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RESEARCH ARTICLE **Open Access**

Phenological dynamics and biometric characterization of introduced highbush blueberry (*Vaccinium corymbosum*) cultivars under the agroecological conditions of Adjara, Western Georgia

Acara, Batı Gürcistan'ın agroekolojik koşullarında introdüksiyonla getirilen yüksek çalı maviyemişi (*Vaccinium corymbosum* L.) çeşitlerinin fenolojik dinamikleri ve biyometrik karakterizasyonu

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ABSTRACT

Highbush blueberry (*Vaccinium corymbosum* L.) is becoming an increasingly important high-value berry crop in Western Georgia, particularly in Adjara, where humid subtropical conditions and expanding market opportunities support commercial production. Reliable introduction of new cultivars, however, requires locally validated information on phenological timing, ripening windows and vegetative performance. This study evaluated the phenological dynamics and biometric characteristics of three introduced cultivars, Legacy, Bluegold and Duke, in Kobuleti, Khelvachauri and Qeda municipalities during the 2024 growing season. Field records were systematized from the available primary dataset and processed by converting calendar dates into day-of-year values, calculating interval midpoints and preparing descriptive cultivar- and municipality-level summaries. Because the dataset contained one cultivar-by-location observation and no replicated plot-level measurements, inferential statistical testing was not applied. The results showed marked cultivar- and location-related differentiation.

ÖZ

Yüksek çalı maviyemişi (*Vaccinium corymbosum* L.), özellikle nemli subtropikal koşulların ve gelişen pazar olanaklarının ticari üretimi desteklediği Batı Gürcistan'da, özellikle de Acara bölgesinde giderek önem kazanan yüksek değerli bir üzümsü meyve türüdür. Ancak yeni çeşitlerin güvenilir biçimde bölgeye kazandırılması, fenolojik dönemler, olgunlaşma zamanları ve vejetatif gelişim özelliklerine ilişkin yerel koşullarda doğrulanmış bilgilere ihtiyaç duymaktadır. Bu çalışmada, 2024 yetiştirme sezonunda Kobuleti, Khelvachauri ve Qeda belediyelerinde yetiştirilen üç introduksiyon çeşidinin; Legacy, Bluegold ve Duke'un fenolojik dinamikleri ile biyometrik özellikleri değerlendirilmiştir. Mevcut birincil veri setinden elde edilen arazi kayıtları sistematize edilmiş; takvim tarihleri yılın günü değerlerine dönüştürülmüş, dönem aralıklarının orta noktaları hesaplanmış ve çeşit ile belediye düzeyinde tanımlayıcı özetler hazırlanmıştır. Veri setinin her çeşit-lokasyon kombinasyonu için yalnızca bir gözlem içermesi ve tekrarlı parsel ölçümlerinin bulunmaması nedeniyle çıkarımsal istatistiksel analiz uygulanmamıştır. Bulgular, çeşitler ve lokasyonlar arasında belirgin farklılıklar olduğunu göstermiştir.

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1. INTRODUCTION

Highbush blueberry (*V. corymbosum* L.) has developed from a regionally important fruit crop into a globally traded horticultural commodity with high economic value. Its expansion has been supported by increasing consumer demand for fresh berries, the recognition of blueberry fruit as a nutritionally valuable product, the growth of export-oriented production systems and the availability of cultivars that differ in chilling requirement, flowering period, ripening time and fruit-quality traits. Modern cultivar evaluation therefore increasingly integrates phenological and pomological indicators, because flowering and ripening schedules directly influence market timing, harvest logistics, frost exposure and fruit-quality stability.

In Georgia, blueberry production has gained particular importance in the western part of the country, where humid climatic conditions, naturally acidic soils in many production areas and access to Black Sea regional markets create favorable conditions for commercial cultivation. Earlier Georgian studies identified blueberry as a promising crop for national horticultural development and described its biological characteristics and cultivation requirements under local conditions. Subsequent investigations in Adjara and neighboring Guria emphasized cultivar-specific differences in growth, phenological development and adaptation potential (Jabnidze & Jabnidze, 2015; Jabnidze et al., 2017; Tsintsadze & Bobokashvili, 2023).

Phenology is one of the most informative indicators of cultivar adaptation because it reflects the interaction among genotype, environment and annual weather conditions. The timing of bud swelling, vegetative growth, flowering, fruit set, ripening, secondary shoot growth, flower-bud initiation and leaf senescence provides practical information on the suitability of a cultivar for a particular production environment. In blueberry, these relationships are especially important because early spring warming may accelerate budbreak and flowering, whereas late frosts, prolonged rainfall and unfavorable pollination conditions may negatively affect fruit set and yield. Flowering phenology is highly responsive to temperature and may be modeled using heat-accumulation approaches (Kirk & Isaacs, 2012). Under increasing climatic variability, chilling requirement, freeze tolerance, deacclimation dynamics and flowering and fruiting phenology have become critical determinants of production resilience (Lobos & Hancock, 2015; Chu, 2025).

International studies confirm substantial variation in blueberry phenology among cultivars and production environments. In Romania, cultivar identity and climatic year influenced the onset of vegetation, flowering and ripening, with phenological stages evaluated by BBCH and Julian-day approaches (Cosmulescu et al., 2022). A multi-year evaluation of 32 cultivars in the Czech Republic further demonstrated the value of combining phenological and pomological traits for breeding and cultivation decisions (Pavliuk et al., 2025). More recently, the codification of highbush blueberry developmental stages according to the BBCH scale has provided a standardized framework for phenological monitoring and cross-regional comparison (Wichura et al., 2024). Within this context, evaluating introduced blueberry cultivars under the contrasting agroecological conditions of Kobuleti, Khelvachauri and Qeda are scientifically justified and practically relevant.

The aim of this study was to evaluate the phenological development and biometric performance of the introduced highbush blueberry cultivars Legacy, Bluegold and Duke under the agroecological conditions of Adjara, Western Georgia, and to assess their preliminary adaptation potential for commercial cultivation.

The specific objectives were to systematize the principal phenological stages of the selected cultivars during the 2024 growing season; to compare vegetation onset, flowering time, flowering duration and fruit-ripening periods among cultivars and municipalities; to evaluate bush height and annual shoot length as indicators of vegetative vigor; to convert reported calendar dates into day-of-year values and summarize the dataset descriptively; and to formulate preliminary recommendations for cultivar zoning, monitoring strategies and future replicated field trials in Adjara.

2. MATERIALS AND METHODS

2.1. Study area and plant material

The study was conducted during the 2024 growing season in three municipalities of Adjara, Western Georgia: Kobuleti, Khelvachauri and Qeda. These municipalities represent contrasting agroecological environments within the region and differ in altitude, thermal regime and degree of coastal climatic influence.

Kobuleti is located in the Black Sea coastal zone and is characterized by a humid subtropical climate, relatively mild winters and early spring warming, conditions that generally promote earlier phenological development. Khelvachauri represents an intermediate agroecological zone influenced by both coastal and inland climatic conditions. Qeda is situated in a more elevated inland area, where cooler temperatures and delayed spring warming generally result in later phenological development.

The plant material consisted of three introduced highbush blueberry (*V. corymbosum* L.) cultivars: Legacy, Bluegold and Duke. These cultivars are widely used in commercial blueberry production systems and differ in growth vigor, flowering phenology, ripening period and adaptation characteristics (Retamales & Hancock, 2018; Pavliuk et al., 2025). Their

contrasting phenological profiles make them suitable candidates for evaluating cultivar adaptation under the diverse environmental conditions of Adjara.

2.2. Phenological observations and data processing

Phenological observations were derived from the primary field dataset reported by Zoidze (2025). The available data included records of vegetation onset, flowering initiation, flowering termination, flowering duration, ripening onset and ripening termination for each cultivar-location combination.

The original monitoring program also included additional developmental stages, including bud swelling, fruit set, green fruit development, secondary vegetative growth, flower-bud initiation and leaf fall. Because quantitative information for these stages was not consistently available in tabulated form, only the phenological variables that could be processed consistently were included in the present descriptive analysis.

To enable comparison among cultivars and locations, reported calendar dates were converted into day-of-year (DOY) values. For date intervals presented as ranges, midpoint values were calculated and used only for descriptive visualization and summary statistics. These transformations supported the preparation of comparative phenological calendars and graphical representations of flowering and ripening dynamics.

Phenological stages were interpreted according to internationally accepted principles of blueberry phenological assessment. Future monitoring in Georgia should adopt the standardized BBCH scale proposed for highbush blueberry by Wichura et al. (2024), which would improve comparability among cultivars, locations, years and research programs.

2.3. Biometric measurements and statistical approach

Biometric characterization was based on two vegetative growth parameters: bush height and annual shoot length. These variables were selected as practical indicators of vegetative vigor and preliminary adaptation under local growing conditions. Bush height was recorded as reported in the source dataset, while annual shoot length was presented as an observed range. For descriptive summaries and graphical visualization, midpoint values of the reported shoot-length ranges were calculated.

The interpretation of vegetative vigor was undertaken cautiously because plant growth can be influenced by factors beyond cultivar genetics, including pruning intensity, crop load, soil properties, nutrient availability, irrigation, plant age and local management practices (Jabnidze et al., 2017; Retamales & Hancock, 2018). Therefore, the biometric results should be treated as preliminary indicators of cultivar performance rather than definitive measures of genetic potential.

Because the available dataset consisted of one observation for each cultivar-by-location combination and did not include replicated plot-level measurements, inferential statistical testing was not conducted. The analysis was limited to descriptive statistics, including means, standard deviations and coefficients of variation where appropriate. The results are therefore interpreted as preliminary and hypothesis-generating.

3. RESULTS

3.1. Cultivar differences in flowering and ripening phenology

The phenological observations revealed clear differences among cultivars in vegetation onset, flowering initiation, flowering duration and fruit-ripening dynamics (Tables 1 and 2; Figures 1-3). Legacy consistently showed the earliest vegetation onset across all municipalities, beginning on 17 February in Kobuleti, 21 February in Khelvachauri and 29 February in Qeda. Bluegold and Duke generally initiated vegetative development later, particularly under the cooler conditions of Qeda.

Table 1. Phenological characteristics of three introduced highbush blueberry cultivars evaluated in Adjara during the 2024 growing season.

Municipality	Cultivar	Vegetation start	Flowering start	Flowering end	Flowering duration (days)	Ripening start	Ripening end
Kobuleti	Legacy	17.02	20-21.03	19-23.04	27-29	24-26.05	9-12.06
Kobuleti	Bluegold	1-2.03	3-5.04	5-7.05	28-29	9-11.06	25-27.06
Kobuleti	Duke	25-27.03	2-4.04	23-25.04	20-22	20-22.05	3-5.06
Khelvachauri	Legacy	21.02	23-25.03	25-27.04	27-28	29-30.05	15-17.06
Khelvachauri	Bluegold	5-7.03	8-9.04	10-11.05	26-27	13-15.06	29-30.06
Khelvachauri	Duke	28-30.03	5-7.04	27-28.04	20-21	23-25.05	5-7.06
Qeda	Legacy	29.02	2-4.04	3-5.05	26-28	7-9.06	20-22.06

Municipality	Cultivar	Vegetation start	Flowering start	Flowering end	Flowering duration (days)	Ripening start	Ripening end
Qeda	Bluegold	14-16.03	15-17.04	19-21.05	25-26	21-23.06	7-9.07
Qeda	Duke	3-6.04	11-13.04	2-5.05	22-24	2-4.06	11-14.06

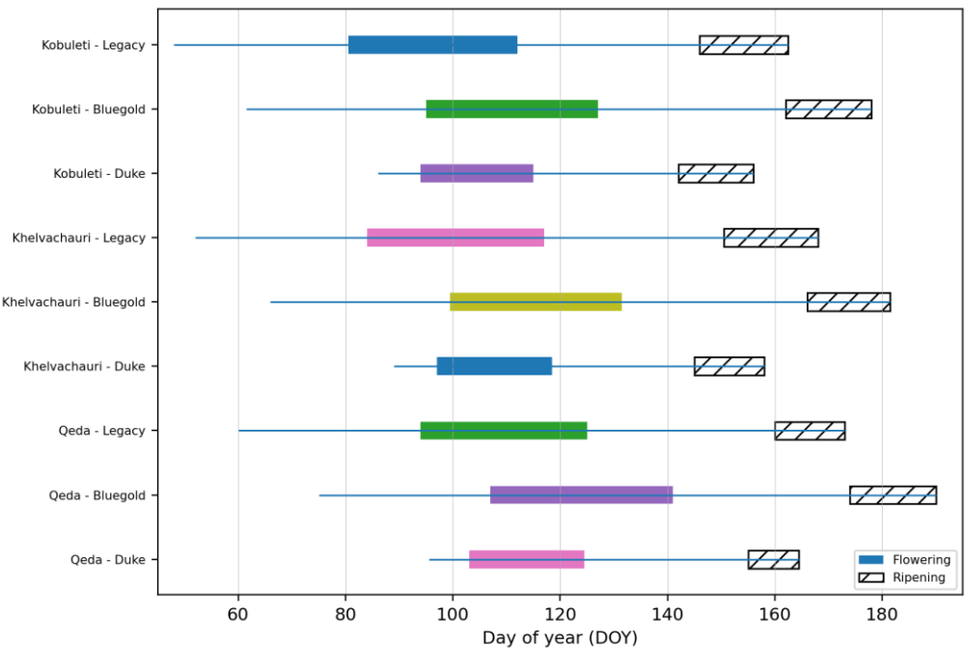

Figure 1. Phenological calendar showing vegetation onset, flowering period and ripening period of three highbush blueberry cultivars across the municipalities of Adjara

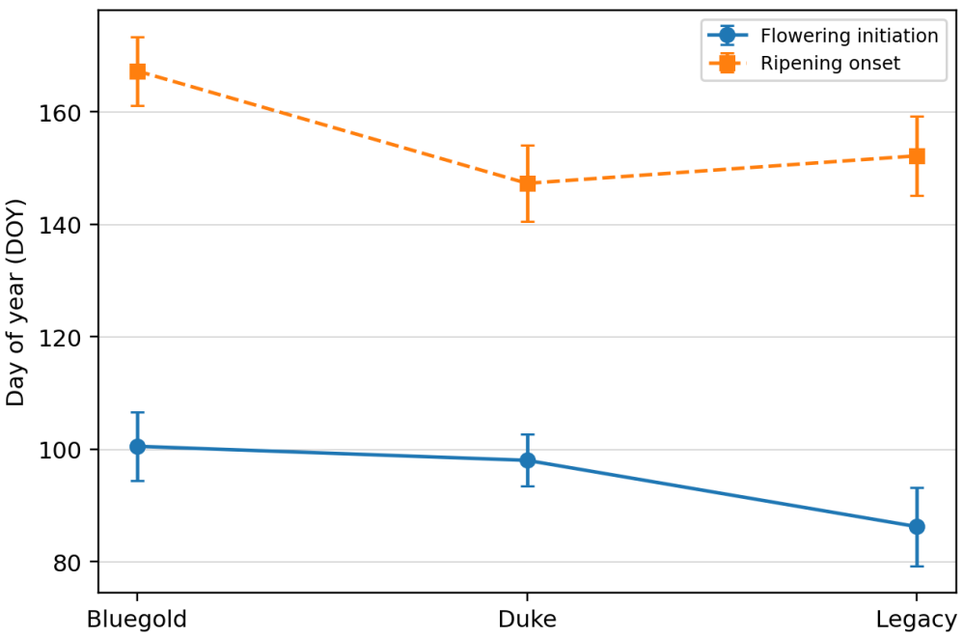

Figure 2. Mean flowering initiation and ripening onset of the evaluated cultivars expressed as day-of-year (DOY) values. Error bars represent descriptive standard deviations among municipalities

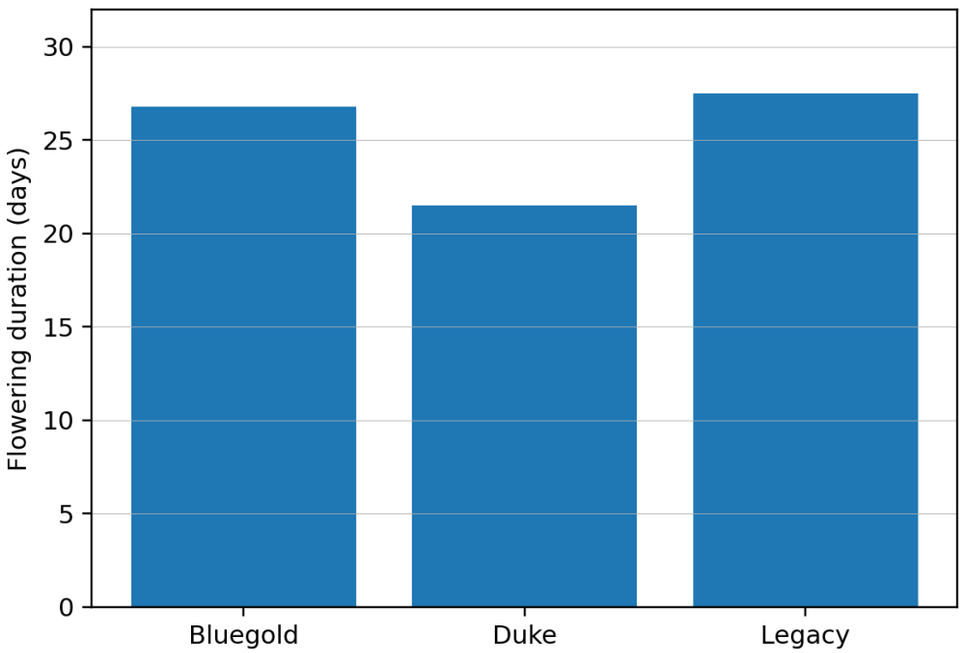

Figure 3. Mean flowering duration of highbush blueberry cultivars across the three municipalities of Adjara

Legacy also entered the flowering stage earlier than the other cultivars. Mean flowering initiation occurred on DOY 86.2 in Legacy, compared with DOY 98.0 in Duke and DOY 100.5 in Bluegold (Table 2). Flowering duration was relatively stable across locations, averaging 27.5 days in Legacy, 26.8 days in Bluegold and 21.5 days in Duke.

Table 2. Cultivar-level descriptive statistics of selected phenological and biometric traits.

Cultivar	Mean vegetation start (DOY)	Mean flowering start (DOY)	SD flowering start (days)	Mean ripening start (DOY)	SD ripening start (days)	Mean flowering duration (days)	Mean bush height (m)	Mean annual shoot midpoint (cm)	CV annual shoot midpoint (%)
Bluegold	67.5	100.5	6.1	167.3	6.1	26.8	1.5	18.5	19.5
Duke	90.2	98.0	4.6	147.3	6.8	21.5	1.5	27.5	48.1
Legacy	53.3	86.2	7.0	152.2	7.1	27.5	2.0	60.5	19.3

Note: DOY = day of year; SD = standard deviation; CV = coefficient of variation. Values summarize location-to-location variation across the three municipalities and are descriptive only

Differences among cultivars were also evident in fruit-ripening dynamics. Duke showed the earliest mean ripening onset (DOY 147.3), followed by Legacy (DOY 152.2) and Bluegold (DOY 167.3). The latest ripening period was recorded in Bluegold, particularly in Qeda, where fruit ripening extended into early July (Table 1). These cultivar-level averages indicate that Legacy combined early vegetative and reproductive development with prolonged flowering duration, whereas

Bluegold exhibited the latest phenological progression and Duke occupied an intermediate position for flowering initiation while showing the earliest average ripening onset.

3.2. Municipality-related variation in phenological timing

Location-related shifts in phenological development were observed among the three municipalities (Table 3; Figure 4). Kobuleti exhibited the earliest mean vegetation onset (DOY 65.2), flowering initiation (DOY 89.8) and ripening onset (DOY 150.0). Khelvachauri displayed intermediate values for all phenological parameters, whereas Qeda consistently showed delayed development.

Table 3. Municipality-level descriptive statistics of phenological development and vegetative growth indicators.

Municipality	Mean vegetation start (DOY)	Mean flowering start (DOY)	Mean ripening start (DOY)	Mean ripening end (DOY)	Mean bush height (m)
Kobuleti	65.2	89.8	150.0	165.5	1.9
Khelvachauri	69.0	93.5	153.8	169.2	1.7
Qeda	76.8	101.3	163.0	175.8	1.5

Note: Values are means across the three cultivars within each municipality; descriptive summary only

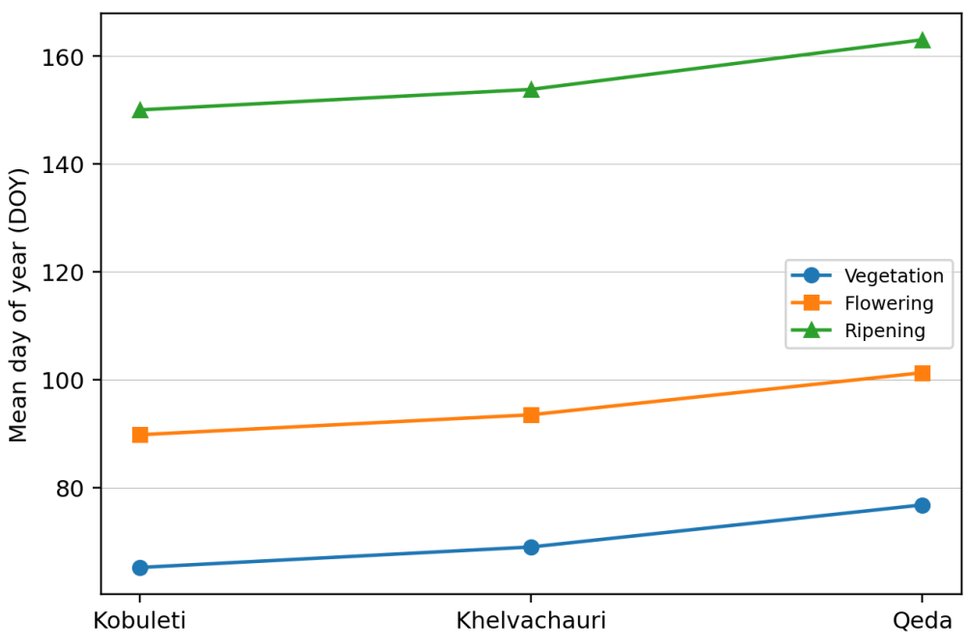

Figure 4. Municipality-related variation in mean vegetation onset, flowering initiation and ripening onset

The magnitude of these differences was evident across all cultivars. For example, vegetation onset in Legacy occurred on 17 February in Kobuleti but on 29 February in Qeda. Similarly, the ripening period of Legacy shifted from late May-early June in Kobuleti to June in Qeda. Average ripening termination also differed among municipalities, occurring on DOY 165.5 in Kobuleti, DOY 169.2 in Khelvachauri and DOY 175.8 in Qeda (Table 3). These results demonstrate a progressive delay in phenological development from the coastal municipality of Kobuleti toward the more upland conditions of Qeda.

3.3. Biometric performance of cultivars

Biometric measurements revealed notable differences in vegetative growth among cultivars and locations (Tables 2 and 4; Figures 5 and 6). Legacy exhibited the greatest vegetative vigor across all municipalities. Bush height reached 2.2 m in Kobuleti, 2.0 m in Khelvachauri and 1.8 m in Qeda. The same cultivar also produced the longest annual shoots, with observed maximum values of 105 cm in Kobuleti and 103 cm in Qeda.

Table 4. Biometric characteristics of the evaluated blueberry cultivars across three municipalities of Adjara.

Municipality	Cultivar	Bush height (m)	Annual shoot length (cm)
Kobuleti	Legacy	2.2	35-105
Kobuleti	Bluegold	1.8	20-25
Kobuleti	Duke	1.7	40-45
Khelvachauri	Legacy	2.0	25-70
Khelvachauri	Bluegold	1.5	15-20
Khelvachauri	Duke	1.6	15-20
Qeda	Legacy	1.8	25-103
Qeda	Bluegold	1.3	13-18
Qeda	Duke	1.3	20-25

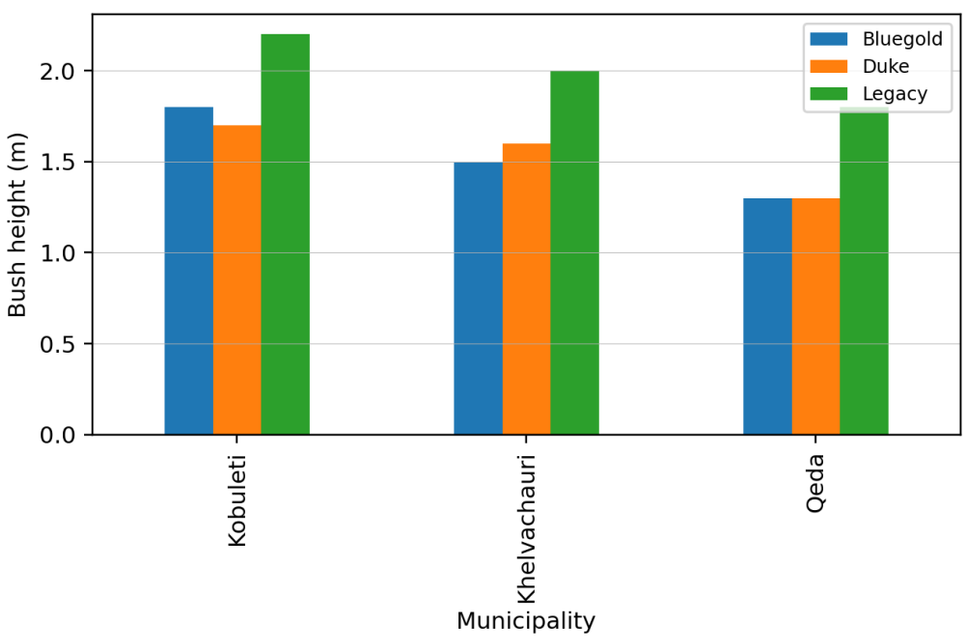

Figure 5. Bush height of the evaluated blueberry cultivars in Kobuleti, Khelvachauri and Qeda

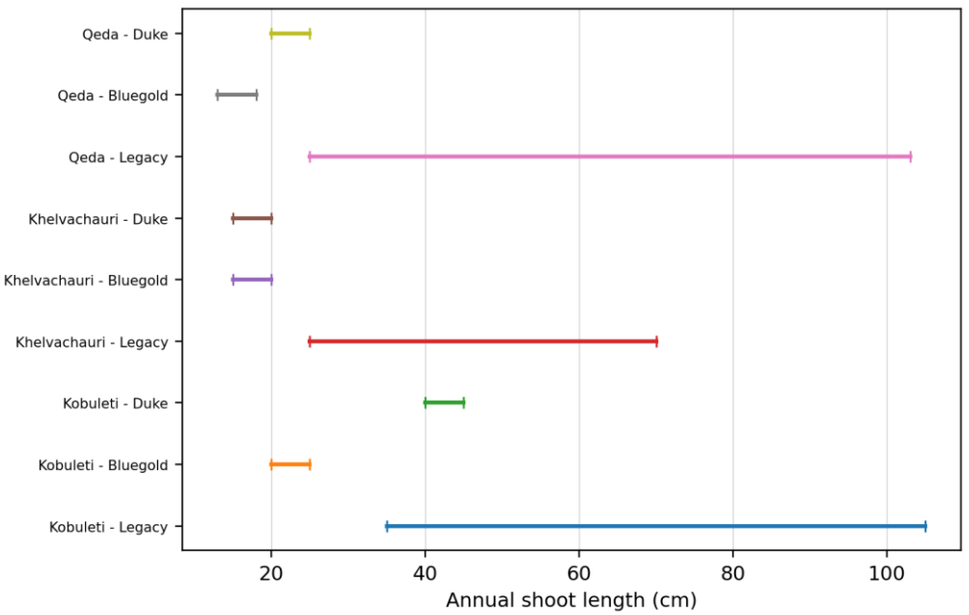

Figure 6. Observed annual shoot-length ranges of the evaluated cultivars across municipalities

Bluegold displayed comparatively lower vegetative growth. Bush height ranged from 1.3 to 1.8 m across municipalities, while annual shoot length varied between 13 and 25 cm, with the lowest values recorded in Qeda. Duke showed intermediate biometric characteristics. Bush height ranged from 1.3 to 1.7 m, while annual shoot length varied between 15 and 45 cm. Compared with Legacy, Duke produced shorter annual shoots but maintained relatively consistent growth across municipalities.

Cultivar-level descriptive statistics confirmed these patterns (Table 2). Legacy achieved the highest mean bush height (2.0 m) and the greatest mean annual shoot midpoint value (60.5 cm), whereas Bluegold and Duke both averaged 1.5 m in bush height. Coefficients of variation for annual shoot midpoint values ranged from 19.3% in Legacy to 48.1% in Duke, indicating differences in growth consistency across locations.

The descriptive statistical analysis provided an integrated overview of cultivar- and municipality-level variation in phenological and biometric traits (Tables 2 and 3). Among cultivars, Legacy recorded the earliest mean vegetation onset and flowering initiation as well as the highest mean bush height. Duke exhibited the earliest mean ripening onset, while Bluegold recorded the latest mean ripening onset.

Variation among municipalities followed a consistent spatial pattern. Mean vegetation onset progressed from DOY 65.2 in Kobuleti to DOY 76.8 in Qeda. Mean flowering initiation increased from DOY 89.8 in Kobuleti to DOY 101.3 in Qeda, while mean ripening onset shifted from DOY 150.0 to DOY 163.0 over the same gradient. Overall, the descriptive statistics confirmed distinct cultivar-specific and location-related patterns in phenological development and vegetative growth under the agroecological conditions represented in this study.

3.4. Descriptive statistical summary

Appendix Table A1. Converted day-of-year and midpoint values used for descriptive visualization and statistical summaries.

Municipality	Cultivar	Vegetation start DOY	Flowering start DOY	Flowering end DOY	Ripening start DOY	Ripening end DOY	Flowering duration midpoint	Annual shoot midpoint (cm)
Kobuleti	Legacy	48.0	80.5	112.0	146.0	162.5	28.0	70.0
Kobuleti	Bluegold	61.5	95.0	127.0	162.0	178.0	28.5	22.5
Kobuleti	Duke	86.0	94.0	115.0	142.0	156.0	21.0	42.5

Municipality	Cultivar	Vegetation start DOY	Flowering start DOY	Flowering end DOY	Ripening start DOY	Ripening end DOY	Flowering duration midpoint	Annual shoot midpoint (cm)
Khelvachauri	Legacy	52.0	84.0	117.0	150.5	168.0	27.5	47.5
Khelvachauri	Bluegold	66.0	99.5	131.5	166.0	181.5	26.5	17.5
Khelvachauri	Duke	89.0	97.0	118.5	145.0	158.0	20.5	17.5
Qeda	Legacy	60.0	94.0	125.0	160.0	173.0	27.0	64.0
Qeda	Bluegold	75.0	107.0	141.0	174.0	190.0	25.5	15.5
Qeda	Duke	95.5	103.0	124.5	155.0	164.5	23.0	22.5

Note: DOY = day of year. Values were calculated from the midpoint of source date ranges. Midpoint values are descriptive only

4. DISCUSSION

The present study demonstrated cultivar-specific and location-related differences in phenological development and vegetative growth among the introduced highbush blueberry cultivars Legacy, Bluegold and Duke under the agroecological conditions of Adjara. Although the dataset is limited to a single growing season and does not include replicated experimental observations, the observed patterns provide useful preliminary evidence regarding cultivar adaptation and production potential in Western Georgia.

Legacy consistently showed the earliest vegetation onset and flowering initiation across all municipalities. Early phenological development may be advantageous for growers targeting premium early-season markets, because fruit can be harvested before peak supply. However, early development may also increase vulnerability to late spring frost events and unfavorable pollination conditions. Similar relationships

between early flowering and environmental risk exposure have been reported in blueberry studies showing that flowering phenology is highly responsive to temperature accumulation and seasonal climatic variability (Kirk & Isaacs, 2012). Consequently, the early developmental pattern observed in Legacy should be interpreted as both an agronomic advantage and a management challenge, particularly under increasingly variable spring weather conditions.

Duke showed relatively later vegetation onset and flowering while maintaining the earliest average ripening onset among the evaluated cultivars. This combination is practically important because delayed flowering may reduce exposure to damaging spring weather while still allowing commercially attractive harvest timing. Previous research has emphasized the importance of integrating flowering phenology, chilling requirements, freeze tolerance and deacclimation dynamics when evaluating blueberry adaptation to changing climatic conditions (Lobos & Hancock, 2015; Chu, 2025). The phenological profile observed in Duke therefore suggests a potentially favorable balance between production security and market timing.

Bluegold displayed the latest ripening pattern and comparatively weaker vegetative growth in the available observations. Although later ripening may reduce competitiveness in premium early-season markets, it can contribute to extending the harvest period and diversifying production schedules. This characteristic may be especially relevant for cooler production zones, where delayed phenological development can support a more continuous supply of fresh fruit. The extension of ripening into July in Qeda illustrates the importance of matching cultivar selection with local environmental conditions.

The municipality-level differences further emphasize the need for microzonal evaluation. Phenological development consistently occurred earliest in Kobuleti, was intermediate in Khelvachauri and was delayed in Qeda. These differences likely reflect variation in temperature regime, altitude and local climatic conditions. Similar genotype-by-environment interactions have been documented in blueberry production systems worldwide. For example, Cosmulescu et al. (2022) reported significant effects of cultivar identity and climatic year on blueberry phenology, while Pavliuk et al. (2025) demonstrated substantial variation in phenological and pomological traits across multiple environments and years. The present findings support the conclusion that cultivar recommendations for Adjara should be location-specific rather than based on generalized regional assumptions.

Biometric observations were generally consistent with the phenological findings. Legacy exhibited the greatest vegetative vigor, as reflected by bush height and annual shoot growth. Vigorous vegetative development may support future productivity through increased canopy formation and reproductive potential. However, excessive vegetative growth

can also influence canopy structure, light penetration and fruit-quality management unless balanced by appropriate pruning and crop-load regulation (Retamales & Hancock, 2018). Conversely, the weaker growth observed in Bluegold may reflect cultivar characteristics, environmental influences, management history or their interaction. Because the present study was not designed to isolate these effects experimentally, caution is required when interpreting biometric differences as direct indicators of genetic performance.

An important methodological implication concerns the standardization of phenological monitoring. The BBCH scale for highbush blueberry provides a comprehensive framework for describing vegetative growth, flowering, fruit development, ripening and harvest stages in a consistent manner (Wichura et al., 2024). Its adoption in Georgian blueberry research would improve comparability among studies, facilitate integration with international datasets and strengthen future phenological modeling. Such standardization is increasingly important as climate variability continues to influence crop development and production planning.

Recent research also highlights the broader significance of phenological traits in blueberry improvement. Babiker et al. (2025) reported associations between phenological variation and the stability of fruit-quality traits in cultivated tetraploid blueberry. This suggests that phenological adaptation should not be viewed solely as a determinant of flowering and harvest timing, but also as a factor potentially influencing long-term fruit quality and production stability. Future cultivar evaluation in Georgia should therefore integrate phenological, biometric, yield and fruit-quality assessments within a unified framework.

Several limitations must be acknowledged. The analysis was based on one growing season, lacked replicated plot-level measurements and did not include yield, fruit quality, soil characteristics, management practices or detailed meteorological variables. Consequently, the findings should be interpreted as preliminary and hypothesis-generating rather than definitive evidence of cultivar superiority. Multi-year replicated trials incorporating environmental, physiological and economic performance indicators are required to validate the patterns identified in this study and to support robust cultivar recommendations for commercial production.

5. CONCLUSIONS

The introduced highbush blueberry cultivars Legacy, Bluegold and Duke demonstrated distinct phenological and biometric responses under the agroecological conditions of Adjara, Western Georgia. The results revealed clear cultivar-specific and location-related variation in vegetation onset, flowering dynamics, ripening timing and vegetative growth.

Legacy exhibited the earliest phenological development and the greatest vegetative vigor, indicating strong preliminary adaptation potential for early-season production, particularly in coastal environments. Duke combined relatively later flowering with the earliest average ripening onset, suggesting a potentially advantageous balance between reduced exposure to spring weather risks and commercially favorable harvest timing. Bluegold displayed the latest ripening pattern and comparatively lower vegetative vigor, indicating potential value as a complementary cultivar for extending the harvest season, especially in cooler production zones.

Phenological development consistently occurred earlier in Kobuleti, was intermediate in Khelvachauri and was delayed in Qeda, highlighting the importance of location-specific cultivar evaluation. These findings demonstrate that cultivar recommendations for Adjara should consider local agroecological conditions rather than relying on uniform regional recommendations.

Although the available dataset was limited, the study provides a useful preliminary framework for cultivar zoning and adaptation assessment in Western Georgia. Future research should validate these findings through multi-year replicated trials integrating meteorological, phenological, biometric, yield, fruit-quality and pest-pressure data to support evidence-based recommendations for commercial blueberry production.

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