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# Analysis of the duration of the vegetation period and phases of development of Somaclonal lines of *Camelina sativa*

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The article presents an analysis of the duration of the vegetation period and phenological phases of development of somaclonal lines of *Camelina sativa*, resistant to salt and osmotic stress. Explant donors used the varieties Stepovyi 1, Peremoha, Klondike and Yevro 12. Somaclones were evaluated during 2017–2019, which differed in water and temperature regimes. The hydrothermal coefficient for the period of crop cultivation (April–July) was 1.13 (2017) and 0.91 (2018, 2019). In addition, there are significant differences in this indicator during the growing season. In 2017, the initial stages of growth of *Camelina sativa* were accompanied by excessive moisture, and a slight deficit of moisture was observed in June. In April–May 2018, a severe drought was observed (hydrothermal coefficient was 0.43 and 0.34, respectively). Therefore, the vegetation period of the created selection materials in 2017 varied from 84 to 96 days, in 2018 — from 72 to 90 days, in 2019 — from 81 to 95 days. Deficiency of moisture and elevated air temperatures contribute to the acceleration of the phases of ontogenetic development and reduce the overall growing season of plants. The required sum of active temperatures is 1300–1700 0C for the ripening of *Camelina sativa* seeds. The created somaclonal lines are ranked into groups according to the duration of the vegetation period into medium-ripe and late-ripe forms.

**Keywords:** *Camelina sativa*; Hydrothermal coefficient; Vegetation period; Phenological phases

## Introduction

The biological features of *Camelina sativa* make it possible to grow it in different soil and climatic conditions with high economic efficiency, to obtain environmentally friendly products and make full use of the natural potential of the region. The crop is undemanding to growing conditions, has a short growing season and is the optimal precursor for winter crops. *Camelina sativa* is almost not affected by diseases and pests, which reduces the chemical load on the environment and saves material costs for production (Semenova et al., 2007, Komarova & Rozhkovan, 2003).

Among the oilseeds of the *Camelina sativa* cabbage family, *Camelina sativa* has the highest oil content in the seeds — about 45%. In its composition, camelina oil has a low proportion of erucic acid and high oleic, linoleic and linolenic. It has a balanced complex of natural antioxidants, biologically active substances and has medicinal and dietary properties. The use of this oil restores the stability and elasticity of blood vessels, lowers blood cholesterol, normalizes blood pressure, and prevents disorders of fat metabolism and inflammation. It is recommended for cardiovascular diseases, diabetes, physical and mental exhaustion, etc. (Lyakh & Komarova, 2010, Kulakova et al., 2005). Camelina oil is used for the production of varnishes, paints, soaps, plastics, biodiesel (Komarova & Rozhkovan, 2003, Melnichuk et al., 2012). The vegetable mass of *Camelina sativa* has a high caloric content (energy content in seeds, straw and oil is 26.4, 17.7 and 38.2 J/g, respectively) and is a valuable energy raw material (Kalenska &Yunik, 2011).

In order to increase the production of *Camelina sativa*, works on the creation of high-yielding technological varieties adapted to adverse environmental conditions are becoming relevant. In Ukraine, about 1.9 million hectares of saline soils have been identified (Balyuk et al., 2012), so work on creating forms of plants resistant to salt stress is relevant. In addition, salinization has a similar physiological effect on the plant as drought, so salt-resistant forms are characterized by increased drought resistance.

The use of in vitro methods makes it possible to fully control the growing conditions of the biomaterial, to model the effect of the stress agent on the bio object, to carry out selection at the cellular level. This increases efficiency and speeds up the selection process (Lyubchenko et al., 2016, Babikova et al., 2007). Plant forms obtained by biotechnological methods must be evaluated according to a set of economically valuable traits. The length of the growing season is one of the main breeding characteristics of crop varieties. The use of varieties of different maturity groups in the farm makes it possible to harvest without loss of yield, rationally use the technical resources of the farm, and reduce the risk of negative environmental factors on the crop. Late-ripening varieties are usually more productive and more resistant to environmental stressors. The use of genotypes with a short growing season makes it possible to use the crop as a precursor for winter and place it in post-harvest and post-harvest crops. The combination of early maturity with high yields and product quality is an important area of selection of agricultural plants (Bilyavskaya & Prysyazhnyuk, 2018, Cherchel et al., 2014).

The aim of the work was to analyze the duration of the vegetation period and phenological phases of development of the created somaclonal lines of *Camelina sativa*, resistant to salt and osmotic stress.

## Materials and Methods

Phenological evaluation of somaclonal lines of *Camelina sativa* obtained from explants of Stepovyi 1, Peremoha, Klondike and Yevro 12 varieties was performed during 2017–2019. Created by cell selection, stress-resistant plant material (sodium chloride, mannitol) plant material after microclonal propagation, rooting and adaptation was grown in the research areas of the Department of Genetics, Plant Breeding and Biotechnology, Uman National University of Horticulture.
The soil of the experimental field belongs to the black soil of podzolic low-humus heavy loam, characterized by a low content of humus (3.3%). According to the content of mobile forms of phosphorus and potassium, the soil belongs to the medium, and according to the content of easily hydrolyzed nitrogen — to the weak, has a weak acid reaction of the soil solution (pH 6.5–6.7) and high water permeability.
Seed generation of somaclones R2–R4 was sown with a row spacing of 30 cm at sowing rates of 2 million seeds per hectare. Accounting was performed in accordance with the method of field research (Yeshchenko et al., 2005) and the method of examination of plant varieties for difference, homogeneity and stability (Tkachik et al., 2014).
During phenological studies, the phases of germination, rosette formation, budding, flowering, green pod, and technical maturity were recorded. The total duration of the growing season was determined from germination to technical maturity.

## Results and Discussion

The growing season is a genetic feature of a variety or hybrid, it significantly depends on the growing conditions (agricultural techniques, weather conditions, etc.). Of the climatic factors, the most influential on the duration of the growing season of crops are temperature and water regimes.
The period of our research was characterized by moisture deficiency and elevated temperatures (Table 1). The amount of precipitation that fell during the 2016–2017, 2017–2018 and 2018–2019 agricultural years was 524.8, 680.6 and 420.8 mm, respectively. This was 108.8, 47.6 and 212.2 mm, respectively, less than the long-term average. The driest were June 2017 (–40.6 mm from the norm), July 2017 (–46.0 mm from the norm), April 2018 (–30.5 mm from the norm), May 2018 (–36.7 mm from the norm). The average air temperature over the years of research was higher than the long-term averages and was 9.0, 9.7 and 9.6°C in 2016–2017, 2017–2018 and 2018–2019 agricultural years, respectively. In 2016–2017, the increase in the average annual air temperature was due to high air temperatures in the winter months. The air temperature during the growing season of the crop from April to June did not differ significantly from the average perennial. This somewhat reduced the negative impact of rainfall deficit on plants.

**Table 1.** Meteorological conditions of research (according to the meteorological station Uman).

| Years | For agricultural year | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX |
| Air temperature, °C | | | | | | | | | | | | | |
| 2016–2017 | 9,0 | 6,5 | 1,7 | –1,9 | –5,2 | –2,8 | 5,9 | 9,7 | 14,8 | 20,0 | 20,6 | 22,1 | 16,5 |
| ± from norm | 1,6 | –1,1 | –0,4 | 0,5 | 0,5 | 1,4 | 5,5 | 1,2 | 0,2 | 2,4 | 1,6 | 3,9 | 2,9 |
| 2017–2018 | 9,7 | 8,7 | 3,4 | 2,1 | –3,0 | –3,6 | –1,5 | 13,5 | 17,9 | 20,2 | 20,7 | 22,1 | 15,8 |
| ± from norm | 2,3 | 1,1 | 1,3 | 4,5 | 2,7 | 0,6 | –1,9 | 5,0 | 3,3 | 2,6 | 1,7 | 3,9 | 2,2 |
| 2018–2019 | 9,6 | 10,1 | 0,2 | –2,0 | –4,7 | 0,5 | 4,5 | 9,6 | 17,0 | 23,4 | 20,0 | 20,7 | 15,6 |
| ± from norm | 2,2 | 2,5 | –1,9 | 0,4 | 1,0 | 4,7 | 4,1 | 1,1 | 2,4 | 5,8 | 1,0 | 2,5 | 2,0 |
| **The amount of precipitation, mm** | | | | | | | | | | | | | |
| 2016–2017 | 524,2 | 87,0 | 49,2 | 33,2 | 21,8 | 38,9 | 25,8 | 53,3 | 46,4 | 41,0 | 59,2 | 29,9 | 38,5 |
| ± from norm | –108,8 | 54,0 | 6,2 | –14,8 | –25,2 | –5,1 | –13,2 | 5,3 | –8,6 | –46,0 | –27,8 | –29,1 | –4,5 |
| 2017–2018 | 680,6 | 53,9 | 37,9 | 102,2 | 58,4 | 43,7 | 65,6 | 17,5 | 18,3 | 82,4 | 92,9 | 2,6 | 105,2 |
| ± from norm | 47,6 | 20,9 | –5,1 | 54,2 | 11,4 | –0,3 | 26,6 | –30,5 | –36,7 | –4,6 | 5,9 | –56,4 | 62,2 |
| 2018–2019 | 420,8 | 13,8 | 49,9 | 50,5 | 55,1 | 23,8 | 16,3 | 22,4 | 35,6 | 69,8 | 33,8 | 19,2 | 30,6 |
| ± from norm | –212,2 | –19,2 | 6,9 | 2,5 | 8,1 | –20,2 | –22,7 | –25,6 | –19,4 | –17,2 | –53,2 | –39,8 | –12,4 |

The growing season in 2018 was characterized by high temperatures. The average daily temperature in April exceeded the norm by 5.0°C, in May — by 3.3°C, in June — by 2.6°C. In 2019, the hottest month was June — the average daily temperature was 22.4°C, which was 4.8 0C above normal. In April–May, the excess of the average long-term temperature data was 1.1–2.4 0°C.
The indicator that objectively assesses the moisture content of plants is the hydrothermal coefficient (HTC) — the ratio of precipitation to the sum of temperatures over a period of time with a temperature above 10°C. HTC characterizes not only the inflow of moisture, but also its unproductive evaporation from the soil and plant surface (Adamenko et al., 2011). The hydrothermal coefficient for the period of cultivation (April–July) in 2017 was 1.13, in 2018 and 2019 — 0.91 (Figure 1). In addition, there are significant differences in this indicator during the growing season. In 2017, the initial stages of *Camelina sativa* growth were accompanied by excessive moisture (HTC for April — 1.83). Low moisture deficit was observed in June (HTC was 0.68). In 2018, in April and May, a severe drought was observed — the hydrothermal coefficient was 0.43 and 0.34, respectively. This contributed to the rapid passage of the initial phases of development of Camelina. The largest moisture deficit in 2019 was recorded in July (HTC — 0.57), but this did not affect crop productivity, as the plants were in the last stages of ontogenesis.

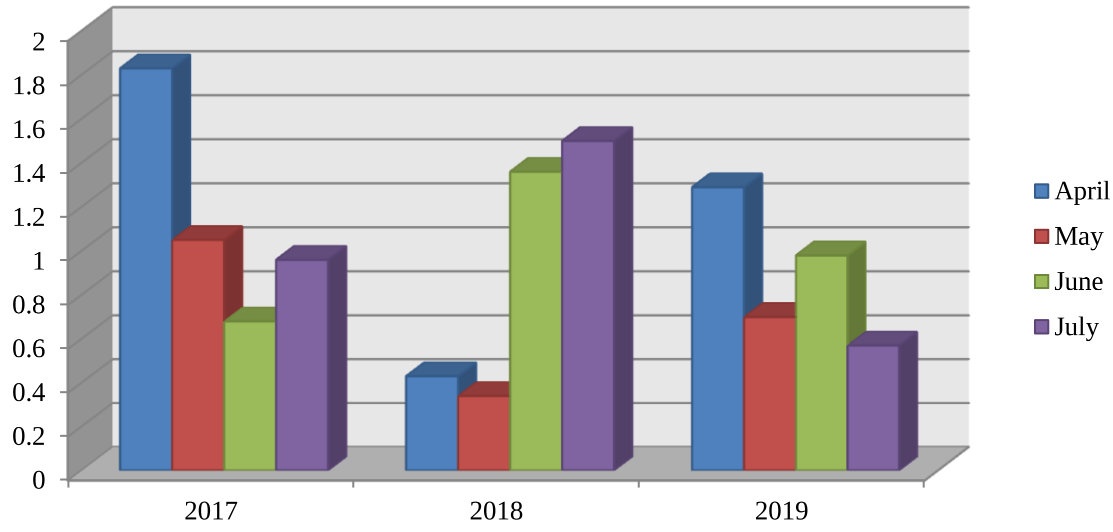


**Figure 1.** Hydrothermal coefficient for the growing season of *Camelina sativa*.

The vegetation period of the culture is determined by the duration of individual phenological phases. The calendar dates of the onset of the phenological phases of the development of the somaclonal lines of the *Camelina sativa* differed in the years of research. The duration of the phenological phases of development on average during the study period are presented in Table 2.
The timing of sowing *Camelina sativa* in the experiment depended on weather conditions and physical maturity of the soil. Sowing of selection numbers was carried out on April 4, 2017, April 16, 2018 and March 25, 2019.
The duration of the «sowing-germination» period did not depend on genotypic features and was nine days in 2017 and 2018, and in 2019 — 13 days. The rate of seed germination depended on weather conditions. The decrease in air temperature after sowing the crop in 2019 caused a delay in seedling production.
The formation of the rosette was the shortest phenological phase of culture development and lasted, depending on the genotype and weather conditions, 8–13 days. In 2018, rosette formation in all genotypes was faster, due to later sowing dates, high temperatures and a lack of moisture in April.
The duration of the period of stalking and budding on average by genotypes in 2017 was 26 days, in 2018 — 18, and in 2019 — 20 days. Low air temperature and sufficient moisture supply in May 2017 contributed to the prolongation of the formation of the generative sphere of *Camelina sativa*. On average over three years of research, the longest phase was in the lines C-87-4 and C-384-4, and the shortest in the numbers C-87-4 and C-384-4 and was 24 and 19 days, respectively.
The duration of flowering of *Camelina sativa* plants over the years of research, depending on the genotype, varied from 8 to 27 days. The longest flowering period was observed in genotypes C-384-4, C-87-7, C-121-2, C-121-11 (16–17 days). In breeding numbers П-485-4 and П-618-6 the duration of flowering was the shortest and was 11 days.

**Table 2.** Duration of phenological phases of development of the created somaclonal lines of *Camelina sativa* (2017-2019 years), days.

| **Somaclonal lines** | **Phenological phase** | | | | | |
|---|---|---|---|---|---|---|
| | **sowig – germination** | **germination –formation of the rosette** | **formation of the rosette – budding** | **budding - flowering** | **flowering –green pod** | **green pod – technical ripeness** |
| C-87-4 | 10 | 11 | 24 | 14 | 13 | 31 |
| C-87-7 | 10 | 10 | 23 | 17 | 14 | 29 |
| C-121-2 | 10 | 11 | 23 | 16 | 13 | 29 |
| C-121-11 | 10 | 10 | 22 | 16 | 14 | 29 |
| C-234-8 | 10 | 10 | 21 | 15 | 15 | 29 |
| C-326-9 | 11 | 9 | 22 | 14 | 14 | 29 |
| C-384-4 | 10 | 10 | 24 | 16 | 12 | 30 |
| C-402-6 | 10 | 9 | 23 | 15 | 13 | 31 |
| C-419-6 | 10 | 9 | 23 | 15 | 13 | 30 |
| C-586-7 | 10 | 10 | 22 | 15 | 14 | 29 |
| П-46-2 | 10 | 10 | 21 | 12 | 14 | 27 |
| П-46-5 | 10 | 10 | 22 | 13 | 14 | 27 |
| П-202-6 | 10 | 10 | 23 | 13 | 13 | 27 |
| П-202-7 | 10 | 12 | 21 | 13 | 15 | 28 |
| П-248-8 | 10 | 10 | 22 | 13 | 15 | 28 |
| П-485-4 | 10 | 11 | 20 | 11 | 12 | 28 |
| П-618-6 | 10 | 9 | 19 | 11 | 12 | 26 |
| П-646-3 | 10 | 10 | 20 | 15 | 14 | 28 |
| П-658-8 | 10 | 11 | 20 | 13 | 13 | 29 |
| Є-405-5 | 10 | 10 | 20 | 13 | 13 | 28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Є-405-8 | 10 | 9 | 21 | 12 | 13 | 27 |
| К-478-2 | 10 | 9 | 19 | 13 | 12 | 27 |
| К-480-2 | 10 | 10 | 21 | 13 | 12 | 27 |
| К-480-4 | 10 | 11 | 21 | 14 | 12 | 28 |
| Середнє | 10 | 10 | 22 | 14 | 13 | 28 |

Achieving the harvest of *Camelina sativa* begins with the phase of the green pod, which on average by genotype in 2017 was 12 days, in 2018 — 15 days, in 2019 — 13 days. Over the years of research, the fastest passage of this phase was characterized by plant lines С-384-4, П-485-4, П-618-6, К-478-2, К-480-2 and К-480-4 (12 days), the longest — С-234-8, П-202-7 and П-248-8 (15 days). The period from the beginning of pod browning to the onset of full ripeness of seeds in 2017 and 2019 on average by genotype lasted 29 days, and in 2018 — 27 days. The shortest phase of maturation was in the sample П-618-6 and the average for the years of research was 26 days, the longest — in the selection numbers С-402-6 and С-87-4 (31 days).

The vegetation period of the created samples of *Camelina sativa* in 2017 averaged 91 days, in 2018 — 80, and in 2019 — 89 days (Table 3). The reduction in the duration of the growing season in 2018 is due to high air temperatures and a lack of moisture during the period of plant growth and development.

The vegetation period of the created somaclonal plant lines of *Camelina sativa* obtained from callus tissue of the Stepovyi 1 variety in 2017 was 94–96 days, in 2018 — 82–90 days, and in 2019 — 89–95 days. For the samples obtained from the biomaterial of the Peremoha variety, this indicator was 84–94, 68–81 and 83–91 days, respectively, from the Yevro 12 variety — 87–88, 73–79 and 85–88 days, and from the Klondike variety — 80–88, 77–82 and 81–87 days. The most stable in terms of vegetation period were selection numbers С-87-4, С-87-7, Є-405-5, К-478-2, К-480-2, К-480-4 with a difference of variation of 5–8 days. Somaclonal plant lines С-402-6, П-46-2, П-202-7, П-485-4, П-618-6, Є-405-8 were characterized by a wide range of variability in this indicator (more than 13–14 days).

**Table 3.** Influence of climatic indicators on the duration of the vegetation period of the created somaclonal lines of *Camelina sativa*.

| Somaclonal lines | 2017 year | | 2018 year | | 2019 year | | Average | |
|---|---|---|---|---|---|---|---|---|
| | vegetation duration, days | ΣTactive >5,°C | vegetation duration, days | ΣTactive >5,°C | vegetation duration, days | ΣTactive >5,°C | vegetation duration, days | ΣTactive >5,°C |
| С-87-4 | 95 | 1651 | 89 | 1677 | 95 | 1653 | 93 | 1660 |
| С-87-7 | 95 | 1651 | 90 | 1682 | 93 | 1616 | 93 | 1650 |
| С-121-2 | 95 | 1651 | 86 | 1610 | 93 | 1616 | 91 | 1626 |
| С-121-11 | 95 | 1651 | 85 | 1590 | 94 | 1636 | 91 | 1626 |
| С-234-8 | 95 | 1651 | 82 | 1528 | 93 | 1616 | 90 | 1598 |
| С-326-9 | 95 | 1651 | 80 | 1502 | 90 | 1555 | 88 | 1569 |
| С-384-4 | 95 | 1651 | 85 | 1590 | 94 | 1636 | 91 | 1626 |
| С-402-6 | 96 | 1671 | 80 | 1487 | 94 | 1636 | 90 | 1598 |
| С-419-6 | 94 | 1631 | 85 | 1590 | 89 | 1535 | 89 | 1585 |
| С-586-7 | 95 | 1651 | 85 | 1590 | 91 | 1575 | 90 | 1605 |
| П-46-2 | 89 | 1531 | 76 | 1404 | 89 | 1535 | 85 | 1490 |
| П-46-5 | 90 | 1551 | 81 | 1507 | 86 | 1459 | 86 | 1506 |
| П-202-6 | 90 | 1551 | 80 | 1487 | 90 | 1555 | 87 | 1531 |
| П-202-7 | 94 | 1631 | 80 | 1487 | 91 | 1549 | 88 | 1556 |
| П-248-8 | 93 | 1611 | 82 | 1528 | 90 | 1555 | 88 | 1565 |
| П-485-4 | 91 | 1571 | 72 | 1328 | 84 | 1433 | 82 | 1444 |
| П-618-6 | 84 | 1434 | 68 | 1252 | 83 | 1411 | 78 | 1366 |
| П-646-3 | 93 | 1611 | 79 | 1466 | 89 | 1535 | 87 | 1537 |
| П-658-8 | 92 | 1591 | 77 | 1425 | 87 | 1494 | 85 | 1503 |
| Є-405-5 | 88 | 1511 | 79 | 1466 | 85 | 1453 | 84 | 1477 |
| Є-405-8 | 87 | 1492 | 73 | 1347 | 88 | 1492 | 83 | 1444 |
| К-478-2 | 80 | 1357 | 77 | 1409 | 81 | 1350 | 79 | 1372 |
| К-480-2 | 86 | 1473 | 80 | 1487 | 83 | 1411 | 83 | 1457 |
| К-480-4 | 88 | 1511 | 82 | 1528 | 87 | 1494 | 86 | 1511 |
| НІР05 | 5 | - | 4 | - | 4 | - | - | - |

The amount of active temperatures required for all stages of ontogenesis of *Camelina sativa* plants significantly depends on the genotype. Created somaclonal lines, for the full cycle of development require different amounts of temperatures. This indicator averaged 1537 °C over the years of research and varied from 1366 0C in the П-618-6 sample to 1660°C in the С-87-4 number.

According to the Methodology of examination of *Camelina sativa* for difference, homogeneity, stability [12] the obtained data make it possible to rank the created somaclonal plant lines by the duration of the growing season on: medium-ripe — С-234-8, С-326-9, С-402-6, С-419-6, С-586-7, П-46-2, П-46-5, П-202-6, П-202-7, П-248-8, П-485-4, П-618-6, П-646-3, П-658-8, Є-405-5, Є-405-8, К-478-2, К-480-2, К-480-4; late-ripening — С-87-4, С-87-7, С-121-2, С-121-11, С-384-4.

## Conclusion

Thus, the analysis of the duration of the vegetation period and phenological phases of development of somaclonal lines of *Camelina sativa* resistant to salinity and osmotic stress was performed. It is established that the lack of moisture and elevated air temperatures contribute to the acceleration of the phases of ontogenesis and the reduction of the total growing season. The required sum of active temperatures is 1300–1700°C for seed culture maturation. The created materials are ranked into medium-ripe and late-ripe forms.

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