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# GROWING SEASON LENGTH AND THE METHOD OF HEAT UNITS IN SPRING VEGETABLE PEA PRODUCTION

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**ABSTRACT**

Vegetable pea production hinges significantly on the duration of its growing season, primarily due to the fact that the period of optimal technological maturity of pea grains is short. Knowledge of the duration of the growing season for vegetable peas is of great importance from the aspect of production planning, especially on large-scale farms, in order to synchronize sowing and maturation timing with the capacities of mechanization for harvesting and processing. Interpretation of results based on weather conditions is of great importance as well, because environmental conditions closely determine pea yield and quality. In this paper, the length of the pea growing season was determined using the method of heat units for 12 different spring vegetable pea genotypes. The research included genotypes with varying growing season lengths, categorized as early, mid-early, mid-late, and late, spanning from 60 to 76 days. The examined pea genotypes accrued heat units ranging from 612.1 to 986.3, signifying varying degrees of heat accumulation. The methodology adopted for employing heat units in the planning of spring vegetable pea cultivation and maturation operates on the premise that heat accumulation during the growing season correlates linearly with growth and development intensity, as well as the duration of the growing season itself. Consequently, the summation of heat units emerges as a distinctive characteristic of each cultivar, facilitating informed decision-making in agricultural practices.

**Keywords**: vegetable pea, *Pisum sativum* L., mean temperature, number of days, pea sowing.

## INTRODUCTION

The length of growing season from sprouting to technological maturity is a cultivar characteristic most affected by climate. During growing season, the pea crop is known to be highly sensitive to climatic conditions. More precisely, high temperatures during the grain formation period have a significant impact on pea (*Pisum sativum* L.) yield (Bénézit et al., 2017). Each crop has specific requirements for optimal environmental conditions to ensure proper growth and yield. Temperature stands out as a critical weather parameter that plays a crucial role in controlling plant growth and development. It has adverse effects on various physiological processes, including photosynthesis, respiration, membrane stability, fertilization, maturity, seed quality, and nutrient absorption. The method of heat units is quite useful in predicting growth and yield of various crops, including vegetable peas (Devi et al., 2019).

The system of heat units is used for the purpose of linking growth, development and maturity of plants with air temperatures. The direct and linear relationship between plant growth and temperature is generally assumed (Parthasarathi et. al., 2013).

Olivier and Annandale (1998) concluded that, due to the effect of temperatures, crops will not need the same amount of calendar time to reach a particular developmental stage. Bourgeois et al. (2000) stated that the system of heat units includes the sum of mean daily temperatures above a given base temperature. It is often stated that the base temperature of 0 to 5°C is most favourable for pea production, although each cultivar requires its own specific temperature. The system of heat units is used in the processing of peas so as to determine the date of sowing and relative maturity during the growing season based on data on mean daily temperatures. Heat unit systems often predict the time from sowing to crop maturity.

The aim of our study was to determine the length of the growing season and the sum of heat units in order to identify the optimal sowing time for the selected vegetable pea breeding lines. Additionally, we aimed to illustrate the method of determining the sum of heat units as a significant approach in planning optimal sowing dates for vegetable pea production.

## MATERIAL AND METHODS OF WORK

Field trial

The field trial was set up during 2022, at the Rimski Šančevi site on chernozem-type land, in an irrigation system, at the Department of Vegetable and Alternative Crops of the Institute of Field and Vegetable Crops Novi Sad (45° 19'
55.7" northern latitude 19° 50' 14.9" east longitude and 86 m above sea level). The trial was set up as a randomized block design with five replications. The main plot consisted of two rows of peas with interrow spacing of 20 cm, intrarow spacing of 5 cm, and row length of 3 m. The distance between the two plots was 80 cm for easier manipulation and inter-row processing during the growing season.

Pea varieties can be classified according to their use into varietes grown for their grain and varieties where the young pod is used (Jovićević, 2011). Peas are grown primarily for their grain and less often for their pods (Đorđević et al., 2021). All genotypes used in this study belong to the group of peas cultivated for their grain. The research included 10 lines, named S-1 to S-10, and 2 domestic cultivars: Tamiš (S-T) and Dunav (S-D) of spring vegetable peas. The examined material is a part of the collection of *Pisum sativum* L. maintained at the Institute of Field and Vegetable Crops Novi Sad.

Harvesting of all tested genotypes was done manually at technological maturity. The primary sample for analysis consisted of 10 plants per repetition, i.e. 50 plants in total per one genotype.

The sum of heat units is calculated as the sum of mean daily temperatures minus minimum pea growing temperature of 4.5 °C from sowing to technological maturity (Đinović et al., 1984).

Agrometeorological conditions during the trial

Interpretation of results based on weather conditions is of great importance because environmental conditions largely determine the yield and quality of vegetable crops.

The values of the analyzed parameters were compared with the corresponding values of the multi-year average for the reference period from 1964 to 2014. The multi-year average data were taken from the electronic publication Meteorological yearbook-climate data of the Hydrometeorological Institute of the Republic of Serbia (http://www.hidmet.gov.rs). As an important parameter in vegetable pea production, the number of days in the growing season with maximum temperatures above 25 °C is shown. Maximum daily temperatures above 25°C have a depressive effect on the vegetative phase, flowering, pod setting, and pod development (Đinović, 1984; Fallon et al., 2006; Bénézit et al., 2017). The negative effect becomes stronger as temperatures rise and persist longer. Growth stops at 35°C. The plant is most sensitive to high temperatures immediately after flowering. Flowers drop, pods remain small and stunted, and only a small number of tiny seeds develop in them. Furthermore, high temperatures accelerate and shorten the period to technological maturity (Đinović, 1984). In the vegetative phase of development, high temperatures hinder optimal plant growth, resulting in significantly shorter plants that rapidly transition to the generative phase (Jovićević, 2011).

Precipitation sum during February was lower than the multi-annual average by 5.2 mm. Amounting to 1 mm, precipitation sum in March was negligible compared to the multi-annual average of 38.8 mm. The long period from sowing (February 24) to emergence (March 25) can thus be explained by the precipitation deficit in the period after sowing, as well as slightly lower temperatures during March as compared to the multi-annual average. During April, the precipitation sum was higher than in March, but still below average values, while the temperature was within the multi-annual average (Tab. 2). At the time of flowering and pod formation in May, precipitation were44.6 mm below the multi-annual average. The same trend continued during June, even though the highest sum of precipitation during the growing season was measured in mid-June. The average temperatures in May were slightly higher than the multi- annual average.

Table 1. Mean maximum, minimum and average air temperatures (°C) at the investigated locality during the growing season.

| Month | Maximum (°C) | | | Minimum (°C) | | | Mean (°C) | | | Multiannual average (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Period | | | | | | | | | | | |
| | I | II | III | I | II | III | I | II | III | I | II | III |
| February | 18.0 | 18.4 | 18.1 | -3.3 | -3.8 | -1.7 | 5.8 | 7.7 | 6.2 | 1.3 | 1.6 | 2.6 |
| March | 9.2 | 16.6 | 23.3 | -4.5 | -9.4 | -6.3 | 2.5 | 4.3 | 10.3 | 4.3 | 6.2 | 8.8 |
| April | 22.3 | 24.8 | 23.2 | -2.5 | -1.4 | 1.6 | 10.4 | 9.3 | 13.1 | 10.8 | 10.8 | 13.5 |
| May | 26.0 | 31.4 | 32.3 | 8.5 | 6.0 | 11.7 | 17.2 | 19.6 | 19.7 | 15.8 | 17.2 | 17.9 |
| June | 33.0 | 33.7 | 36.2 | 12.8 | 12.4 | 15.3 | 23.2 | 22.0 | 24.9 | 19.2 | 20.0 | 20.9 |

Table 2. Precipitation sum (mm) per 10-day period at the investigated location during the growing season.

| Month | Period | | | Sum | Multiannual sum |
|---|---|---|---|---|---|
| | I | II | III | | |
| February | 8 | 5 | 16 | 29 | 34.2 |
| March | 1 | 0 | 0 | 1 | 38.8 |
| April | 18 | 2 | 17 | 37 | 47.5 |
| May | 0 | 3 | 17 | 20 | 64.6 |
| June | 8 | 23 | 12 | 43 | 87.7 |

Table 3. Number of days with maximum temperatures above 25 °C.

| | 10 day period | | |
|---|---|---|---|
| Month | I | II | III |
| February | 0 | 0 | 0 |
| March | 0 | 0 | 0 |
| April | 0 | 0 | 0 |
| May | 1 | 9 | 6 |
| June | 10 | 10 | 8 |

The optimal average daily temperature for the growth and development of peas is 16±7°C (9-23°C), (Đinović, 1994). In the vegetative phase 12-16°C, during flowering 16-20°C, and at pod development 16-22°C (Đinović, 1984; Cervenski et al., 2021). Most days with maximum temperatures above 25°C, which have a mitigating effect during flowering and immediately after flowering, were recorded in the second decade of May and throughout June (Tab. 1, 2, 3).

Early harvesting decreases pea yield but improves crop quality due to greater softness and sweetness of pea seed. Later harvesting increases pea yields at the expense of quality. Therefore, it is important to determine harvest dates that ensure both acceptable quality and yield. Pea yields are sensitive to environmental conditions, especially extreme temperatures and water deficit. Heat stress (> 27°C) in the period between flowering and harvest has the great negative impact on pea yield (Lambert and Linck 1958; Fallon et.al. 2006). Each degree/day above 25.6°C during flowering and pod filling reduces yield. Water stress during flowering has a greater negative impact on yield than if stress occurs during pod filling (Fallon et al., 2006).

## RESULTS AND DISCUSSION

The length of growing season is a highly significant characteristic for peas, given that the period of optimal technological maturity for pea grains is short. In order to ensure harvesting peas at optimal technological maturity, when the grain is of the highest quality, it is necessary to plan the sowing carefully. When planning sowing, it should be adjusted so that the crops reach technological maturity in line with the harvesting machinery capacity and processing capacity (Đinović et al., 1984).

Given the percentage of sugar is in direct correlation with the quality of pea seed, more attention is paid to maturity (Jovićević et al., 2009). As the seed matures, the content of sugar and peptides decreases while the content of protein and starch increases, resulting in harder seed with higher tenderometric values, as such unsuitable for any form of processing. Physiologically mature grain has little water, higher energy value and is a significant protein food (Červenski et al., 2021; Zec, 2022).

According to Maynard and Hochmuth (2007), technologically mature pea grain contain 21% dry matter, 5.4% protein, and an average of 81 calories per 100 grams of grain. On the other hand, the dry matter content in botanically mature seeds ranges from 86 to 90%, with protein content between 21 and 28% (Jovićević, 2011).

The production of peas for processing can be planned with greater precision using the method of heat units. The methodology of heat units used in the planning of pea sowing and maturity is based on the assumption that the heat accumulated during the growing season is linearly proportional to the intensity of growth and development, and to the length of growing season. For pea crops, the sum of heat units is calculated as the sum of mean daily temperatures minus 4.5 °C for all days from sowing to technological maturity. The temperature of 4.5 °C is considered minimum growth temperature. Therefore, the days with an average daily temperature of 4.5 °C or lower enter the sum with 0 heat units because under such conditions the plant mostly does not grow. The sum of heat units depends on the cultivar. However, it is not a 'one size fits all', as the sum of heat units is also affected by other factors, namely the type and fertility of soil, slope of the terrain, sowing depth, humidity, etc. For these reasons, the sum of heat units should be determined for each area and each cultivar. In our climate, the sum of heat units is from 600 to 1000 heat units, depending on the cultivar (Đinović et al., 1984;, Lešić et al. 2002).

The production of large-scale pea seed is achieved by successive sowing of one variety, or simultaneous sowing of cultivars with different duration of growing season (Ambrose, 2008). Research conducted by Takač et al. (2012) concluded that safer production is achieved by sowing more cultivars with different duration of growing season, as compared to sowing fewer cultivars with the same length of growing season. Vegetable pea breeding lines with different duration of growing season (early, mid-early, mid-late and late) were included in the research. The length of the growing season ranged from 60 days to 76 days, and the sum of heat units ranged from 612.1 to 986.3 (Tab. 5). According to Savić (2019) early maturity of genotypes is an important criterion in breeding, while genotypes with a shorter growing season can be used when selecting parental pairs for breeding for a shorter growing season. Sums of heat units, growing season lenght and harviest dates for each genotype are shown in the tables 4 and 5.

Table 4. Heat units (from sowing time to harviest) at Rimski Šančevi in 2022

| M | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | SDT | KDTJ | ATJ | SDT | KDTJ | ATJ | SDT | KDTJ | ATJ | SDT | KDTJ | ATJ | SDT | KDTJ | ATJ |
| 1 | x | x | x | 2.8 | 0 | 3.8 | 12.5 | 8 | 88.3 | 16.7 | 12.2 | 287.2 | 22 | 17.5 | 746.5 |
| 2 | x | x | x | 1.6 | 0 | 3.8 | 3.4 | 0 | 88.3 | 15.3 | 10.8 | 298 | 23.6 | 19.1 | 765.6 |
| 3 | x | x | x | 2.7 | 0 | 3.8 | 3.2 | 0 | 88.3 | 15.9 | 11.4 | 309.4 | 24.9 | 20.4 | 786 |
| 4 | x | x | x | 2.1 | 0 | 3.8 | 4.9 | 0.4 | 88.7 | 17.5 | 13 | 322.4 | 24.1 | 19.6 | 805.6 |
| 5 | x | x | x | 0.1 | 0 | 3.8 | 10.5 | 6 | 94.7 | 18.4 | 13.9 | 336.3 | 26.5 | 22 | 827.6 |
| 6 | x | x | x | 1.1 | 0 | 3.8 | 14.2 | 9.7 | 104.4 | 18.1 | 13.6 | 349.9 | 22.7 | 18.2 | 845.8 |
| 7 | x | x | x | 1.7 | 0 | 3.8 | 10.8 | 6.3 | 110.7 | 16.6 | 12.1 | 362 | 23.3 | 18.8 | 864.6 |
| 8 | x | x | x | 1.2 | 0 | 3.8 | 16.6 | 12.1 | 122.8 | 17.8 | 13.3 | 375.3 | 21.1 | 16.6 | 881.2 |
| 9 | x | x | x | 2.6 | 0 | 3.8 | 10.5 | 6 | 128.8 | 18.5 | 14 | 389.3 | 22.5 | 18 | 899.2 |
| 10 | x | x | x | 1.6 | 0 | 3.8 | 6.7 | 2.2 | 131.0 | 16.1 | 11.6 | 400.9 | 22.2 | 17.7 | 916.9 |
| 11 | x | x | x | -2.3 | 0 | 3.8 | 6.9 | 2.4 | 133.4 | 20.0 | 15.5 | 416.4 | 22.5 | 18 | 934.9 |
| 12 | x | x | x | -0.4 | 0 | 3.8 | 10.1 | 5.6 | 139.0 | 22.8 | 18.3 | 434.7 | 22.9 | 18.4 | 953.3 |
| 13 | x | x | x | 2.1 | 0 | 3.8 | 11.9 | 7.4 | 146.4 | 24.1 | 19.6 | 454.3 | 22.8 | 18.3 | 971.6 |
| 14 | x | x | x | 5.0 | 0.5 | 4.3 | 12.6 | 8.1 | 154.5 | 20.7 | 16.2 | 470.5 | 19.2 | 14.7 | 986.3 |
| 15 | x | x | x | 8.9 | 4.4 | 8.7 | 14.9 | 10.4 | 164.9 | 21.2 | 16.7 | 487.2 | 20.9 | 16.4 | 1002.7 |
| 16 | x | x | x | 8.7 | 4.2 | 12.9 | 11.2 | 6.7 | 171.6 | 22.5 | 18 | 505.2 | 23.8 | 19.3 | 1022 |
| 17 | x | x | x | 5.3 | 0.8 | 13.7 | 8 | 3.5 | 175.1 | 20.5 | 16 | 521.2 | 21.8 | 17.3 | 1039.3 |
| 18 | x | x | x | 4.2 | 0 | 13.7 | 5 | 0.5 | 175.6 | 15.7 | 11.2 | 532.4 | 21.7 | 17.2 | 1056.5 |
| 19 | x | x | x | 4.3 | 0 | 13.7 | 8.3 | 3.8 | 179.4 | 17.2 | 12.7 | 545.1 | 24.4 | 19.9 | 1076.4 |
| 20 | x | x | x | 3.2 | 0 | 13.7 | 7.6 | 3.1 | 182.5 | 21.9 | 17.4 | 562.5 | 27.2 | 22.7 | 1099.1 |
| 21 | x | x | x | 4.1 | 0 | 13.7 | 12.6 | 8.1 | 190.6 | 24.3 | 19.8 | 582.3 | 25.6 | 21.1 | 1120.2 |
| 22 | x | x | x | 7.8 | 3.3 | 17.0 | 14.8 | 10.3 | 200.9 | 19.7 | 15.2 | 597.5 | 23.8 | 19.3 | 1139.5 |
| 23 | x | x | x | 9.2 | 4.7 | 21.7 | 13.3 | 8.8 | 209.7 | 19.1 | 14.6 | 612.1 | 21.2 | 16.7 | 1156.2 |
| 24 | 4.6 | 0.1 | 0.1 | 10.9 | 6.4 | 28.1 | 15.3 | 10.8 | 220.5 | 22.5 | 18 | 630.1 | 24.6 | 20.1 | 1176.3 |
| 25 | 5.8 | 1.3 | 1.4 | 9.9 | 5.4 | 33.5 | 14.9 | 10.4 | 230.9 | 24.7 | 20.2 | 650.3 | 23.3 | 18.8 | 1195.1 |
| 26 | 5.7 | 1.2 | 2.6 | 10.4 | 5.9 | 39.4 | 14.9 | 10.4 | 241.3 | 20.7 | 16.2 | 666.5 | 25.4 | 20.9 | 1216 |
| 27 | 5.7 | 1.2 | 3.8 | 10.2 | 5.7 | 45.1 | 13.5 | 9 | 250.3 | 23.6 | 19.1 | 685.6 | 27.4 | 22.9 | 1238.9 |
| 28 | 1.6 | 0 | 3.8 | 11.4 | 6.9 | 52.0 | 11.1 | 6.6 | 256.9 | 14.3 | 9.8 | 695.4 | 28.6 | 24.1 | 1263 |
| 29 | x | x | x | 13.3 | 8.8 | 60.8 | 13 | 8.5 | 265.4 | 15 | 10.5 | 705.9 | 27.5 | 23 | 1286 |
| 30 | x | x | x | 14.4 | 9.9 | 70.7 | 14.1 | 9.6 | 275 | 14.4 | 9.9 | 715.8 | 29.3 | 24.8 | 1310.8 |
| 31 | x | x | x | 14.1 | 9.6 | 80.3 | x | x | x | 17.7 | 13.2 | 729 | x | x | x |
| sum | | 3.8 | | | 76.5 | | | 194.7 | | | 454 | | | 581.8 | |

Legend: M-month; D-day; SDT-mean daily temperature; KDTJ-daily heat unit; ATJ-accumulated heat unit

Table 5. Duration of growing season, harviest date and ATJ for examined vegetable pea genotypes

| Genotype | Growing season | Harviest date | ATJ |
|---|---|---|---|
| S-1 | 65 | June 1$^{st}$ | 746.5 |
| S-2 | 61 | May 24$^{th}$ | 630.1 |
| S-3 | 60 | May 23$^{th}$ | 612.1 |
| S-4 | 66 | June 2$^{nd}$ | 765.6 |
| S-5 | 65 | June 1$^{st}$ | 746.5 |
| S-6 | 70 | June 8$^{th}$ | 881.2 |
| S-7 | 70 | June 8$^{th}$ | 881.2 |
| S-8 | 72 | June 10$^{th}$ | 916.9 |
| S-9 | 76 | June 13$^{th}$ | 971.6 |
| S-10 | 76 | June 14$^{th}$ | 986.3 |
| S-T | 63 | May 27$^{th}$ | 685.6 |
| S-D | 64 | May 28$^{th}$ | 695.4 |

Growing season length of peas represents the period from sprouting to technological maturity. The specified property is expressed in the number of days. Growing season length of the pea genotypes tested in our research was from 60 days to 76 days. Genotype S-3 had the shortest growing season (60 days). Followed by S-2 with 61 days, S-T with 63 days, S-D with 64 days, S-1 and S-5 with 65 days, S-4 with 66 days, S-6 and S-7 with 70 days, S-8 with 72 days and finally with the longest growing season were genotypes S-9 and S-10 with 76 days of growing season (Tab 5).

According to growing season length, all cultivars can be classified into four groups:

1. Early up to 60 days of growing season
2. Mid-early 61-65 days of growing season
3. Mid-late with 66-70 days of growing season
4. Late 70 days of growing season and longer (Đinović et al., 1984; Jovićević, 2011).

Genotype S-3 was the earliest in this research, where 60 days passed from germination to technological maturity, accumulated a sum of 612.1 heat units from sowing to technological maturity. The next genotype with 61 days was S-2, which accumulated 630.1 heat units from sowing to technological maturity. 685.6 heat units were required from sowing to technological maturity for the S-T genotype, with a growing season length of 63 days, and 695.4 heat units for the S-D genotype with 64 days of growing season. Genotypes S-1 and S-5 with 65 days of growing season accumulated 746.5, and genotype S-4 with 66 days of growing season accumulated 765.6 heat units. With 70 days of growing season, genotypes S-6 and S-7 accumulated 881.2 heat units. Genotypes S- 8 with 72 days of growing season accumulated 916.9 heat units. As the latest in the experiment with 76 days of growing season, genotypes S-9 and S-10 accumulated 971.6 and 986.3 heat units (Tab. 4 and 5). Olivier and Annandale (1998), showed that the sum of heat units from sowing to flowering varied from 770°C to 890°C depending on the cultivar, and from 1370°C to 1450°C from sowing to maturity (where harvest date was defined with a tenderometric value of 130). They also stated that the optimum temperature is somewhere between 25 °C and 30 °C. A detailed research on the impact of temperature on the growth and development of vegetable peas suggests that, considering the accumulated temperature during growing season, it is possible to strategically plan the sowing time and harvest dates in alignment with mechanization capacities.

Pea cultivars in the research of Bourgeois et.al. (2000) had the sum of thermal units from 711 to 996. In the results of Ivić (2016), growing season of the studied cultivars was from 80 to 88 days. During the growing season, the examined varieties accumulated from 799 to 935°C heat units.

**CONCLUSIONS**

The research included vegetable pea genotypes of different duration of growing season (early, mid-early, mid-late and late) which ranged from 60 days to 76 days. Line S-3 had the shortest growing season (60 days), followed by S-2 with 61 days, ST with 63 days, SD with 64 days, S-1 and S-5 with 65 days, S-4 with 66 days, S-6 and S-7 with 70 days, S-8 with 72 days and finally lines S-9 and S-10 with the longest growing season of 76 days. The methodology of heat units in planning pea sowing and maturity is based on the assumption that the heat accumulated during the growing season is linearly proportional to the intensity of growth and development as well as the length of vegetation.

The sum of heat units is characteristic of the cultivar, and the tested pea genotypes accumulated sums from 612.1 to 986.3 heat units.

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