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К вопросу об отнесении *Pisum sativum* к группам спелости в Красноярской лесостепи

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Даны рекомендации отнесения гороха к группам спелости в условиях Красноярской лесостепи. Исследования проводились в 2017–2023 гг. Объекты исследования – образцы гороха. Количество анализируемых образцов в разные годы изменялось от 178 шт. в 2018 г. до 74 шт. в 2022 г. и в общей сложности за период исследования составило 937 шт. Исследование образцов проводилось в питомнике изучения исходного материала (коллекции) Красноярского НИИСХа согласно методике ВИР. Почва опытного участка – чернозем обыкновенный среднемощный среднегумусный тяжелосуглинистый. Погодные условия лет исследования различались по тепло- и влагообеспеченности вегетационного периода, изменяясь от засушливых до достаточно увлажненных. Определяли продолжительность вегетационного периода, ее зависимость от ГТК и наиболее приемлемую методику отнесения образцов к группам спелости в условиях региона. Продолжительность вегетационного периода образцов зависела от ГТК периода июнь – август. На основании проведенных исследований с учетом градаций согласно международному классификатору рода СЭВ и методике Госсортосети, а также при расчете ГТК вегетационного периода предложена схема отнесения образцов гороха к группам спелости в условиях Красноярской лесостепи. В засушливых условиях вегетационного периода для классификации рекомендуется следующее распределение образцов: ультраскороспелые (менее 60 сут), скороспелые (61–65), среднескороспелые (66–70), среднеспелые (71–75), среднепоздние (76–80), позднеспелые (81–85), очень позднеспелые (более 90 сут). В увлажненных условиях вегетационного периода (достаточном и недостаточном увлажнении): ультраскороспелые (менее 70 сут), скороспелые (71–75), среднескороспелые (76–80), среднеспелые (81–85), среднепоздние (86–90), позднеспелые (91–95), очень позднеспелые (более 96 сут). Чрезмерное выпадение осадков в августе позволяет сдвинуть сроки градации в сторону позднеспелого созревания, повышение температур – в сторону раннеспелости.

Ключевые слова: вегетационный период, горох, продолжительность, группы спелости, методика, ГТК

To the question of attributing *Pisum sativum* to maturity groups in the Krasnoyarsk forest-steppe

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Recommendations for pea maturity groups in the conditions of the Krasnoyarsk forest-steppe are given. The research was conducted in 2017–2023. The objects of research were pea samples. The

number of the analyzed samples in different years varied from 178 pieces in 2018 to 74 pieces in 2022 and totaled 937 pieces during the study period. The study of the samples was carried out in the nursery of the source material (collection) research of the Krasnoyarsk NIISKh according to the methodology of VIR. Soil of the experimental plot was ordinary chernozem medium thick medium-humic heavy loamy soil. Weather conditions of the years of the study differed in terms of heat and moisture availability during the growing season, changing from dry to sufficiently humid conditions. The duration of the growing season, its dependence on HTC and the most acceptable method of assigning samples to maturity groups in the conditions of the region were determined. The duration of the growing season of the samples depended on the HTC of the June–August period. On the basis of the conducted research, taking into account the gradations according to the international classifier of the CMEA genus and the methodology of the State Variety Testing Network, as well as when calculating the HTC of the vegetation period, the scheme of assigning pea samples to maturity groups in the conditions of the Krasnoyarsk forest-steppe was proposed. In arid conditions of the growing season, the following distribution of samples is recommended for classification: ultra-early ripening less than 60 days, early-ripening 61–65 days, medium early-maturing 66–70 days, medium-maturing 71–75 days, middle-late 76–80 days, late maturing 81–85 days, very late maturing more than 90 days. In humidified conditions of the growing season (sufficient and insufficient moisture): ultra-early ripening less than 70 days, early-ripening 71–75 days, medium early-maturing 76–80 days, medium-maturing 8–85 days, middle-late 86–90 days, late maturing 91–95 days, very late maturing more than 96. Excessive precipitation in August allows grading dates to be shifted toward late maturing, increased temperatures toward early maturing.

Keywords: growing season, peas, duration, maturity groups, methodology, HTC

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INTRODUCTION

The duration of the growing season of cultivated plant varieties, which allows them to be assigned to one or another ripeness group, depends on the genotype of the variety, cultivation conditions (geographical location) and the interaction of these factors [1]. The genotype of a sample may respond differently to growing conditions [2–4]. Even the substances contained in the soil can influence the duration of the period [5]. Soil-climatic conditions that determine the duration of the growing season also affect the adaptive capacity of the genotype [6]. The issue of assigning pea samples to ripeness groups is very ambiguous, its study may have its individual features in different climatic zones.

To assign pea samples to maturity groups, various methodologies can be used. According to the international CMEA classifier of the genus *Pisum* L. (1986)[1], the maturity group of cultivars corresponds to the number of unproductive nodes up to the first flower (in non-fasciated forms): ultra-early ripening (< 8); early-maturing (8–9); middle-early maturing (10–11); medium-maturing (12–14); semi-late (15–16); late maturing 17–18; very late maturing (> 18).

When using this methodology, it should be taken into account that in recent years, as a result of targeted breeding efforts, the phenotype

[1]International CMEA classifier of the genus *Pisum* L./ ed. by I.A. Tarasyuk. L.: VIR, 1986, 54 p.

and genotype of pea plants have undergone significant changes—new cultivars of various morphotypes with shortened stems and high lodging resistance have been developed [7–9]. Plant height, in turn, is strongly influenced by internode length and moderately correlated with the number of internodes [10]. Therefore, the changes that have occurred in the genotype and phenotype of the plants may have introduced adjustments to this method of determining cultivar maturity groups.

Under the conditions of the Tambov region during the study period from 1995 to 2017, using the CMEA classifier which identifies seven maturity groups, the authors classified the pea cultivars as ultra-early ripening variety samples with the period sprouting – ripening from 50 to 55 days, as early-maturing – from 56 to 60, as middle-early maturing – from 61 to 65, as medium-maturing – from 66 to 70, as semi-late – from 70 to 75, as late maturing – from 76 to 80 and very late maturing from 81 day and more [11]. This classification system is logically consistent and aligns with the methodology of the State Variety Testing Network (Gossortoset), where pea accessions are evaluated according to maturity groups (early-, mid-, and late-maturing). A significant criterion for assigning cultivars to maturity groups is a minimum observed difference of 5 days in the duration of this developmental phase[2].

Under the conditions of the Central Chernozem region, while analyzing the sample of studied pea accessions for the period 2016-2018, the authors applied the following classification: early-maturing – 60–75 days, medium-maturing – 76–85, late maturing – 86–100 days [12]. In the Rostov region during 2018–2020, the authors found that the average duration of the vegetative period among the 100 pea accessions they studied was 81.8 days, with annual variations ranging from 71.2 to 93.8 days [13]. In their study of the collection accessions under the conditions of Northern Kazakhstan (2021–2022), the authors determined that the longest vegetative period (81 days) in their sample was observed in short-stemmed accessions [14].

The growing season duration response in some plant species depends on the amount of positive temperatures [15]. In Eastern Siberia, a clear dependence of pea vegetation period duration on precipitation and temperature was also revealed: it increases with more precipitation, but decreases with increasing average daily temperatures [16].

Studies conducted in Kazakhstan have also determined that the vegetation period of a variety is not constant, but varies according to both climatic conditions of the zone and the year of cultivation [17]. A significant influence of moisture regime conditions on the duration of the growing season was revealed in Kirov region [18].

At the same time, it remains necessary to be able to characterize an individual sample, attributing it to one or another group of ripeness in a particular area. The absence of a specific regulation for assigning samples to ripeness groups in the conditions of the region actualizes this study.

The purpose of the study was to identify the most acceptable methodology for assigning seed pea accessions to ripeness groups in the Krasnoyarsk forest-steppe and to compare the duration of the growing season of pea accessions with climatic conditions.

MATERIAL AND METHODS

The research was conducted in the Krasnoyarsk forest-steppe in the fields of the Krasnoyarsk Research Institute of Agriculture in the laboratory of pea breeding. The soil of the experimental field was represented by medium-thick medium-humus heavy loamy ordinary chernozem.

The weather conditions of the years of research differed in heat and moisture availability during the growing season and varied from dry to sufficiently moistened (see Table 1).

The number of the analyzed samples in different years varied from 178 pieces in 2018 to 74

[2]Methodology of state variety testing of agricultural crops. Moscow: State Commission for Variety Testing of Agricultural Crops, 2019, vol. 1, General part, 329 p.

pieces in 2022 and totaled 937 during the study period.

The study of the specimens was carried out in the nursery of the study of the source material (collection) according to the method of VIR[3]. Statistical processing, calculation of correlation coefficients, plotting were carried out in the Microsoft Office Excel program, calculation of the correlation error and interpretation of the correlation coefficient was carried out according to Dospekhov's methodology[4].

RESULTS AND DISCUSSION

The correlation was calculated to verify the possibility of using the classification by ripeness groups depending on the number of unproductive nodes in the region. When calculating the correlation between the duration of the vegetation period of the samples in the conditions of the Krasnoyarsk forest-steppe and the number of both productive and unproductive nodes, no strong degree of dependence was revealed. Correlation of the vegetation period with the number of non-productive nodes had a positive direction and varied from weak ($r = 0.102 \pm 0.008$) to medium degree of dependence ($r = 0{,}552 \pm 0{,}009$).

When analyzing the conjugation of all nodes on the plant with the duration of the growing season, the maximum relationship was determined in 2022 ($r = 0.604 \pm 0.009$), interpreted as a medium degree of correlation (see Table 2).

A non-parametric measure of rank correlation was also determined to test the hypothesis about the presence or absence of dependence – Spearman's coefficient was calculated, the results of which did not have significant differences with Pearson's coefficient, and also did not exceed the average dependence for all parameters. The maximum dependence was found in 2018 with a total number of nodes of 0.602 ± 0.004, while the minimum dependence was found in 2023 with a number of unproductive nodes of 0.060 ± 0.008.

Attributing samples to ripeness groups, taking into account only the duration of the growing season, is highly undesirable due to the fact that the same sample in different years can significantly change it, and if you evaluate the sample for 2–3 years, it is possible to obtain incorrect results. Thus, the standard Radomir, located in the collection nursery every 10 samples, changed the average values from 75(2018) to 103 days (2020), the range of variation of the indicators in the sample also underwent significant changes – from 51–93 (2018) to 73–103 (2020) (see Table 3).

Табл. 1. Погодные условия лет исследования (2017–2023)
Table 1. Weather conditions of the years of study (2017–2023)

Year	Total precipitation, mm					Temperature, °C					HTC
	May	June	July	August	September	May	June	July	August	September	
2017	36,0	48,0	61,0	154,0	82,0	11,2	19,8	18,8	16,4	8,3	0,47
2018	33,0	28,0	28,0	20,0	65,0	7,9	20,0	17,8	17,9	10,2	0,45
2019	10,0	43,0	82,0	43,0	29,0	9,8	18,2	18,8	18,2	10,1	0,90
2020	46,0	96,0	109,0	79,0	48,0	14,0	15,7	18,8	17,3	10,5	1,46
2021	30,0	122,0	48,0	62,0	21,0	9,9	15,6	19,7	17,4	8,1	1,34
2022	15,0	75,0	49,0	65,0	63,0	13,9	17,0	17,7	14,9	9,3	1,02
2023	40,0	42,0	49,0	30,0	30,0	9,4	18,6	20,1	18,1	11,5	0,82
Long-term average annual	32,4	51,6	80,7	58,8	38,0	10,4	17,1	19,1	15,7	8,9	1,20

[3]Collection of grain legume genetic resources of VIR: replenishment, conservation and study / M.A. Vishnyakova, I.V. Seferova, T.V. Buravtseva et al; edited by M.A. Vishnyakova. St. Petersburg: VIR, 2018, 143 p.

[4]*Dospekhov B.A.* Methodology of field experiment. Moscow: Agropromizdat, 1985. 351 p.

Табл. 2. Корреляция количества узлов с вегетационным периодом образцов (по Пирсону) в условиях Красноярской лесостепи

Table 2. Correlation of the number of nodes with the growing season of the samples (according to Pearson) in the conditions of the Krasnoyarsk forest-steppe

Year	Number of samples analyzed, *n*	Nodes		
		unproductive	productive	total number
2017	84	0,350 ± 0,007	0,190 ± 0,008	0,424 ± 0,07
2018	178	0,402 ± 0,005	0,494 ± 0,004	0,562 ± 0,004
2019	167	0,114 ± 0,006	0,285 ± 0,005	0,239 ± 0,005
2020	150	0,266 ± 0,007	0,294 ± 0,006	0,393 ± 0,006
2021	150	0,472 ± 0,005	0,327 ± 0,006	0,545 ± 0,005
2022	74	0,552 ± 0,009	0,381 ± 0,011	0,604 ± 0,009
2023	134	0,102 ± 0,008	0,413 ± 0,007	0,247 ± 0,007

When determining the dependence of the duration of the growing season with HTC by years of study it was revealed that the correlation with the average for the collection indicator was 0.634, and directly with the standard Radomir – 0.969. Since the share of early- and late-maturing accessions in the collection changed during the years of the study, the correlation with the standard was preferred. On the basis of which it was possible to correlate the duration of the growing season and HTC of the standard growing season (June–August).

Pea samples belonging to ripeness groups were graded, adhering to the distribution by ripeness groups defined in the classifier, but the attribution of the samples to one or another ripeness group in the conditions of the Krasnoyarsk forest-steppe was carried out according to the method of the State Variety Testing Network (Gossortoset).

To determine the assignment of the samples to ripeness groups, the boundaries of the vegetation period value spread – minimum and maximum values for the whole sample – were taken into account. As a result of the research, an experimental-analytical classification with the following distribution was developed: in dry years (severely dry and dry years) – ultra-early ripening (under 60 days), early-maturing (61–65), middle-early maturing (66–70), medium-maturing (71–75), semi-late (76–80), late maturing (81–85), very late maturing (over 90 days); in moistened conditions of the growing season (sufficient and insufficient moisture) –

Табл. 3. Продолжительность вегетационного периода образцов и стандарта в коллекционном питомнике (2017–2023 гг.)

Table 3. Duration of the growing season of the samples and the standard in the collection nursery (2017–2023)

Year	Number of samples, *n*	Average duration of the growing season*	Standard Radomir	min	max	*CV*, %	Reliability level, 95,0%
2017	84	81,3	88	42	89	8,78	1,63
2018	178	69,6	76	51	93	10,12	1,04
2019	167	71,0	75	60	84	6,13	0,66
2020	150	90,7	103	73	103	7,90	1,21
2021	150	80,4	92	75	92	6,28	0,82
2022	74	85,4	99	72	100	8,49	1,68
2023	134	72,9	84	66	85	7,32	0,91

*p = 9,8162E-171.

ultra-early ripening (under 70 days), early-maturing (71–75), middle-early maturing (76–80), medium-maturing (81–85), semi-late (86–90), late maturing (91–95), very late maturing (over 96 days), i.e. with a difference of 5 days between the groups (see Table 4).

For clarity, Box Plot graphs and sample distribution table were plotted, which revealed that the early maturing samples in 2017 are outlier points from the total sample population, and the bulk of the sample falls between 76 (lower quartile) and 82 (upper quartile), the sample boundaries lie between 71–89 days, and the table data show a shift towards late maturity (see the figure, Table 4).

In 2018, there were outliers on the graph, but the samples evenly occupied all niches of the distribution by ripeness groups. In 2019, there was a slight shift towards early maturing samples. In 2020, the sample was shifted towards late maturity. In 2021, the entire sample was within the proposed boundaries. In 2022 it was almost within the sample boundaries. In 2023, it was within the sample boundaries (see the figure, Table 5).

As a result, it became necessary to analyze in detail the conditions of crop maturation, namely, in August – HTC, the sum of temperatures and precipitation. It turned out that dry conditions in 2017 allowed samples to start early maturation, but abundant precipitation in August (+95.16 mm to the long-term average) significantly delayed this period, shifting the maturation of the bulk of the sample to later dates. The excessive precipitation in August 2020 (+20.16 mm to the long-term average) was determined, which, in turn, was reflected in the shift of samples towards late maturity (see Tables 5, 6).

When calculating the correlation between the amount of precipitation in August and the duration of the growing season, the average positive dependence with the sample average r = 0.559, with Radomir standard r = 0.408 was revealed. With the average temperature of August, the dependence of the duration of the growing season was negative – with the sample average r = –0.620; with Radomir standard r = –0.630. Consequently, the increase in moisture availability in August allows shifting the terms towards late ripening, the increase in temperature– towards early ripening.

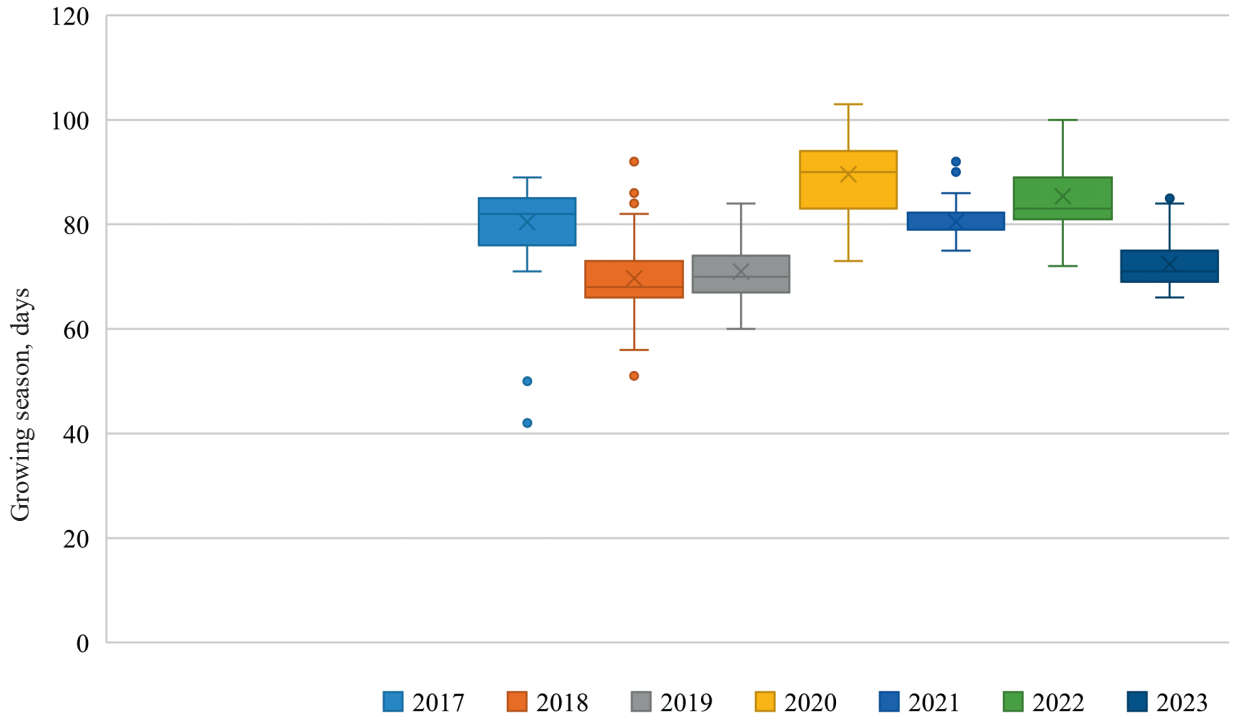
CONCLUSION

On the basis of the conducted research, taking into account the gradations according to the international CMEA genus classifier and the methodology of Gossortoset, as well as the

Табл. 4. Отнесение продолжительности вегетационного периода образцов гороха к группам спелости за период 2017–2023 гг.

Table 4. Assignment of the duration of the growing season of the pea samples to maturity groups for the period 2017–2023

Prematurity group	2017	2018	2019	2020	2021	2022	2023
Ultra-early ripening	< 60	< 60	< 60	<70	<70	<70	< 60
Early-maturing	61–65	61–65	61–65	71–75	71–75	71–75	61–65
Middle-early maturing	66–70	66–70	66–70	76–80	76–80	76–80	66–70
Medium-maturing	71–75	71–75	71–75	81–85	81–85	81–85	71–75
Semi-late	76–80	76–80	76–80	86–90	86–90	86–90	76–80
Late maturing	81–85	81–85	81–85	91–95	91–95	91–95	81–85
Very late maturing	>86	>86	>86	>96	>96	>96	>86
HTC	0,47	0,45	0,90	1,46	1,46	1,02	0,90
Characteristics of the growing season conditions	Severely arid	Severely arid	Arid	Sufficiently moisturized	Sufficiently moisturized	Insufficiently moisturized	Arid



Распределение выборок образцов по продолжительности вегетационного периода

Distribution of specimen samples by duration of the vegetation period

Табл. 5. Распределение исследуемых образцов по группам спелости в условиях Красноярской лесостепи

Table 5. Distribution of the studied samples by maturity groups in the conditions of the Krasnoyarsk forest-steppe

Prematurity group	Year						
	2017	2018	2019	2020	2021	2022	2023
Ultra-early ripening	2	7	1	0	0	0	0
Early-maturing	0	33	7	4	32	7	0
Middle-early maturing	0	81	80	12	69	1	51
Medium-maturing	16	29	55	31	29	32	65
Semi-late	20	13	18	34	2	17	0
Late maturing	26	9	6	48	18	10	18
Very late maturing	20	6	0	21	0	7	0

Табл. 6. Характеристика тепло- и влагообеспеченности августа по годам

Table 6. Characteristics of heat and moisture supply in August by years

Indicator	Year						
	2017	2018	2019	2020	2021	2022	2023
HTC in August	3,03	0,37	0,76	1,45	1,15	1,46	0,76
Sum of August temperatures, °C	508,4	554,9	564,2	536,3	539,4	461,9	561,1
Precipitation, mm	154,0	20,2	43,0	79,0	63,0	65,1	30,3
Deviation from long-term average annual, mm	95,16	–38,64	–15,84	20,16	4,16	6,26	–28,54

calculation of HTC of the growing season, the scheme of assigning pea samples to ripeness groups in the conditions of the Krasnoyarsk forest-steppe is proposed. In dry conditions of the growing season, the following distribution of the samples is recommended for classification: ultra-early ripening (under 60 days), early-maturing (61–65), middle-early maturing (66–70), medium-maturing (71–75), semi-late (76–80), late maturing (81– 85), very late maturing (over 90 days). In moistened conditions of the growing season (under sufficient and insufficient moisture): ultra-early ripening (under 70 days), early-maturing (71–75), middle-early maturing (76–80), medium-maturing (81–85), semi-late (86–90), late maturing (91–95), very late maturing (over 96 days).

Excessive precipitation in August allows shifting the grading dates towards late ripening, while an increase in the average temperature of the month shifts the grading dates towards early ripening.

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