DBH), and crown diameter—and fruit yield parameters, including fruit number and fruit weight. The results are expected to provide a scientific basis for the sustainable management, conservation, and cultivation of *C. mas* populations.

EXPERIMENTAL

Study Area

The study was conducted in two contrasting natural habitats within the native distribution range of *C. mas* in southwestern Turkey. The first site represented a rocky vegetation (RV) type located at 37.7838° N, 30.9196° E, with a southern aspect and an elevation of approximately 1210 m above sea level (asl). The second site was a streamside vegetation (SV) type situated at 37.7708° N, 30.9299° E, with a northern aspect and an elevation of about 1090 m asl (Fig. 1).

Rocky habitats are characterized by well-drained soils, whereas streamside habitats are defined by water-saturated conditions. From each habitat, thirty mature trees representing typical individuals of the natural population were randomly selected. (Fig. 2).

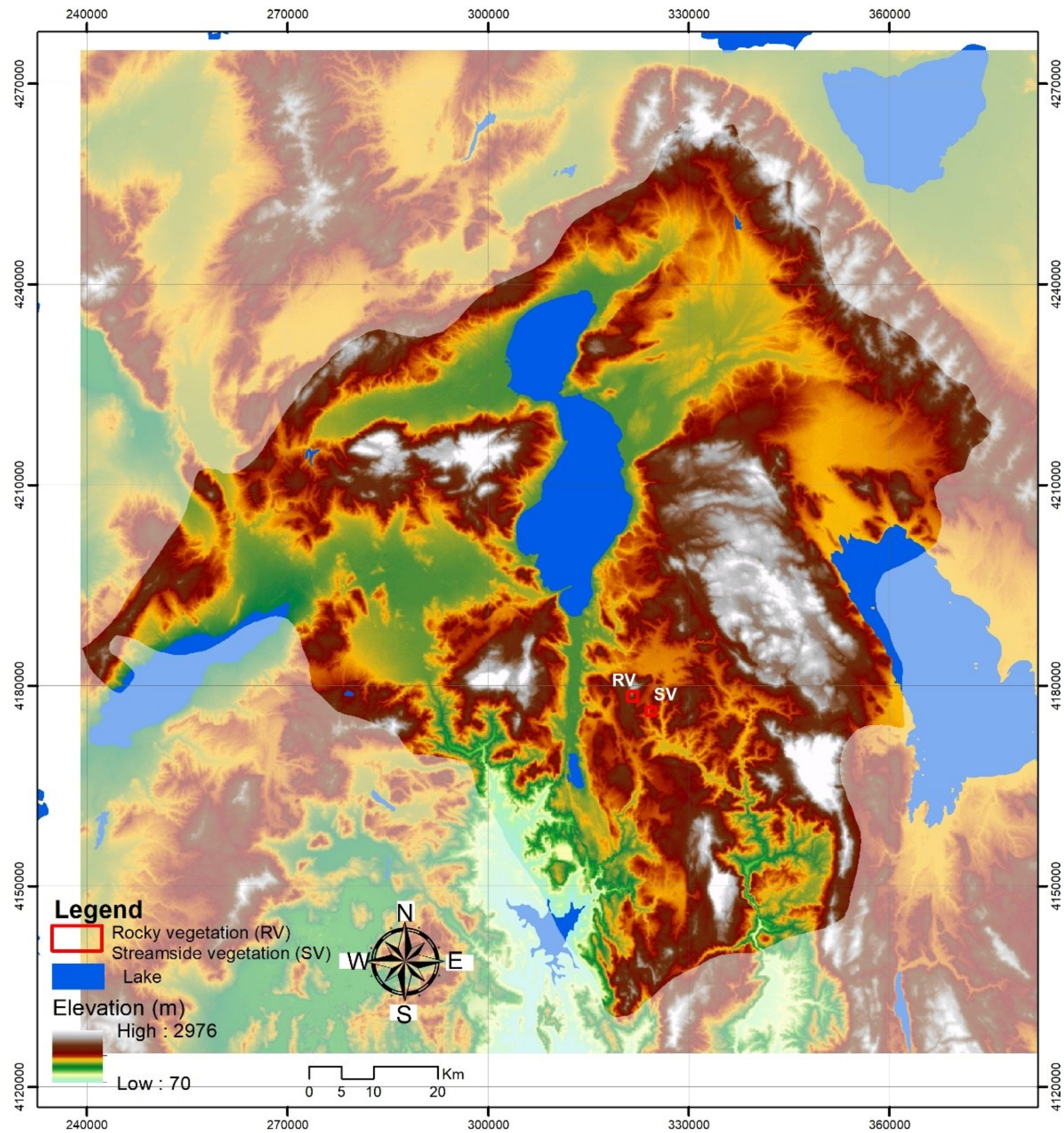

Fig. 1. Location of the study area

Data Collection

For each sampled tree, the following growth variables were measured: tree height (H, m), basal diameter (D_0, cm), diameter at breast height (DBH, cm), crown diameter (CD, m), and tree age (A, years). Age was determined from increment cores extracted at breast height using an increment borer during the 2025 growing season. All measurements were conducted in situ while preserving the trees; thus, no trees were completely removed or uprooted (Fig 2). Tree age and growth assessments were performed using increment cores extracted with an increment borer, along with additional measurements carried out directly in the field. This approach minimizes disturbance to the natural population while ensuring the acquisition of accurate and reliable data.

Fruit production was evaluated based on the number of mature fruits (FN) and total fruit weight (FW). Mature fruits were harvested from four branches oriented toward the main cardinal directions (north, south, east, and west) to ensure representative sampling.

The total fruit number per tree was estimated by summing the branch-level counts, while fruit weight was determined by weighing all harvested fruits using a precision digital balance (± 0.01 g).

Fig. 2. Streamside habitat (1, 2) and rocky habitat (3, 4)

Statistical Analysis

Descriptive statistics (mean, standard deviation, and coefficient of variation) were calculated for all measured traits. Differences between habitats (RV and SV) were analyzed using one-way analysis of variance (ANOVA), implemented in SPSS software (IBM SPSS Statistics, Version 22; IBM Corp., Armonk, NY, USA). The general linear model used for ANOVA was,

$$Y_{ij} = \mu + P_j + e_{ij} \quad (1)$$

where Yij is the observation from the jth tree of the ith habitat, μ is the overall mean, P_j represents the fixed effect of the ith habitat (rocky or streamside), and e_{ij} is the random error term associated with each observation Eq. 1.

When significant differences were detected ($p < 0.05$), means were compared using the Least Significant Difference (LSD) test to determine pairwise differences between habitats.

Phenotypic correlation coefficients (rpr_prp) among traits were calculated following the method of Rohlf and Sokal (1995),

$$r_P = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \quad (2)$$

where $\sum xy$ is the sum of the cross-products between two traits x and y, and $\sum x^2$ and $\sum y^2$ are the sums of squares (phenotypic variances) of traits x and y, respectively.

All data were checked for normality and homogeneity of variance before analysis. Correlation analyses were separately conducted for each habitat to examine the relationships between growth and fruit production characteristics.

RESULTS

Growth Characteristics and Variation

Growth traits and fruit production varied substantially between habitats and among trees within the same habitat (Table 1, Fig. 3). Trees growing in the rocky habitat produced approximately 60% more fruits (26.855 fruits tree^{-1}) and 85% greater fruit weight (61.4 kg tree^{-1}) than those from the stream habitat (16.732 fruits tree^{-1} and 32.6 kg tree^{-1}). The cumulative contribution of parental-balance curves across grades and years is shown in Fig. 4.

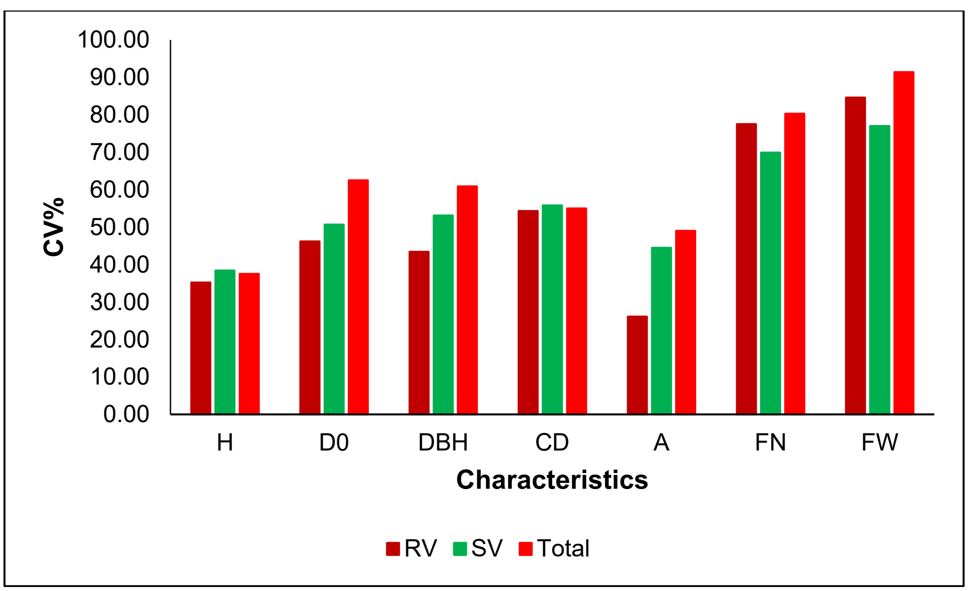

Fig. 3. Mean cone production across grades and years

Table 1. Means (x̄), Ranges, and Coefficients of Variation (CV%) for Measured Traits Across Vegetation Types

	RV			SV			Total		
Characteristics	**x̄**	**Range**	**CV%**	**x̄**	**Range**	**CV%**	**x̄**	**Range**	**CV%**
H (m)	6.9	3-14	35.2	5.8	3-11	38.4	6.4	3-14	37.5
D_0 (cm)	45.2	15-79	46.2	20.5	5-41	50.7	32.8	5-79	62.5
DBH (cm)	26.5	6-48	43.4	12.1	3-27	53.1	19.3	3-48	60.9
CD (m)	11.6	3-25	54.3	10.6	2-23	55.8	11.1	2-25	55.0
A (year)	79.3	25-120	26.1	36.6	9-80	44.5	58.0	9-120	49.0
FN	26855	1878-75000	77.5	16732	1723-40160	69.9	21794	1723-75000	80.3
FW (kg)	61.4	5-200	84.6	32.6	3-82	77.0	47.0	3-200	91.4

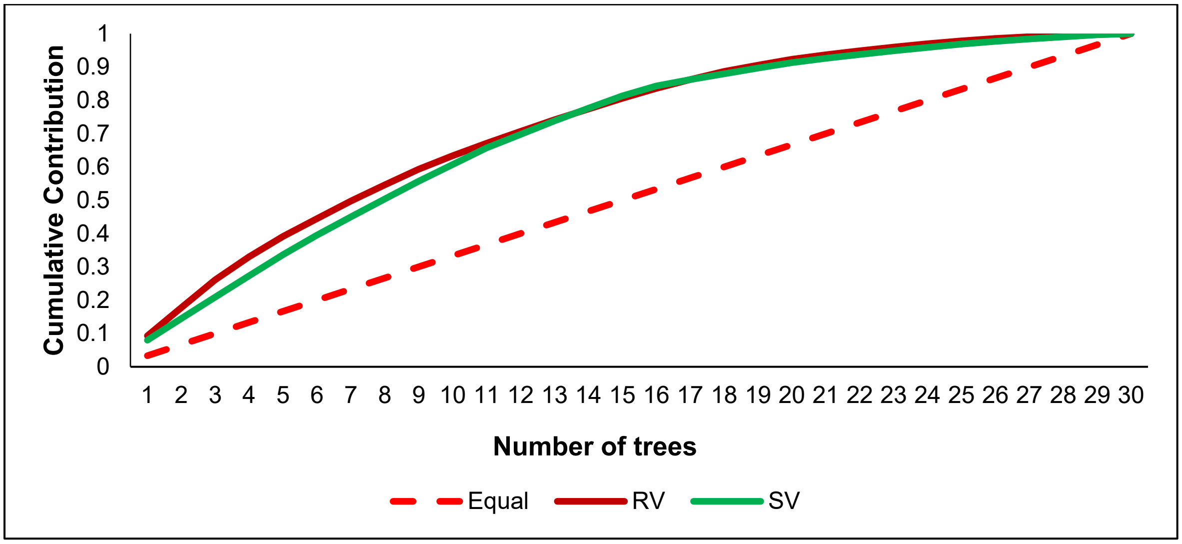

Fig. 4. Cumulative contribution of parental-balance curves across grades and years

Table 2. Correlation Coefficients among Measured Traits across Vegetation

	r_p	H	D_0	DBH	CD	A	FN
RV		0.521**	-				
SV	**D_0**	0.650**	-				
Total		0.558**	-				
RV		0.490**	0.750**	-			
SV	**DBH**	0.475**	0.876**	-			
Total		0.504**	0.860**	-			
RV		0.416*	0.721**	0.459*	-		
SV	**CD**	0.709**	0.847**	0.570**	-		
Total		0.554**	0.629**	0.429**	-		
RV		0.156NS	0.373*	0.421*	0.387*	-	
SV	**A**	0.420*	0.639**	0.570**	0.481**	-	
Total		0.344**	0.687**	0.706**	0.338**	-	
RV		0.325NS	0.592**	0.402*	0.539**	0.292NS	-
SV	**FN**	0.719**	0.568**	0.398*	0.459*	0.619**	-
Total		0.483**	0.623**	0.482**	0.498**	0.463**	-
RV		0.308NS	0.585**	0.421*	0.589**	0.372*	0.941**
SV	**FW**	0.811**	0.557**	0.398*	0.544**	0.454*	0.905**
Total		0.484**	0.639**	0.516**	0.543**	0.492**	0.937**

**; Correlation is significant at the 0.01 level, *; correlation is significant at the 0.05 level, NS; correlation is not significant at the 0.05 level

Relationships Among Growth and Fruit Characteristics

Correlation analysis indicated that most growth parameters were positively and significantly ($p < 0.05$) associated with both fruit number and weight in both habitats (Table 2).

Diameter at base (D_0) emerged as the best predictor of fruit number ($r_p > 0.59$, $R^2 = 0.40$), suggesting its potential use in yield estimation and orchard management (Fig. 5). The regression model was expressed as: $y = 5 \times 10^{-9} x^2 + 0.0004x + 19.882$.

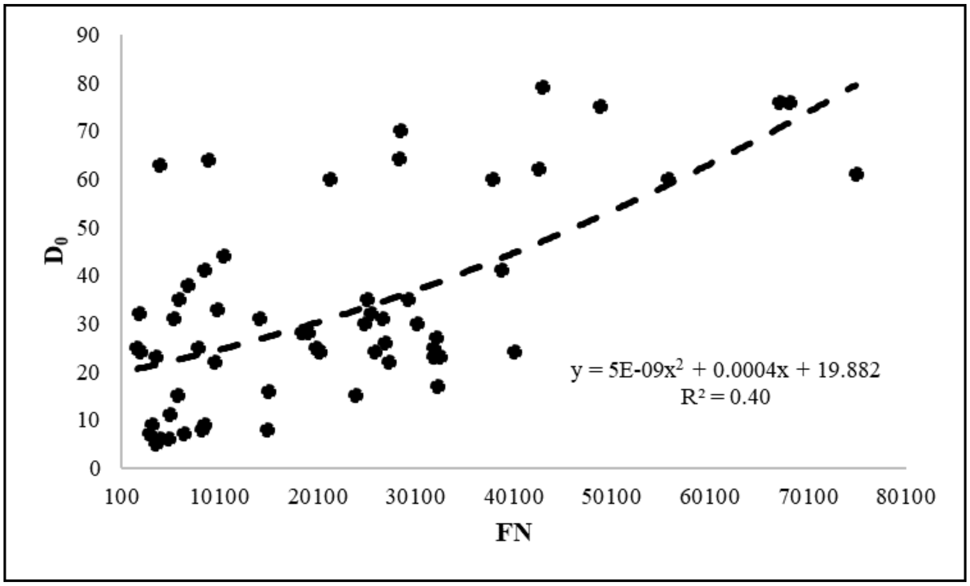

Fig. 5. Relationship between diameter at base (D_0) and fruit number (FN) across all habitats

DISCUSSION

Rock vegetation typically develops on steep and stony slopes characterized by shallow, clayey–calcareous soils with low organic matter content, high coarse fragment ratios, and well-drained conditions. These environments are subjected to pronounced summer drought, with precipitation largely concentrated in winter and spring. Such constraints favor drought- and nutrient-tolerant plant species while simultaneously providing heterogeneous microhabitats that support insect pollinators and reptile fauna. In contrast, riparian vegetation occurs on deeper, alluvial soils with relatively higher organic matter content and hydromorphic features resulting from fluctuating groundwater levels and periodic flooding (Dindaroğlu and Vermez 2019).

The present study revealed pronounced variation in growth traits and fruit yield between habitats and among individual trees within habitats. Trees growing in rocky habitats produced significantly higher fruit numbers and yields (26,900 fruits and 61.4 kg tree^{-1}) compared with those in streamside habitats (16,700 fruits and 32.6 kg tree^{-1}). Most growth parameters showed significant relationships with fruit production ($p < 0.05$), with diameter at the stem base emerging as the most reliable predictor of yield. These findings indicate that structural growth traits can serve as practical indicators for estimating reproductive output in *C. mas* populations.

The present results are consistent with previous studies demonstrating that environmental heterogeneity strongly influences reproductive performance in *C. mas* (Tóth *et al.* 2021; Zhou *et al.* 2023). Reported yields for wild-growing individuals range from 2.8 to 10 kg per shrub, while cultivated trees may reach up to 80 kg tree^{-1} (Klimenko 2004). Similarly, fruit weight has been reported to vary widely (2.09 to 9.17 g), depending on genotype and environmental conditions (Yılmaz *et al.* 2009; Milenković-Andjelković *et al*. 2015). In the present study, individuals from rocky habitats were generally older and larger than those from stream habitats, suggesting enhanced adaptation to microclimatic stressors and reduced competitive pressure.

Analysis of variance revealed significant differences ($p < 0.05$) between habitats for most growth and yield traits, with the exception of tree height and crown diameter. Comparable habitat-driven variation in fruit production has also been reported in other woody species, such as *Rosa canina* (Bilir 2011). Such patterns are widely attributed to interactions between genetic background and environmental conditions (Eriksson *et al.* 1973).

The coefficient of variation for fruit number (CV ≈ 78%) remained within acceptable limits for natural populations, indicating sufficient genetic diversity and a strong potential for sustainable regeneration (Kang *et al.* 2023). The relatively consistent cumulative contribution of individual trees across habitats further supports this interpretation. Collectively, these findings suggest that rocky habitats may promote superior growth and reproductive performance, likely due to enhanced solar radiation, effective drainage, and localized nutrient availability (Tóth *et al.* 2021).

Parallel relationships between vegetative growth and reproductive traits have been documented across a range of woody species (Baloğlu and Bilir 2020; Bilir and Kang 2021, Zhou *et al.* 2023). These associations may be utilized to improve *C. mas* management strategies through optimized planting density, selective pruning, and informed genotype selection, thereby enhancing fruit yield while maintaining genetic sustainability.

Genotypic variation further contributed to the observed differences in yield and pomological traits. Previous studies have shown that phenological timing, fruit morphology, and chemical composition in *C. mas* are strongly influenced by genotype–environment interactions (Selçuk and Özrenk 2011; Demir *et al.* 2020). Climatic variability, particularly under Central European conditions, has been reported to affect flowering phenology and fruit size, with early-season frost events posing a significant limitation to yield (Szot and Lysiak 2022). These findings underscore the importance of integrating habitat-specific conditions into agroecological planning and breeding programs. Moreover, the high ecological plasticity of *C. mas* enhances its cultivation potential across diverse environments. The species has been shown to tolerate extreme cold conditions, surviving temperatures as low as −40 °C while remaining productive under suboptimal settings (Brindza *et al.* 2006). Such resilience highlights the economic and ecological value of *C. mas* and emphasizes the need for site-adapted management approaches.

CONCLUSIONS

The present findings demonstrate that *Cornus mas* trees growing in rocky habitats exhibited superior growth performance and higher fruit yield compared with those in riparian environments. Well-drained soil conditions in rocky habitats likely facilitate improved root respiration and nutrient uptake, while periodic water saturation in streamside soils may restrict root oxygen availability and constrain growth. Microclimatic conditions associated with rocky sites such as higher light availability, enhanced air circulation, and greater thermal variability are also likely to promote photosynthetic efficiency and carbon assimilation, favoring greater allocation of assimilates to fruit development.

In contrast, elevated humidity and shading in riparian habitats may limit carbon allocation to reproductive structures, thereby reducing fruit formation. Additionally, lower interspecific competition in rocky environments may allow more efficient resource use at the individual tree level. Overall, the results indicate that *C. mas* growth and yield are shaped by the combined influence of environmental conditions, physiological responses, and genetic variability. However, the mechanistic basis of these interactions requires further clarification through integrated physiological and ecophysiological studies.

These findings highlight the ecological significance of microhabitat differentiation and its practical implications for management, breeding, and conservation of *C. mas*. Future research should adopt multi-year, multi-site, and genotype-inclusive experimental designs to better elucidate the long-term plasticity and resilience of fruit yield in response to environmental and genetic drivers.

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