

# Peculiarities of Development of Phenological Phases of Some New Introduced Cultivars of Blueberry (*Vaccinium corymbosum* L.) in Georgia (Guria Region)

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## Research Article

### Abstract

The purpose of this study was to feature the phenological phases of the 6 newly introduced blueberry (*Vaccinium corymbosum* L.) varieties in the region of Guria, in Georgia. For this study was selected southern (New Hannover, Legacy, Gupton) and northern (Bluegold, Duke, Bonus) high bush blueberry cultivars.

The main phenological phases (bud break, flowering, maturity, end of vegetation) of plant development were studied according to a modified version of the BBCH berry scale. The result shows that the phenological phases markedly differs according to varieties and years. It was found out that, on average, in the following conditions, the legacy is the earliest variety which starts vegetation and the Bluegold is the latest. Depending on the varieties, flowering begins on average at the beginning of April and lasts 21-24 days. The maturity period starts from the first decade of June and lasts until the end of July. From the following varieties, New Hannover and Duke belonged to the group of early season varieties, Legacy and Bonus to medium and Gupton and Bluegold to the late season. Northern highbush varieties (Bluegold, Bonus and Duke) start to go to dormancy earlier (from the second half of October) than southern highbush varieties.

**Keywords:** Northern highbush; Southern highbush; Phenology; Flowering; Maturity period; Dormancy; Georgia

### Highlights

- Peculiarities of blueberry phenological phases in Guria region were analyzed.
- The periods and durations of vegetation, flowering, maturity and dormancy of introduced varieties were determined.
- The phenological phases of the introduced blueberry varieties in Ozurgeti municipality in the Guria region are different depending on the year, although the phases take place in the same

month.

- In the Guria region, in the village of Likhauri, the harvested varieties are harvested from the first decade of June and continue until July.
- Among the varieties available in the research in Ozurgeti municipality, the early-season varieties are New Hannover and Duke, the medium season varieties are Legacy and Bonus and the late season varieties are Gupton and Bluegold.
- Varieties begin vegetation in the first decade of February and finish in mid-March, although climatic data can significantly vary the beginning of vegetation.
- Climate has the greatest influence on the initiation of vegetation in New Hannover.
- Maturity period is 18-28 days according to research varieties.
- There is a correlation between the length of the maturity period and flowering  $R=0.87+0.34$ .

### Introduction

Blueberry belongs to the family *Ericaceae* and genus *Vaccinium* [1,2]. It is a perennial bushy, berry plant. The fruit has a bluish-black epidermis, which is covered with waxy flakes and gives the berries a light blue color. The color of the juice and berry pulp ranges from cream-white to green [3,4]. It is known that blueberries are one of the richest sources of a number of substances useful for humans, including antioxidants and various vitamins [5,6].

It should be noted that blueberry (*V. corymbosum* L.) is a very important and interesting new berry crop for industrial purposes, whose commercial value and production volumes in the world are irreversibly

increasing [7]. Currently, the global blueberry area in the world is 248,660 ha and the production reaches 1,860,080 tons [8].

It is significant that the history of research and production of this culture in Georgia begins only from 2005. Nevertheless, the scale of the current growth of the blueberry production sector is impressive. If the total area of blueberry orchards did not exceed 30 ha in 2012 in Georgia, already in 2022, the areas occupied by the mentioned culture exceeded 2500 ha. It is interesting to note that over the last 15 years; more than 30 varieties of blueberries have been introduced in Georgia by various international programs, scientific organizations, nurseries and private companies [9].

It should be taken into account that blueberry in Georgia is commercially found mainly in western Georgia due to soil and climate characteristics. The main regions of blueberry production are: Samegrelo-Zemo Svaneti, Imereti, Guria and Adjara [10].

It should be noted that most of the common varieties of blueberries come from the Northern highbush and Southern highbush. Due to the location of Western Georgia, it belongs to mid-high chill location. Because of this, southern varieties in commercial orchards are mainly planted in mid chill regions, where plants collect 400-800 chilling hours and in the case of the Northern varieties in conditions more than 800-1000 chilling units [11]. In late autumn and winter, blueberries enter in dormancy and this time the vegetative growth of the plant does not continue and the metabolic activities of the green parts are significantly reduced [12].

Well known that flowering and ripening times is very significantly depending on the location and climatic conditions of the year [13]. If the variety cannot collect the chilling hours, it can be raised problems related to fruit development, reduce the intensity of flowering, which leads to low yield [14].

Therefore, optimal selection of cultivars has a special importance and the introduced varieties in Georgia require targeted research, about their economic usefulness and ecological plasticity in the region, which quite differ from other countries by climatic and soil conditions. Unfortunately, apart from some fragmentary studies [15,16], there are few local studies on the commercial and biological characteristics of blueberry varieties and the evolution of development of phenological phases of blueberry in Georgia, especially in the research region of Guria, which is the second largest blueberry area in Georgia, the mentioned research is being conducted for the first time.

Based on the above, the purpose of this study is to evaluate the features of the phenological phases of blueberry varieties in the Guria region and to make appropriate conclusions in the mentioned direction.

Scientific studies confirm that in different countries blueberry varieties phenologically develop differently. For

example, in Spain (Andalusia, Huelva) blueberry varieties begin flowering in late January or early February. Maturity and harvesting starts from the second half of April and lasts until July [17].

Also, on the base of the research in Portugal showed that the varieties-Legacy, Elizabeth and Duke is flowering in the months of February-March. Harvesting of these varieties begins at the end of May (Legacy) and the latest variety begins ripening at the end of June (Elizabeth) [18].

It is interesting to note that in the climatic conditions of Southern Poland, blueberries begin flowering quite late, only in the first decade of May and last for 14-20 days. The dormancy of blueberry in Poland starts from the middle of November and lasts until the end of January. The blueberry harvesting season in Poland starts from July 1 and lasts until the end of September [19]. The main blueberry varieties in the USA (Florida) start flowering in late winter or early spring. Harvesting starts from March and continues until the end of May [20].

## Materials and Methods

The object of the study was 6 introduced leading cultivars, predominantly grown in the Guria region of Georgia (Figure 1). In particular, the southern highbush types which include New Hannover, Gupton, Legacy and the Northern highbush type which include Duke, Bonus and Bluegold (Figure 2).

The varieties were planted in a commercial farm, plants were planted in the spring of 2020 in the village of Likhauri, (Köppen classification: Cfa humid subtropical climate) south part of Ozurgeti, in the western hilly part of Guria-Adjara mountains, at an altitude of 90 meters above sea level (latitude/longitude: 41.973691, 41.888270) (Figure 3).

The climate in this area is characterized by moderately warm winters and hot summers. The average annual temperature is 13.0°C-13.5°C, 4.8°C in January, 22.3°C in July. Absolute minimum (since 1980) is -10°C to -12°C, absolute maximum is 40°C to 41°C. The annual amount of precipitation is around 1700 mm-1900 mm (Figure 4).

Soil-red soil (nitisol), with high acidity and low presence of stones. The soil is characterized by the following characteristics: pH: 4.5; organic matter: 3.2%; carbonates: 0.5%; clay (<2 µm): 33%; silt (2-50 µm): 7%; sand (>50 µm): 48%.

## Short description of research cultivars

**New Hannover:** Southern highbush, bred in 2007 by hybridization of varieties NC 1522 × O'Neal. Breeders: James Ralph Ballington and Susan Rooks (North Carolina State University, USA). New Hannover is an early-medium season variety. According to the data, the demand for chilling is 600-800 hours [21]. Introduced in Georgia in 2018 by Bluefield Company.

**Gupton:** Southern highbush, obtained by crossing of MS122 × MS6. The variety was selected in 1991 by Drapper et al. (USA). This variety is of medium season.

It is characterized by good hardiness. According to the data, the demand for chilling is 600-800 hours. It is characterized by high fruit quality and pulp hardiness. Introduced in Georgia in 2018 by Bluefield.

**Legacy:** Southern highbush, obtained by hybridization of Elizabeth x US 75 in 1976 D. Drapper (USA) Legacy is early-medium season variety. The variety is characterized by strong growth and the leaves are clearly green. The plant do not leave the leaves even during the winter season. The demand for chilling is 400-600 hours. Legacy is Introduced in Georgia in 2007.

**Duke:** Northern highbush, was bred by crossing G-100 x 192-8 in 1972 by American breeders (G. Galeta, N Vorsa, G Jelenkovich, A.D. Draper) in the USA. It was put into sale in 1987. Duke is early season variety. The demand for chilling more than 800 hours. Introduced in Georgia in 2005.

**Bluegold:** Northern highbush, bred by crossing MEUS-5 x bluehaven in 1976 by A.D. Draper. Bluegold is mid-late season variety. The fruits are characterized by high hardiness, the shape of the bush is directed upright. The demand for chilling in dormancy more than 800 hours. Introduced in Georgia in 2005.

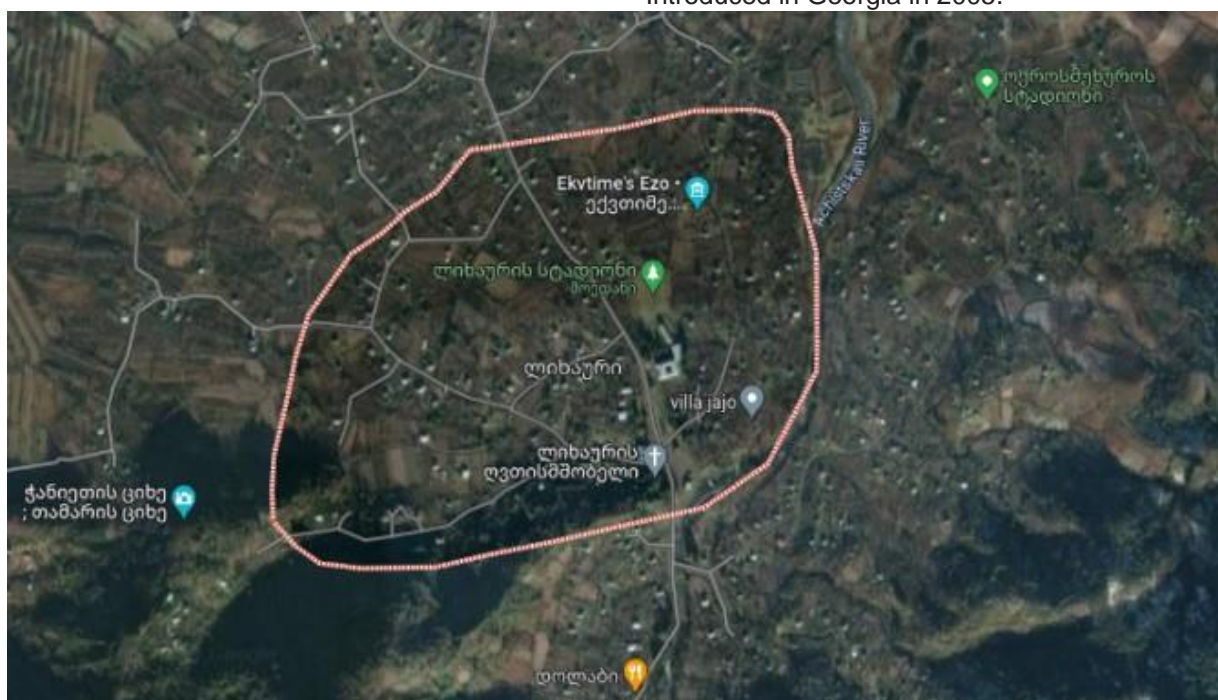


Figure 1: Research location - Likhauri village, Ozurgeti Municipality, Guria.



Figure 2: Blueberry orchard-Likhauri village.



Figure 3: Study cultivars site location.

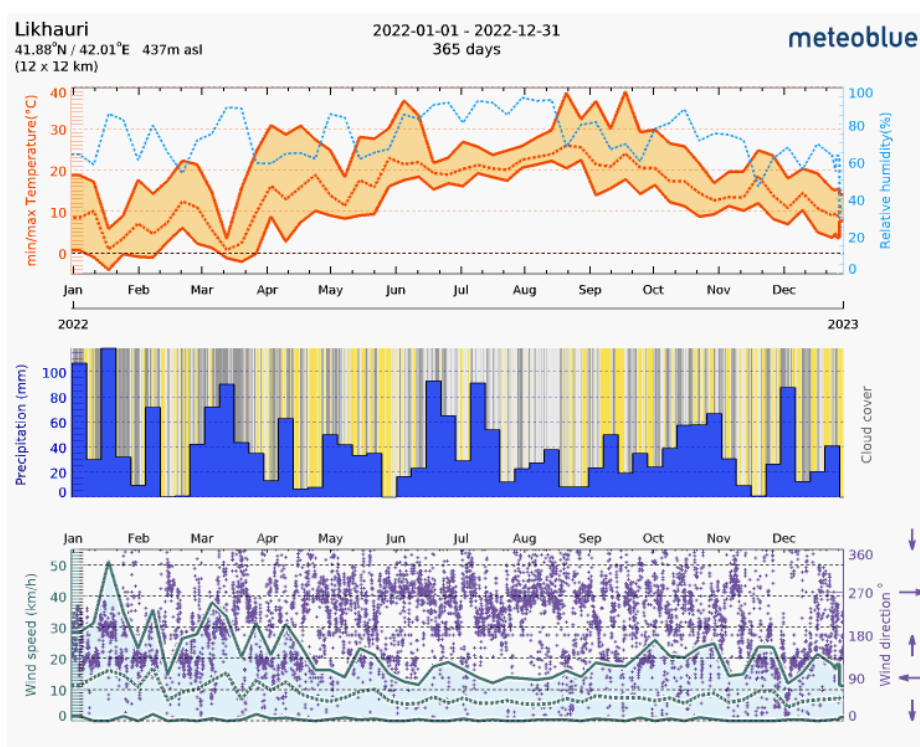


Figure 4: Data from the satellite weather station (MeteoBlue) of the research object (2022).

**Bonus:** Northern highbush, bred by University of Michigan by breeder James Hancock, Bonus is a mid-late season variety. The bush is characterized by medium growth. The demand for chilling in dormancy more than 800 hours. Introduced in Georgia in 2020 by the blueberry farm.

Agronomic practices of the experiment plants were purchased from a commercial nursery; the age of the plants is 1.5 years. Planting layout is 3.0 × 1.0 meters (3333 plants 1 ha), raised beds (width-60 cm; height-25 cm), with drip irrigation system (with integrated/compensating drippers, 0.5 m distance, 1.6 l/h), polyethylene PVV with woven film mulching.

In the orchard was used routine agronomic practices for blueberry (fertigation-N 90-P60-K 90+Micro Mg+Micro, foliar feeding-amino acids, Ca, Mn, Mg, B, Zn and others), IPM practices (12 sprays per season, combined fungicides and insecticides), between the rows established sod with permanent mowing-mulching (on the 50 cm perimeter of raised beds was used contact-systemic herbicide).

For research 5 plants were taken in randomized blocks for each variety in 3 repetitions, in total was - 90 plants. The studied plants were well developed and were not damaged.

Phenological studies were carried out according to the

following UPOV Blueberry TG/137/5 descriptors, with Michigan University protocol and a modified version of the BBCH scale. As a result of this, the following phenological development phases were recorded as per the given BBCH code.

- Beginning of vegetative growth (green bud)-BBCH 03/ When the first vegetative buds begin to open.
- The phase of the beginning of the bud break-BBCH 52-53/10% of flower buds is separated.
- The beginning of the pink bud-BBCH 54-55/10% of flower buds is pink.
- Appearing popcorn phase-BBCH 58-59/10% of flowers are fully formed.
- Beginning of flowering on a one year shoot-BBCH 61/10% of flowers is open.
- Massive flowering-BBCH 65-66/50% of flowers is open.
- End of flowering-BBCH 67-69/90% of flowers is open, 10% of flowers is closed.
- Green fruit phase-BBCH 74/when 10% or more of the fruits turn green.

- The pink phase of fruits-BBCH 76-77/when more than 10% of the fruits turns pink.
- Beginning of the fruit coloring-BBCH 80-81/when more than 10% of the fruits turn a purple-blue color.
- The beginning of maturity-BBCH 82-83/when 10% of the fruits turn blue and reach maturity.
- Full maturity-BBCH 84-85/when 75% of the fruits have been picked or turned blue and reach ripeness for harvesting.
- End of maturity-BBCH 86-87/when the last 10% of the fruits are ready to harvest.
- The beginning of the dormancy-BBCH 93/when 10% of the leaves start fall.

### Results and Discussions

It was established as a result of the conducted research the characteristics of the development of phenological phases of new varieties of blueberry (*Vaccinium corumbosum*) in the Guria region. In 2021 and 2022, full phenological phases were observed, and in 2023 until the end of maturity (Tables 1-3).

**Table 1.** Research results-2021 (day/month/year).

	Legacy	New Hannover	Gupton	Duke	Bonus	Bluegold
Beginning of vegetation	5/2/2021	25/2/2021	5/3/2021	8/3/2021	12/3/2021	16/3/2021
The beginning of flowering	8/4/2021	10/4/2021	29/4/2021	20/4/2021	27/4/2021	17/4/2021
End of flowering	1/5/2021	4/5/2021	25/5/2021	7/5/2021	16/5/2021	7/5/2021
Duration of flowering, days	23	24	26	17	19	20
The beginning of maturity	20/6/2021	14/6/2021	30/6/2021	20/6/2021	20/6/2021	2/7/2021
The end of maturity	14/7/2021	5/7/2021	20/7/2021	8/7/2021	10/7/2021	25/7/2021
Maturity duration, days	24	21	20	18	20	23
Beginning of leaf fall	5/11/2021	1/11/2021	1/11/2021	18/10/2021	22/10/2021	22/10/2021
Vegetation duration, days	273	249	241	224	224	220
The end of leaf fall	10/11/2021	12/11/2021	18/11/2021	28/10/2021	6/11/2021	2/11/2021

**Table 2.** Research results-2022 (day/month/year).

	Legacy	New Hannover	Gupton	Duke	Bonus	Bluegold
Beginning of vegetation	10/2/2022	16/2/2022	2/3/2022	6/3/2022	9/3/2022	15/3/2022
The beginning of flowering	16/4/2022	24/4/2022	27/4/2022	20/4/2022	19/4/2022	15/4/2022
End of flowering	12/5/2022	15/5/2022	19/5/2022	10/5/2022	12/5/2022	10/5/2022
Duration of flowering, days	26	21	22	20	23	25
The beginning of maturity	24/6/2022	13/6/2022	30/6/2022	13/6/2022	22/6/2022	20/6/2022
The end of maturity	17/7/2022	6/7/2022	24/7/2022	3/7/2022	14/7/2022	16/7/2022
Maturity duration, days	23	23	24	20	22	23
Beginning of leaf fall	30/12/2022	25/12/2022	27/12/2022	1/12/2022	28/11/2022	27/11/2022
Vegetation duration, days	323	312	300	270	264	257
The end of leaf fall	Keeps the leaves	Keeps the leaves	Keeps the leaves	5/12/2022	5/12/2022	5/12/2022

**Table 3.** Research results-2023 (day/month/year).

	<b>Legacy</b>	<b>New Hannover</b>	<b>Gupton</b>	<b>Duke</b>	<b>Bonus</b>	<b>Bluegold</b>
Beginning of vegetation	2/2/2023	8/2/2023	1/3/2023	5/3/2023	7/3/2023	12/3/2023
The beginning of flowering	29/3/2023	28/3/2023	2/4/2023	13/4/2023	12/4/2023	10/4/2023
End of flowering	22/4/2023	24/4/2023	28/4/2023	29/4/2023	30/4/2023	29/4/2023
Duration of flowering, days	24	27	26	16	18	19
The beginning of maturity	15/6/2023	7/6/2023	21/6/2023	12/6/2023	14/6/2023	21/6/2023
The end of maturity	13/7/2023	3/7/2023	16/7/2023	5/7/2023	10/7/2023	16/7/2023
Maturity duration, days	28	26	25	23	26	25

Observation of the vegetation period showed that blueberry varieties in Ozurgeti municipality begin vegetation in February-March, when the first vegetative buds begin to open (Table 4). As a result of the research, it was found that the beginning of bud break varies from year to year, however, regardless of the difference in climatic conditions, the varieties start vegetation in the first decade of February and finish in the middle of March.

According to the climate data of 2022, the average temperature in February was 5.66°C and in March, it was 7.38°C. In 2023, the average temperature in February was 4.42°C and in March, it was 8.29°C.

The research showed that the largest differences between vegetation start are found in the case of New Hannover. If we compare 2021 and 2023, between the beginning of vegetation's of New Hannover was 17 days, when in the following varieties difference was one week.

Despite the difference in climate data, it can be seen that in 2021-2023, Legacy starts vegetation first and then New Hannover, Gupton, Duke, Bonus and Bluegold starts vegetation last.

The study showed that the flowering period varied between cultivars and years (Table 5).

In 2021, the varieties began flowering from March 8 and continue until May 25. The first which start and finish flowering was Legacy, which lasted 23 days and the last variety was Gupton.

In 2022, the average temperature in April was 10.27 degrees and in May 17.15°C like 2021, 2022 was relatively late, but again Legacy started flowering first and finished on May 12, like Bonus, after Duke and Bluegold. Also in 2022, the latest flowering ended with Gupton on May 19. The longest flowering was distinguished by Legacy, whose flowering lasted 26 days.

In 2023, the average temperature in April was 9.69°C and in May 15.48°C. Despite the relatively low average temperature, the varieties finished flowering in the month of April. Legacy and New Hannover were the first to start and finish flowering, however, unlike previous years, Duke was the last to start flowering, which continue just 16 days.

The average duration of flowering in varieties was longer in 2022 than in 2021 and 2023. In 2021, flowering lasted for 21.5 days, 22.8 days in 2022 and 21.6 days in 2023 on an average in all varieties.

Like the flowering, data analysis confirmed that harvest periods were different among cultivars and years (Table 6). In 2021 harvest period lasts 21 days, which begins with New Hannover on June 14 and ending with Bluegold on July 25. Legacy was distinguished by its long harvest period, which continued for 24 days and began on June 20, similar to Bonus and Duke. The 2021 data shows that of the mentioned varieties, New Hannover is the earliest to start harvesting, followed by Duke, Bluegold, Legacy and ending with late Gupton and Bluegold.

The average temperature for June 2022 was 21.32 degrees, when New Hannover and Duke starting harvest, followed by Bluegold, Bonus, Legacy and ending with Gupton on July 24, when average temperature of July 23.09 degrees. Unlike the previous year, Bluegold was distinguished by a long harvest period in 2022, which lasted 26 days. The average maturity duration of the mentioned year was 23 days.

In 2023, the average June temperature was 21.86 degrees, which is almost similar to the average June temperature of the previous year. Also this year, New Hannover was the first which start mature on June 7, followed by Duke, Bonus, Legacy, Bluegold and Gupton.

Average harvest period was 25.5 days, which finished firstly by New Hannover and Duke and Bluegold and Gupton was last varieties finished on June 17. Like 2021, Legacy had the longest harvest duration, which lasted 28 days.

The data of 2021-2023 show that in the Guria region, Ozurgeti municipality, the varieties New Hannover and Duke are early-season varieties, Legacy and Bonus are mid-season varieties, Gupton and Bluegold are late season varieties.

Within the framework of the study, two-year observation of leaf fall was held which varied according to varieties. In the Guria region, Ozurgeti municipality, the fall of leaves begins in late autumn.

**Table 4.** Bud break-Georgia 2021-2023 YY.

	2021	2022	2023
Legacy	5-Feb	10-Feb	2-Feb
New Hannover	25-Feb	16-Feb	8-Feb
Gupton	5-Mar	2-Mar	1-Mar
Duke	8-Mar	6-Mar	5-Mar
Bonus	12-Mar	9-Mar	15-Mar
Bluegold	16-Mar	7-Mar	12-Mar

**Table 5.** Beginning of flowering end of flowering, Georgia, 2021-2023 YY.

Years	2021		2022		2023	
	The beginning of flowering	End of flowering	The beginning of flowering	End of flowering	The beginning of flowering	End of flowering
Legacy	8-Apr	1-May	16-Apr	12-May	29-Mar	22-Apr
New Hannover	10-Apr	4-May	24-Apr	15-May	15-Mar	24-Apr
Gupton	29-Apr	25-May	27-Apr	19-May	2-Apr	28-Apr
Duke	20-Apr	7-May	20-Apr	10-May	13-Apr	29-Apr
Bonus	27-Apr	16-May	19-Apr	12-May	12-Apr	30-Apr
Bluegold	17-Apr	7-May	15-Apr	10-May	10-Apr	29-Apr

**Table 6.** Beginning of ripening-end of ripening, Georgia, 2021-2023 YY.

Years	2021		2022		2023	
	The beginning of maturity	The end of maturity	The beginning of maturity	the end of maturity	The beginning of maturity	The end of maturity
Legacy	20-Jun	14-Jul	24-Jun	17-Jul	15-Jun	13-Jul
New Hannover	14-Jun	5-Jul	13-Jun	6-Jul	7-Jun	3-Jul
Gupton	30-Jun	20-Jul	30-Jun	24-Jul	21-Jun	16-Jul
Duke	20-Jun	8-Jul	13-Jun	3-Jul	12-Jun	5-Jul
Bonus	20-Jun	10-Jul	22-Jun	16-Jul	14-Jun	10-Jul
Bluegold	2-Jul	25-Jul	20-Jun	16-Jul	21-Jun	16-Jul

It should be noted, that in 2021, Duke, Bluegold and Bonus began leaves falling in late October and Legacy, New Hannover and Gupton in early November. Duke completed the falling of leaves the earliest, at the end of October and the other varieties in the second decade of November. As a result of the research, it was found that the northern varieties begin the falling earlier than the southern varieties. By the first week of November, northern varieties were without leaves, while southern cultivars still had a small number of leaves on the top of the bush.

Despite of 2021, 2022 Years varieties did not start falling the leaves until the end of November. By mid-November, the northern varieties, Duke, Bluegold and Bonus, had red-Yellow leaves, indicating the starting of dormancy, while the southern varieties: New Hannover, Legacy and Gupton still had green leaves.

The study in 2022 showed, that leaves fall started later in the varieties than in 2021. The average temperature in November 2022 was 8.38°C and in December -3.93°C also January had a high average temperature, 4.72°C, so the southern varieties, Legacy, New Hannover and Gupton, retained their leaves and did not fall the leaves, while in 2022, Bonus and Bluegold began falling the leaves in late November and finished on December 5

with Duke, which started falling the leaves on the first of December.

As a result of the conducted research, it was possible to determine the duration of vegetation period duration of new varieties of blueberry (*Vaccinium corumbosum*) in Ozurgeti municipality.

The average vegetation duration of varieties in 2021 was 238.5 days. Legacy had the longest growing season, lasting 273 days. After Legacy, New Hannover, Gupton, Duke, Bonus were distinguished by the longest vegetation season. The shortest vegetation variety was Bluegold *Vaccinum* its duration was 220 days.

A similar sequence of vegetation was observed in 2022, however, unlike 2021, the vegetation duration of Legacy was 323 days and Bluegold was 257 days. The average duration of vegetation in varieties was 286.7 days (Supplementary figures 1-8).

## Conclusions

Despite of the difference in climatic data, the budbreak begins cultivar Legacy, then New Hannover, Gupton, Duke, Bonus and last is Bluegold. The flowering period is different according to varieties and years. Basically flowering begins in early April. Flowering time per

cultivar is average 21-23 days. The cultivar Legacy starts flowering first and finishes almost the earliest. Duke was distinguished by the shortest flowering period, whose flowering lasts 16-20 days. Gupton flowering the latest. Harvesting periods are different according to varieties and years. In the Guria region, in the village of Likhauri, harvest begins from the first decade of June and continues until the end of July. The observation of the maturity period showed that among the cultivars the early season varieties are New Hannover and Duke, the mid-season varieties are Legacy and Bonus and the late season varieties are Gupton and Bluegold. Leaves falling process varies according to varieties and years. In Guria region leaves fall begins in the second half of October (Northern highbush varieties) and ends in December (Legacy) In case of a warm winter, the southern varieties retain their leaves till next vegetation period.

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### Contribution Matrix of Authors

- Development of the idea of the article, conceptualization, drawing up of methodology and trial scheme S.T; Z.B.
- Guiding the preparation of the article Z.B.
- Data collection, field and laboratory work implementation S.T.
- Preparation of the article, analysis and interpretation of data and results, assignment of important intellectual content, verification of scientific sources S.T.
- Critical revision and final editing of the article ZB.
- All authors have read and agree to publish this version.

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The authors confirm that the given scientific paper presents their own original research and analysis, and therefore no part of it is taken from someone else's work/article and/or copied. The authors declare that there is no conflict of interest related to this article.

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