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Influence of abiotic factors on sambucus nigra l. Phenorhythmics under central chernozem conditions

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Abstract. This article is the research of the influence of meteorological conditions on the passage of phenophases on the example of black elderberry in the conditions of the Belgorod region. Direct dependence of the developmental phases of black elderberry on the meteorological conditions of the growing season was revealed. It was found that the course of phenological phases in representatives of this species growing in natural conditions is less dependent on the meteorological deviations of each specific year, in comparison with plants growing in artificially created environmental conditions.

1. Introduction

Black elderberry is one of the most common plants in Russia in natural conditions. Among the species of the genus Sambucus L. available in the collection, representatives of this species are the most demanding on the temperature factor for the beginning and passage of all phenological phases. Black elderberry is a shrub or tree 2-6 m high. Leaves are opposite, 20-30 cm long, pinnate, with 3-7 leaves. The flowers are white or yellowish-white, collected in multi-flowered corymbose inflorescences. The fruit is a juicy, black-purple drupe with 2-4 seeds; the taste is sweet and sour with a special aftertaste. Fruiting on the growths of the last year. Bears fruit annually and abundantly. The root system is superficial [1-4]. This work aims to study the influence of temperature regime on the seasonal rhythm of development of black elderberry.

2. Methodology

The studies were carried out in the conditions of the Central Black Earth Region based on the botanical garden of the National Research University BelSU. The temperature characteristics of the years under study are presented according to the data of the meteorological station of the village. Races of the Belgorod region of the Belgorod region. Phenological observations were carried out according to the "Method of phenological observations in the botanical gardens of the USSR" [5-6].

3. Results and discussion

The beginning of the growing season (bud opening). Blossoming of buds in black elderberry plants is observed (figures 1a, b) with a stable transition of average daily air temperatures to 0 °C.

Figure 1. Sambucus nigra L.: a - the phase of the opening of the vegetative bud; b - the phase of the opening of the generative kidney; c - the phase of the beginning of the growth of shoots; d - flowering phase; d - maturation phase; e - ripe elderberry brush.

Table 1. Depending on the weather conditions of each specific year, the onset of this phenological phase occurs at different times.

Year	Data	∑t°>0°C	Precipitation,mm.
2015	08.04±1	50.4	153.1
2016	24.04±1	192.6	245.7
2017	10.04±1	200.7	135.1
2018	26.03±1	100.6	141.6
2019	15.04±2	129.7	195.8
$\bar{x}$	10.04±10	134.8	115.7
σ	9.7	63.3	48.7
V,%	24	46.9	-
r data/∑t°>0°C	-	0.55	-
r data/ precipitation	-	-	0.73

The table above (table 1) illustrated the dependence of the passage of the beginning of the growing season on abiotic factors, where is the mean value, σ is the standard deviation, V is the coefficient of variation, r is the coefficient of correlation, ∑t°> 0°C is the sum of positive temperatures.

Depending on the weather conditions of each specific year, the onset of this phenological phase occurs at different times (table 1). Thus, the earliest budding in black elderberry was noted in 2018 (26.03 ± 1), which was directly related to the early spring of the year 2018 and a significant increase in relatively short periods of average daily air temperatures in March. The entry into this phenophase by black elder plants was homogeneous, as evidenced by the insignificant standard deviation of ± 1 - 2 days. The sum of positive air temperatures required for plants to enter this phenophase in the year 2018 was 100.6 °C. The latest beginning of the phenophase of kidney opening was noted in 2016 (24.04 ± 1 day), with a sum of positive temperatures of 192.6 °C, which is directly related to the protracted and rather cold spring of this year and the transition of average daily air temperatures to 0 ° C only in the third decade of March. The average long-term period for the onset of bud budding was recorded in the region of 10.04 ± 10 days. The mean long-term value of the sum of positive temperatures by the moment of the beginning of this phenophase was 134.8 ± 63 °C. During the observation period, the variation of this indicator was determined by the nature of weather conditions in the early spring period, the amplitude of the transition of average daily air temperatures from negative values to positive values, and in some years it ranged from 50.4 ° C (2015) to 200.7 °C (2017). The onset of the bud opening phase in black elderberry plants, according to the results of long-term studies, has a heterogeneous character, as evidenced by a rather significant variability from year to year with a deviation from the mean value of ± 10 days and a significant value of the coefficient of variation (Vδ) - 24% for the date of the onset of the phenophase and 47% for the sum of positive temperatures. There is a direct correlation of the mean value (r = + 0.55) between the sum of positive temperatures and the date of the beginning of the phase. A high-degree direct correlation (r = + 0.73) was revealed between the amount of precipitation at the beginning of the precipitation phase and the date of entry of Sambucus nigra L. into the bud opening phase.

Shoot growth begins (SGB)). The passage of this phenophase by black elderberry plants (figure 1c) has a number of its peculiarities revealed during the period of research. In particular, the earliest onset of this phase in plants was noted in 2018 (12.04 ± 1) (table 2), which, as in the case of the beginning of the bud opening phase, is confirmed by the significantly warm and early spring of this year. The sum of positive temperatures by this moment reached a value of 261.3 °C. Latest start date of the phase table 2.

Table 2. Dependence of the passage of the phase of the beginning of shoot growth on abiotic factors.

Year	Data	∑t°>0°C	Precipitation,mm.
2015	01.05±1	299.6	170

2016	11.05±1	382.5	263.5
2017	25.04±1	308.7	141.8
2018	12.04±1	261.3	150.4
2019	05.05±1	352.7	201.8
$\bar{x}$	29.04±10	321	141.6
σ	9.8	47.3	49.3
V,%	16	14.7	-
r data/∑t°>0°C	-	0.93	-
r data/ precipitation,mm	-	-	0.75

The dependence of the passage of the phase of the beginning of shoot growth on abiotic factors was revealed in 2016 (11.05 ± 1), when the sum of positive temperatures reached 382.5 ° C. The amount of precipitation at that time was only 12.7% of the average annual norm. The average long-term start of shoot growth was recorded in the region of 29.04 ± 10 days. The mean long-term value of the sum of positive temperatures by the time of the beginning of this phenophase was 321 ± 47 °C and had a range of values from 261.3 °C (2018) to 382.5 °C (2016). The onset of the phase of the beginning of shoot growth in Sambucus nigra L. plants, according to the results of long-term studies, has a heterogeneous character, as evidenced by a rather significant variability from year to year with a deviation from the average value of ± 10 days and the average value of the coefficient of variation - 16% for the date of the onset of the phenophase and 15% for the sum of positive temperatures. There is a direct correlation of a high degree (r = + 0.93) between the sum of positive temperatures and the date of the beginning of the phase. A high degree of correlation (r = + 0.75) was revealed between the amount of precipitation at the beginning of the precipitation phase and the date of entry of Sambucus nigra L. into the phase of the start of shoot growth. There is a high correlation between the date of bud opening and the date of the start of shoot growth - r = + 0.95 (table 3.6).

Flowering period (FP). The course of this phenological phase has several specific characteristics (table 3). According to the results of long-term observations, the blooming of black elderberry (figure 1d) on average begins in the period from 31.05 ± 4 days when the sum of positive temperatures reaches 792.8 °C; the coefficient of variation of this feature is insignificant - 5% for the date of the start of the phase and 8% for the sum of positive temperatures. The earliest beginning of flowering was noted in 2015 (25.05 ± 2 days) with a sum of positive temperatures of 691.5 °C, and the latest - in 2016 (07.06 ± 1 day) with a sum of positive temperatures of 816.9 °C. A direct correlation of the average value was established between the date of the beginning of flowering and the sum of positive temperatures (r = + 0.47).

Table 3. Dependence of the passage of the flowering phase on abiotic factors.

Year	Start			Completion			Overall
	Data	∑t°>0°	Precipitation,m	Data	∑t°>0°	Precipitation,m	/
2015	25.05±	691.5	225.8	11.06±	1016.1	284.6	17±2
2016	07.06±	816.9	295.1	20.06±	1036.9	347.7	14±1
2017	29.05±	843.1	158.8	13.06±	1148.2	177.2	15±0
2018	30.05±	843.1	256.4	20.06±	1207.3	285.6	21±1
2019	02.06±	769.4	253.8	17.06±	1061.4	266.4	15±2
$\bar{x}$	31.05±	792.8	190	16.06±	1093.9	223.6	16±3
Σ	4.4	64.1	50.7	3.9	80.9	61.4	2.8
V,%	4.7	8.1	-	3.6	7.4	-	17

r data/$\sum t^o>0^o$	-	0.47	-	-	0.32	-	-
r data/ precipit	-	-	0.60	-	-	0.54	-
r $\sum t^o>0^oC$/ days	-	-	-	-	-	-	0.69
r precipit / days	-	-	-	-	-	-	-0.01

The dependence of the passage of the flowering phase on abiotic factors with a direct relationship between the peculiarities of the weather characteristics of a particular year and the beginning of plants in the growing phase. There is also a direct correlation of average degree between the date of the beginning of the growing season and the date of the beginning of flowering (r = + 0.65), as well as between the beginning of growth and the beginning of flowering (r = + 0.50) (table 6). The end of flowering in black elderberry plants, as well as the beginning, is determined primarily by the nature of the weather conditions. The long-term average date of the end of the flowering period was noted on 16.06 ± 4 days when the sum of positive temperature marks reached 1094 °C. There are year-to-year deviations for the entire observation period ranging from 11.06 ± 1 day with the sum of positive temperatures from 1016.1 ° C (2015) to 20.06 ± 2 days with the sum of positive temperatures 1207.3 °C (2018). The correlation relationship between the date of the end of the phase and the sum of positive temperatures, as well as between the date of the end of the phase and precipitation, is slightly lower than similar relationships at the time of the beginning of flowering and, accordingly, r = + 0.32 and r = + 0.54. The coefficient of variation for the phase of completion of flowering averaged 3.6%, which indicates a slight discrepancy of this indicator for the entire observation period and the relative constancy in the course of this phenophase in black elderberry plants. A high direct relationship between the dates of the beginning and end of flowering was determined - r = + 0.77 (Table 6). The duration of the flowering phase for the entire observation period for Sambucus nigra L. plants averages 16 ± 3 days with an average coefficient of variation of 17%, which characterizes this indicator for representatives of this species as relatively constant with the noted deviations from the average: minimum - 14 days ± 1 (2016), maximum - 21 days ± 1 (2018). A high direct correlation was revealed between the duration of the flowering period and the sum of positive temperatures at the end of this phenological phase (r = + 0.69). A high inverse dependence of the flowering duration on the beginning of the growing season (r = -0.88) and at the start of shoot growth (r = -0.83), i.e. the later the start date of the growing season and the start date of shoot growth, the shorter the flowering period for black elderberry. A moderate inverse relationship is also observed between the duration of flowering and its onset (r = -0.48).

Ripening period. The beginning of this phenological phase in representatives of Sambucus nigra L. (figures 1 e, f) has a number of the following characteristics (table 4). The beginning of ripening falls on the third decade of July - the first decade of August (28.07 ± 7 days), with the highest among all the species of elderberry, the long-term average value of the sum of positive temperatures 1928.3 ± 169 °C. The greatest deviations from this date were noted in 2015 (21.07 ± 2 days) with a sum of positive temperatures of 1740.1 ° C and in 2019 (08.08 ± 6 days) with a sum of positive temperatures of 2165.3 ° C. The value of the coefficient of variation for the average date of the onset of ripening and the average sum of positive temperatures is, respectively, 4.4% and 8.7% for each.

Table 4. Dependence of the passage of the maturation phase on abiotic factors.

Year	Start			Completion			Overall
	Data	$\sum t^o>0^o$	Precipitation,m	Data	$\sum t^o>0^o$	Precipitation,m	/
2015	21.07±	1740.1	393.7	12.08±	2218.3	436.8	21±2
2016	28.07±	1794.5	425.1	19.08±	2256.9	440.5	22±1
2017	25.07±	1988.3	318.8	16.08±	2469.3	361	23±2

2018	27.07±	1953.1	335.9	20.08±	2489.7	360.4	23±1
2019	08.08±	2165.3	317.7	27.08±	2501.6	321.3	21±3
$\bar{x}$	28.07±	1928.3	315.3	19.08±	2387.2	356.3	22±2
σ	6.6	168.6	48.5	5.3	137.7	52.4	1.7
V,%	4.4	8.7	-	3.1	5.8	-	7.8
r data/∑t°>0°	-	0.82	-	-	0.64	-	-
r data/ precipit.	-	-	-0.39	-	-	-0.69	-
r ∑t°>0°C/	-	-	-	-	-	-	0.29
r precipit / days.	-	-	-	-	-	-	-0.02

The revealed direct correlation of a high degree between the sum of positive temperatures and the beginning of fruit ripening in black elderberry (r = + 0.82) indicates the dependence of the onset of this process on the weather conditions of a particular year. Besides, the existing inverse correlation of the average degree between the onset of maturation and the amount of atmospheric precipitation at that moment (r = -0.39) indicates that earlier maturation will be noted in cases where the amount of precipitation is greater. A direct correlation of the average value was noted between the beginning of flowering and the beginning of ripening - r = + 0.40 (table 6).

The end of the phase of fruit ripening takes place in the second - third decade of August with an average long-term value of 19.08 ± 6 days; the sum of positive temperatures by this moment reaches 2387.2 ± 138°C. The earliest ripening was noted in 2015 (12.08 ± 4 days) with a sum of positive temperatures of 2218.3°C, and the latest in 2019 (27.08 ± 2 days) when the sum of temperatures above 0 ° C reached 2501.6°C. The value of the coefficient of variation is 3.1% for the date and 5.8% for the sum of positive temperatures, which indicates the relative constancy of this feature over the entire observation period. As well as the beginning, the completion of maturation occurs in direct dependence on the temperature conditions of the year, as evidenced by the direct correlation of the average degree between the sum of positive temperatures and the end of the phase (r = + 0.64), and the inverse dependence on the amount of precipitation on the moment of the end of the phase (r = -0.46). A direct correlation of the mean value was recorded between the end of ripening and the beginning of flowering (r = + 0.52) and the end of flowering (r = + 0.54) (table 6).

The duration of fruit ripening in black elderberry over the entire observation period is on average 22 ± 2 days with an average value of the coefficient of variation equal to 7.8%, which indicates the constancy of this indicator with existing deviations in different years from 21 ± 3 days (2019) to 23 ± 1 days (2018). A low correlation was noted between the duration of ripening and the sum of positive temperatures at the end of this phenological phase, which has a value of r = + 0.29.

The period of leaf falls. The beginning of this phenological phase for the entire study period falls on average in mid-September - 14.09 ± 3 days (table 5) with the lowest sum of positive temperatures among all elderberry species (2857.4 ± 133 ° C) and a certain variation at the level of 1.3% for the date of the start of the phase and 4.6% for the sum of temperatures above 0°C.

Table 5. Dependence of the passage of the leaf fall phase on abiotic factors.

Year	Start			Completion			Overall
	Data	∑t°>0°	Precipitation,m	Data	∑t°>0°	Precipitation,m	/
2015	14.09±	2803.8	445.3	19.10±	3246.8	479.4	35±2
2016	17.09±	2721.2	515	23.10±	3133.4	540.6	35±1
2017	15.09±	3037.6	401.8	19.10±	3409.1	518.4	34±2
2018	15.09±	2954.5	383.5	16.10±	3302.7	461.2	31±1

2019	11.09±	2769.7	334.1	12.10±	3165.2	348.2	32±2
$\bar{x}$	14.09±	2857.4	396.7	18.10±	3251.4	444.7	33±2
Σ	2.5	133.2	68.2	3.851	110.5	74.7	2.1
V,%	1.3	4.7	-	1..7	3.4	-	6.4
r data/∑t°>0°	-	0.11	-	-	-0.01	-	-
r data/ precipit.	-	-	0.83	-	-	0.93	-
r ∑t°>0°C/	-	-	-	-	-	-	-0.15
r precipit / days	-	-	-	-	-	-	0.69

The maximum deviations from the average value were recorded in 2009 (11.09 ± 3 days) when the sum of positive temperatures reached 2769.7 ° C. and in 2006 (17.09 ± 1 day) with the value of the sum of positive temperatures 2721.2 ° C. A high direct correlation was revealed between the amount of precipitation at the beginning of the phase and the beginning of leaf fall (r = + 0.83). An inverse correlation of an average degree is observed between the beginning of leaf fall and the beginning (r = - 0.49) and also the end (r = - 0.40) of maturation (table 6).

The end of leaf fall occurs on average in the second decade of October - 18.10 ± 4 days with a noted average sum of positive temperatures of 3251.4 ° C. The homogeneity of this indicator is confirmed by the insignificant value of the coefficient of variation at around 1.7% for the date of the end of the phase and 3.4% for the sum of positive temperatures. The earliest completion of leaf fall was noted in 2019 when the value of the sum of positive temperatures was 3165.2 C° and the latest - in 2016 with the lowest value of the sum of temperatures above 0 ° C from the entire series (3133.4°C). A direct correlation of a high degree (r = + 0.93) between the end of leaf fall and the amount of precipitation was determined, which is confirmed by the noted amplitudes at the end of this phase by years. Besides, an inverse correlation of the average value (r = -0.55) between the end of leaf fall and the beginning, as well as the end of maturation, was revealed (table 1 and 6).

In general, the duration of leaf fall for the noted period of research is a relatively constant value, as evidenced by the following criteria for assessing the phase: the average duration of the phase is 33 ± 2 days with an insignificant value of the coefficient of variation - 6.4%. The available largest deviations from the average over the years refer to 2018 (31 ± 1 day) and 2015 (35 ± 2 days) years. The duration of leaf fall in black elderberry is greatly influenced by the amount of precipitation, as evidenced by a high direct correlation (r = + 0.69) between these indicators. A direct correlation of average degree (r = + 0.54) was revealed between the duration of leaf fall and the beginning of the growing season (table 6). A medium inverse relationship (r = -0.42) exists between the onset of ripening and the duration of leaf fall, as well as between the duration of flowering and the duration of leaf fall (r = -0.54).

Table 6. Correlation coefficient for phenological phases of Sambucus nigra L.

r	B.v.p.	B.f.g.p	B.fl.p.	C.fl.p.	L.fl.p	B.m.p	C.m.p	L.m.p	B.l.f	C.l.f	L.l.f
B.v.p	-	0.95	0.65	0.09	-0.88	0.24	0.18	-0.21	0.10	0.37	0.54
B.f.g.p	-	-	0.50	-0.04	-0.83	0.23	0.10	-0.31	-0.01	0.30	0.55
B.fl.p	-	-	-	0.77	-0.48	0.38	0.52	0.14	0.22	0.19	0.08
C.fl.p	-	-	-	-	0.19	0.35	0.54	0.27	0.24	-0.01	-0.30
L.fl.p	-	-	-	-	-	-0.11	-0.07	0.17	-0.01	-0.30	-0.54
B.m.p	-	-	-	-	-	-	0.88	-0.25	-0.49	-0.55	-0.42
C.m.p	-	-	-	-	-	-	-	0.13	-0.40	-0.55	-0.53
L.m.p	-	-	-	-	-	-	-	-	0.31	0.08	-0.22

B.l.f	-	-	-	-	-	-	-	-	-	0.86	0.36
C.l.f	-	-	-	-	-	-	-	-	-	-	0.79
L.l.f	-	-	-	-	-	-	-	-	-	-	-

4. Conclusion

The duration of leaf fall is a relatively constant value, as evidenced by the following criteria for assessing the phase: the average duration of the phase is 33 ± 2 days with an insignificant value of the coefficient of variation - 6.4%. The largest deviations from the average over the years refer to 2018 (31 ± 1 day) and 2015 (35 ± 2 days) years.

The duration of leaf fall in black elderberry is greatly influenced by the amount of precipitation, as evidenced by a high direct correlation (r = + 0.69) between these indicators.

Revealed a direct correlation of average degree (r = + 0.54) between the duration of leaf fall and the beginning of the growing season.

Between the onset of ripening and the duration of leaf fall, there is an inverse relationship of average degree (r = -0.42), as well as between the duration of flowering and the duration of leaf fall (r = -0.54).

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