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ANALYSIS OF THE PHENOPHASES OF GROWTH AND FRUITING OF RASPBERRY VARIETIES IN THE CLIMATIC CONDITIONS OF BUCHAREST

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Abstract

The objectives of the research consist in assessing the intensity of the processes that determine the physiological growth of raspberry plants of the Delniwa variety and the Opal variety, which influence the fruiting process and the production of fruits per plant. In the framework of the experiment, the growth and fruiting of the two raspberry varieties under the influence of climatic factors from the experimental location of the raspberry culture established in 2023 within the INMA Bucharest was monitored. Thus, observations were made on the development of the main phenophases of the vegetative organs (foliar) from which the leaves and shoots developed and the fruiting organs (generative / floriferous) from which the flowers developed, hence the harvest. For both varieties, five representative plants of each variety were chosen for monitoring, from which the following parameters were measured every month of the crop`s evolution: the number of shoots, the length and diameter of the stem, the sizes of the fruits and receptacles, as well as the accumulated amounts of fruits specific to each variety analyzed.

Key words*: climatic factors, phenophases, fruits, varieties, raspberries.*

INTRODUCTION

The consumption of small fruits, especially from the genus *Rubus*, which presents an enormous morphological diversity, has increased worldwide, as they are excellent sources of bioactive compounds, especially phenolic compounds, necessary for human nutrition (Fagundes C.M., 2023). If the nutritional components of different raspberry fruits are combined with their high productivity and sensory quality, raspberry varieties are considered to be good quality crops with a high market value. Therefore, by introducing raspberry varieties that possess higher nutritional and antioxidant values, in addition to the standard of high productivity and attractive fruit appearance, it is possible to increase the consumption of healthy fruits (Milivojevic J.M. et al., 2011).

The requirements of raspberries to ecological factors are (Baciu A., 2005; Mihaescu G., 2002; Popescu M. et al., 1982; Sava P., 2017):

• Light: medium requirements;
• Temperature: average optimum: <16-17°C; soil temperature : < 16ºC;
• The relative humidity should be high with annual precipitation of 700-1000 mm (June-August);
- the optimal atmospheric humidity is 70-80% during flowering and 65-70% during the rest of the vegetation period;
- the decrease in relative air humidity below 40% negatively influences physiological processes, and when it reaches values of 20%, assimilation stops.
• Phreatic water: >80 cm;
• Soil: sandy-loamy, fertile, drained, aerated; pH 6.5; rich in nitrogen and protein.

In the paper (Sønsteby et al., 2009) the primocane Polka raspberry variety is presented, similar to the Delniwa variety from the present study, which develops and blooms even at atmospheric temperatures of 30°C, the optimum being at 27°C. But, in the paper (Carew J.G. et al., 2001), the authors present the effects of low temperatures on vegetative growth and flowering of raspberry fruits of the variety

Autumn Bliss. The plants responded significantly to cold treatment and flowering was advanced, indicating a distinct vernalizing effect.

Phenophases at raspberries represent the developmental stages of the raspberry plant, which are influenced by climatic conditions. A study revealed that the average duration of the budding and flowering phases are directly influenced by the temperature values in the months of March-April. A period of 21-65 days passed from the beginning of bud break to the beginning of flowering. A period of 26-69 days passed between the beginning of flowering of raspberry plants and the beginning of fruit ripening (Rusnac C., 2021).

Another study revealed that budding and the beginning of growth mark the start of vegetation, and in the raspberry species it occurred at the end of March, the Benefis variety on the 25th and the Opal variety on the 31st. The raspberry varieties flowered in the second decade of the month May, respectively 12 and 18 (www.cercetarepomicola.ro/).

Phenological evaluations of Primocane raspberry cultivars grown organically in a subtropical region (Fagundes C.M., 2023), respectively a coastal area with a mild climate (Cicala A. et al., 2002) showed two periods of flowering and fruiting, the first in spring/summer and the other in summer/autumn. Phenophases reflect the influence of weather factors on the vegetative and generative development of plants. Each species goes through dozens of phenophases during growing seasons (Rusnac C., 2021; Zejak, D. et al., 2021; Kluza-Wieloch M. et al., 2013; Sava P., 2013). In this sense, the present study analyzes the growth and fruiting phenophases of Opal and Delniwa raspberry varieties, in the climatic conditions of Bucharest.

MATERIALS AND METHODS

The land on which the raspberry culture was established, in March 2023, was represented by an experimental plot of 1000 m^2, located within INMA Bucharest. In order to prepare the land for the planting of the two varieties of cuttings, the land was first scarified, then ground and leveled. The raspberry varieties, scientific name *Rubus idaeus*, planted were cuttings from the Opal variety and cuttings from the Delniwa variety. Both the plant material to be planted and the soil have been ecologically certified.

The slope distance between rows was 3.3 m and between plants 0.5 m for the Opal variety, respectively 0.75 m for the Delniwa variety.

These raspberry varieties were chosen according to the characteristics of the variety, of the fruit, the harvest period, the resistance to the climate of our country, with high rooting power, resistance to frost and pests.

The characteristics of the raspberry varieties used to establish the culture were:

• The floricane variety, the Opal variety (Figure 1), has produced flowers and fruits on stems since spring, fruiting twice a year (replanted), June-July and August-September: the first time in spring on the stems of the previous year and the second time in August-September, on the top of the stems from the current year. This medium-vigorous raspberry variety has bushes with erect stems that bear fruit in the year of formation on about 1/3-1/2 of their length and have a high rooting power. The Opal variety has medium-sized fruits, with small and well-welded drupeoles between them, of a bright red color, rounded shape, intensely aromatic, sweet juicy taste (Popescu M. et al., 1982; Sava P., 2017).

Opal variety raspberry plant, height 40 cm

Ripe Opal variety

Figure 1. Opal cultivar, August 2023

• The primocane variety, the Delniwa variety (Figure 2), in which the emergence of stems, flowering and fruiting took place in the same growing season. The cycle of shoot growth and fruiting occurs in a single year. The Delniwa variety is a variety with fruiting on first-year wood, fruiting from July 15 to November 5-10. It is a Hybrid created by crossing the varieties Polka, Polana and Himbotop, premium variety,

with fruits resistant to transport and handling, they do not turn black after harvesting but keep their natural color 2-3 days after harvesting, pink. The Delniwa variety has large fruits, large drupeoles with small seeds inside each welded together, red color, rounded conical shape, intensely aromatic, sweet and sour taste (Popescu M. et al., 1982; Sava P., 2017).

Delniwa variety raspberry plant, height 120 cm

Ripe Delniwa variety

Figure 2. Delniwa cultivar, august 2023

After establishing the raspberry culture to ensure optimal maintenance, biodegradable film was applied for mulching, a support system was installed on trellises and a drip irrigation system. Also, the raspberry stems were straightened during the growing season and the weeds between the plants and between the rows were periodically removed, in order to aerate the plant and to allow growth and fruiting.

Together with the maintenance works, the phenophases of the raspberry culture were monitored: vegetative rest, bud swelling, leafing, flowering and fruit ripening. The growth and fruiting of the two raspberry varieties under the influence of climatic factors from the experimental site of raspberry culture within the INMA Bucharest was followed. Thus, observations were made on the development of the main phenophases of the vegetative organs from which the leaves and shoots developed and the fruiting organs from which the flowers developed, hence the harvest. Raspberry fruits were harvested in stages as they reached maturity.

RESULTS AND DISCUSSIONS

Taking into account the climate changes that evolve every year, it is necessary to carry out a permanent monitoring of the phenological stages of plants, to highlight the process of adaptation of plants, to identify the varieties most suitable for the given area and to intervene with certain technological procedures in the purpose of improving production quality.

As part of the experience, the growth and fruiting of the two varieties of raspberry under the influence of climatic factors from the experimental location of raspberry culture within the INMA Bucharest, for the period March-November 2023, was followed.

The values of the atmospheric parameters monitored with the help of the sensors were: precipitation (P), solar radiation (R), air temperature (Ta), soil temperature (Ts), relative humidity of the air (Ua), relative humidity of the soil (Us), these being shown in the Table 1, and evapotranspiration (ET0) and wind speed are presented in the Figure 3.

Table 1. Atmospheric conditions recorded in the nine months of raspberry vegetation, in the conditions of Bucharest

Month	P, mm	R, [W/m^2]	Ta [°C]	Ts [°C]	Ua [%]	Us [%]
March	16.4	127	8.24	7.4	71.69	41.96
April	63.0	156	10.79	10.5	79.1	42.43
May	28.6	211	16.69	14.8	68.72	28.93
June	14.4	245	21.95	20.1	64.32	14.12
July	13.2	264	25.96	23.8	60.74	12.24
August	0.6	222	26.35	24.5	53.4	10.78
September	0.0	152	22.13	21.9	54.39	9.46
October	0.8	103	15.71	16.4	65.81	8.75
November	53.2	58	8.2	10.8	84.09	11.25

Figure 3. Wind speed and evapotranspiration

The maximum precipitation was recorded in April (63 mm) and November (53.2 mm), and the lowest precipitation was in August (0.6 mm) and October (0.8 mm). No precipitation was recorded in September. The amount of precipitation during March and November was 190.4 mm. The maximum solar radiation was 264 W/m^2 in July.

Regarding the values of air temperature and soil temperature, we note from the Table 1 that in the months of May and October, the values of these parameters are close to those reproduced in the

specialized literature (Mihaescu G., 2002), namely optimal temperatures of approximately 16-17^{0}C. Atmospheric humidity does not fall within the optimum of 60-80%, as recommended in the literature (Baciu A., 2005; Mihaescu G., 2002; Popescu M. et al., 1982; Sava P., 2017), in August, September. Also in these months, the soil moisture values were low (below 10%). The maximum wind speed (0.9 m/s) was recorded in May and September and the minimum of 0.4 m/s in October. Evapotranspiration recorded increasing values of over 100 mm from May to August, this being a factor that can easily cause plants to get sick.

During the vegetation and fruiting, from March to November, the plants were monitored and weekly and monthly measurements were recorded over time, in order to see the evolution and development of the cuttings and fruits.

Phenological development stages of raspberry plants

1. ***Vegetative dormancy***

- The period of vegetative rest is usually 6 months, October-March.
- The vegetation period varies from 180 days to 260 days.

2. ***Swelling of buds***

- This stage takes place in March.

3. ***Foliage***

- The first leaves of the Opal variety appeared in April and annual shoots of the Delniwa variety appeared in May.
- For the Opal variety, the leaves were counted in the months of April and May, their number varying from 3 to 5 leaves per plant, then in June and July the side shoots grown on the drajon planted in March were counted, these being between 3 and 9 lateral shoots per plant. In the months of August and September, the annual shoots grown from the root of the dragon plant planted in March were counted, these were 1, 2 or 3 annual shoots depending on each individual plant.
- For the Delniwa variety, the annual shoots grown from the root of the planted dragon fruit were counted, which also bore fruit and their number was from 1 to 4 annual shoots depending on each plant.

4. ***Flowering***

In the experimental varieties, flowering (Figures 4 and 5) occurred:

- for the Opal variety in May on the lateral shoots, then the second flowering took place in mid-August on the annual shoots.
- for the Delniwa variety in June on the annual shoots grown from the root of the planted cutting.

Figure 4. Foliage and flowering in the Opal variety

Figure 5. Foliage and flowering in the Delniwa variety

5. ***Fruit ripening***

- In the Opal variety, the first ripening of the fruits took place in the June-July period and the second ripening in the September-October period (Figure 6), depending on the weather conditions.
- In the Delniwa variety, the fruits ripened from the end of July until November (Figure 7).

Figure 6. The first ripening (left) and the second ripening (right) of the Opal variety

Figure 7. Fruit ripening in the Delniwa variety

The fruits of the two varieties (Figure 8) present the following characteristics:

• The Opal variety has medium-sized fruits, with small and well-welded drupeoles between them,

of a bright red color, rounded shape, intensely aromatic, sweet juicy taste, weighing between 2.5 and 1.2 grams, receptacles with heights between between 0.6-0.9 cm (Figure 9).

• The Delniwa variety has large fruits, large drupeoles with small seeds inside each welded together, red color, rounded conical shape, intensely aromatic, sweet and sour taste, weighing between 6.1 and 4.3 grams, receptacles with heights between 0.4-2.0 cm (Figure 9).

Opal variety

Delniwa variety

Figure 8. Raspberry fruit sizes

Opal variety

Delniwa variety

Figure 9. Dimensions of the receptacles of raspberry

Figure 9 shows the shape and dimensions of the receptacles of the two raspberry varieties.

In both varieties, daily observations and monthly measurements of stem length and diameter were made (Tables 2 and 3), as well as the number of fruits and their quantities accumulated monthly on certain plants, depending on the variety.

The average measurements for the height of the Opal variety plants varied from 35.5 cm for plant 2 to 65.7 cm for plant 4, and the stem diameter varied from 4.4 mm for plant 2 to 8.1 mm for plant 1.

The average measurements for the height of the Delniwa variety plants varied from 34.6 cm for plant 5 to 64.9 cm for plant 3, and the stem diameter varied from 8.6 mm for plant 2 to 12.2 mm for plant 2.

Table 2. The dimensions of the plants of the Opal variety

	Plant height (cm)				
Month	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
April	36.00	30.00	38.00	35.00	35.00
May	45.50	31.50	39.50	40.00	37.50
June	49.00	32.50	45.10	46.00	44.00
July	55.00	34.00	51.00	49.00	51.00
August	71.00	37.00	61.00	91.00	96.00
September	91.00	48.00	116.00	133.00	121.00
	Plant stem diameter (mm)				
April	5.29	4.41	6.73	5.21	5.86
May	5.68	4.66	7.14	5.37	4.83
June	6.59	5.75	7.73	6.09	5.11
July	9.22	3.03	5.47	6.26	6.99
August	10.22	3.58	7.75	9.05	11.54
September	11.88	5.21	8.57	12.23	12.4

Table 3. The dimensions of the plants of the Opal variety

	Plant height (cm)				
Month	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
April	20.00	22.00	24.50	13.50	19.50
May	26.00	26.50	28.00	15.00	24.10
June	32.00	40.00	37.00	39.00	31.00
July	53.00	76.00	86.00	45.00	41.00
August	52.00	97.00	102.00	81.00	37.00
September	55.00	111.00	112.00	130.00	55.00
	Plant stem diameter (mm)				
April	6.00	8.23	6.12	7.20	6.10
May	6.94	8.84	6.86	7.70	6.98
June	7.78	9.37	10.55	8.70	7.39
July	9.23	12.19	11.85	9.37	9.43
August	10.16	16.27	15.81	11.04	10.22
September	11.23	18.42	16.41	12.72	12.04

The figures show the monthly production from the first year correlated with the number of fruits for each of five randomly chosen plants from the establishment of the culture for the two raspberry varieties.

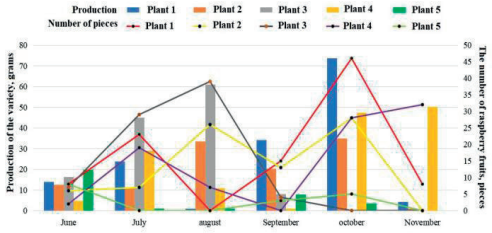

Figure 10. Raspberry crop production, Opal variety

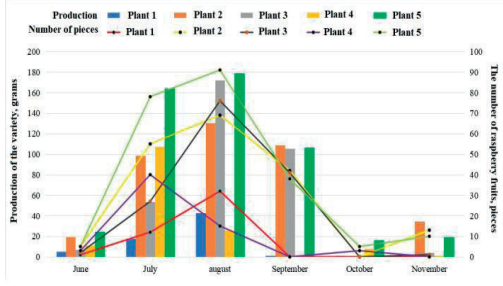

Figure 11. Raspberry crop production, Delniwa variety

From the analysis of Figure 10, it can be seen for the Opal variety that at plant 1, 151.1 g was obtained per 100 pieces, at plant 2, 113.5 was obtained at 80 pieces, at plant 3, 130.6 g was obtained at 79 pieces, at plant 4, 143.5 g was obtained from 88 pieces and at plant 5, 33.4 g was obtained from 16 pieces of fruit. The average variations of the weight of a fruit were 1.42-2.08 g.

From the analysis of Figure 11, it can be seen for the Delniwa variety that at plant 1, 68.5 g was obtained from 45 pieces, at plant 2, 391.5 was obtained from 184 pieces, at plant 3, 342.4 g was obtained from 147 pieces, at plant 4, 154.2 g was obtained from 61 pieces and at plant 5, 508.4 g was obtained from 227 pieces of fruit. The average variations of the weight of a fruit were 1.52-2.52 g.

CONCLUSIONS

From the correlation of the atmospheric conditions recorded in the nine months of vegetation of the year 2023, in the conditions of Bucharest, with the productions obtained in the two raspberry varieties studied, the following was found:

- the Opal variety produces small fruits, a plant of this variety can produce between 16 pieces with a total weight of 33.4 g per plant and up to 100 pieces with a total weight of 151.1 g per plant; the first ripening of the fruits in June-July on the lateral shoots of the cuttings planted in March and the second ripening in September - October on the annual shoots grown from the root of the cutting planted in spring; the dimensional characteristics of the plants: (Table 2) the smallest growth in height of 18 cm in plant 2 and the largest growth of 98 cm in plant 4; stem diameter of 0.8 mm in plant 2 and 7.02 mm in plant 4.
- the Delniwa variety produces large fruits, a plant of this variety can produce between 45 pieces with a total weight of 68.5 g per plant and up to 227 pieces with a total weight of 508.4 g per plant; ripening was later and longer from July to November, with maximum amounts of ripening between July and September; the dimensional characteristics of the plants (Table 3) the smallest growth in height of 35.0 cm in plants 1 and 5, and the largest growth of 116.5 cm in plant 4; stem diameter of 5.2 mm in plant 1 and 10.29 mm in plant 3.

The analysis of the growth and fruiting phenophases can be an indication of the intensity of the physiological processes that determine plant growth and that influence the fruiting process and the production of fruits per plant.

Knowing and establishing the phenophase of the plant is important for farmers in the context in which it allows certain works, operations to be carried out at the optimal time, for example such as combating diseases, pests, cutting.

In general, the good growth of raspberries for both varieties indicates that the production of Opal and Delniwa raspberry varieties can be implemented in Bucharest (Baneasa area), which can provide a continuous and long-term supply of fresh raspberries on the market, as well as fruits good quality.

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