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Length of the growing season and yield in *Triticum monococcum* L., in accordance with the growing conditions

S. Stamatov*, E. Valchinova, G. Desheva, K. Uzundzhalieva, P. Chavdarov, T. Cholakov, B. Kyosev, R. Ruseva, N. Velcheva

Institute of Plant genetic resources „Konstantin Malkov”, 4122 Sadovo, Bulgaria

(Manuscript received 7 June 2017; accepted for publication 1 September 2017)

**Abstract.** The aim of the current study is to trace the changes in the length of the growing season in accordance with the accumulated effective temperatures, rains and plant nutrition during the vegetation period, as well as the influence of these indices on the grain yield. The study was conducted in the period 2015 – 2016 in the experimental field of Institute of Plant Genetic Resources - Sadovo with the local variety B3E0025 from the National Genebank in Sadovo. The experiment was made in block method in four repetitions. Three sowing times were made – autumn, winter and early spring and two options of N fertilization – without additional N and 3 kg/da input of active N substance in tillering phase. The beginning of the basic phenophases has been observed. As a result of the study it was established that the vegetation period in *T. monococcum* L. has 114-238 days’ duration and accumulation of effective temperature of 2266.0-2714.7°C. The length of the growing season and the necessary accumulated temperature depends on the sowing period, the predecessor, the amount of nutrient substances and soil moisture. The extension of the critical phases of autumn sowing favours the obtaining of higher yield. The significance of the effective temperatures decreases with additional N input.

**Keywords:** *T. monococcum* L., effective temperatures, interphase periods, yield

**Introduction**

*T. monococcum* L. is one of the cultivated wheat types. It is considered that the beginning of its cultivation was about 7500 Y.B.C., near Karadag, Southeast Turkey (Heun et al., 1997; Weiss and Zohary, 2011). Stransky (1963) established that *T. monococcum* L. is the oldest cultivated plant in our region, and was probably grown here 10,000 years ago. According to Arnaudov, *T. monococcum* L. was grown on our territory more than 3500 Y.B.C (Arnaudov, 1936 a; 1936 b; Lipshiz, 1945). Demosten (384-322 y.b.c.) mentions about it, kept in Thracian underground garners (Katzarov et al., 1912; Konstantin Ikonom, 1936).

That plant has been grown lately on much larger territories, when during the first ages of the new era the Slavic tribes came to the Balkan peninsula. They continued to grow it and gave it the name “lime”, which means “spall” and demonstrates the way of its use by shaking in stone vessels to get rid of the ear. Nowadays it occurs as wild plant in meadows and along the roads.

*Triticum monococcum* L. belongs to Poacea, genus *Triticum* (Zhukovsky, 1957). It belongs to the group of the diploid wheat (2n=14) with AA genome.

A collection of *Triticum monococcum* L. is maintained in the National Genebank at the Institute of Plant Genetic Resources - Sadovo (IPGR-Sadovo). The diversity of the collection is represented by 13 varieties and a total of 83 samples, 68 of which are stored in the base collection of the genebank, under conditions for long-term storage (Ozdakova et al., 2007; Desheva et al., 2013). The common forms are dry and cold resistant, making them very suitable for growing under changing climatic conditions (Grausgruber et al., 2004; Hai-Chun et al., 2007). They can also grow at a higher altitude of between 700 and 1300 m, where the cultivation of modern wheat is unthinkable. It is not demanding as to soil type and is suitable for cultivation in both poorer soil and saline soils (Hai-Chun et al., 2007). This makes the crop more unpretentious to the cultivation conditions (Stamatov et al., 2012; Desheva et al., 2014).

*T. monococcum* L. is an alternative crop for farmers in Bulgaria, who can include it in their crop rotation, which would guarantee them a stable yield under conditions of sudden climate change. Compared to conventionally grown wheat crops, yields were lower and ranged from 100 to 300 kg/da (paddy). The share of the weeds is 30-35% of the grain yield (Castagna et al., 1994; Grausgruber et al., 2004).

There is currently no well-established breeding technology for *T. monococcum* L. In the period 2014 - 2016 a methodology for cultivation on the territory of Bulgaria was developed under the project "Einkorn - Ancient innovation II". In the present publication, part of the results is presented – changing the vegetation period according to the effective temperature accumulation, the rainfall and the nutrition of plants during vegetation and the influence of these factors on the yield.

**Material and methods**

The study was conducted during the period 2015 – 2016 on the experimental field of IPGR - Sadovo, with the local variety B3E0025 from the National Genebank - Sadovo.

By means of block method in four repetitions with a plot size of 16 m² variants were tested sown during three sowing periods - autumn, winter and early spring. This coincided with the months of October, January and February. Peas and sunflower were used as predecessors. Two variants of nitrogen feed have been tested: no...
further nitrogen injection and 3 kg/da of active nitrate nitrogen in tillering phase. In this way, eight variants were formed with a yield area of 64 m² for each of them.

During the study the time of occurrence of the different phenological phases of the development of einkorn was observed: germination, third leaf, tillering, spindle, spike formation, flowering and the phases of maturity – milk, wax and full maturity.

Correlation analysis was used to determine the correlations between the yield and the factors - length of the growing season, total effective temperatures and rainfall.

Results and discussion

The duration of interphase periods: germination - third leaf, third leaf - tillering, tillering - spindle, spindle - heading, heading - flowering, flowering – milk maturity, milk maturity - wax maturity depending on the predecessor and sowing date are presented in Tables 1 to 6.

Germination is a phase that begins with the emergence of coleoptile. The einkorn spread in Bulgaria, germinates with a coleoptile with violet color. The duration of germination depends on the moisture content of the soil and the accumulation of a certain amount of heat. It runs for 12-21 days with accumulation of an effective temperature sum exceeding 5ºC from 134.6ºC to 228.7ºC (Tables 1-6). Normally, this period is more prolonged when sowing is made in autumn. The entry of the crop into the third leaf phase occurs after 10-15 days with the accumulation of an effective temperature sum of 49.2-168.8ºC (Figures 1-6). The duration of the seed phase, the presence of soil moisture and the predecessor influence the duration of the interphase period. Autumn sowing, soil moisture and the use of predecessors to enrich the soil with nutrient substances favours the rapid germination process – third leaf phase. Just the opposite with spring sowing, when there is lack of soil moisture and the predecessors have exhausted the soil and thus the interphase period is prolonged.

The tillering phase starts when the first tillering knot is formed. It can be situated at different depth under the soil surface. Shallow or surface sowing, as well as frequent freezing and thawing of the soil surface, result in firing node being drawn to the soil surface. The shallower the tillering knot, the less favorable the development of einkorn in the next phases, the seed is diluted and thus the yield is lower. The interphase period third leaf – tillering runs for 10-75 days and accumulation of an effective temperature sum of 149.7-356.8ºC (Tables 1-6). Significant for the duration of this phase apart from the date is also the soil nutrient supply. The shortest and lowest effective amount is the phase when using predecessors, enriching the soil with nutrients and vice versa - precursors that deplete the soil, prolong that period.

Tillering – spindle is an interphase period that is critical to yield formation. The stages of ontogenetic development through which the spike length and number of spickles in the spike are formed,

### Table 1. Autumn sowing of einkorn with predecessor peas

<table>
<thead>
<tr>
<th>Interphase periods</th>
<th>Number of days</th>
<th>∑ ef. t</th>
<th>∑ Rainfall, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing-Germination</td>
<td>21.00</td>
<td>228.7</td>
<td>53</td>
</tr>
<tr>
<td>Germination-Third leaf</td>
<td>15.00</td>
<td>49.2</td>
<td>0</td>
</tr>
<tr>
<td>Third leaf-Tillering</td>
<td>63.00</td>
<td>149.7</td>
<td>80.5</td>
</tr>
<tr>
<td>Tilling-Spindle</td>
<td>57.00</td>
<td>601.7</td>
<td>68.3</td>
</tr>
<tr>
<td>Spindle-Heading</td>
<td>34.00</td>
<td>517.9</td>
<td>129.4</td>
</tr>
<tr>
<td>Heading-Flowering</td>
<td>10.00</td>
<td>165.7</td>
<td>16.6</td>
</tr>
<tr>
<td>Flowering-Milk maturity</td>
<td>15.00</td>
<td>302.2</td>
<td>26.5</td>
</tr>
<tr>
<td>Milk maturity-Wax maturity</td>
<td>10.00</td>
<td>243.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Wax maturity-Full maturity</td>
<td>13.00</td>
<td>331.0</td>
<td>19.8</td>
</tr>
<tr>
<td>Duration of vegetation period</td>
<td>238.00</td>
<td>2589.1</td>
<td>395.5</td>
</tr>
</tbody>
</table>

### Table 2. Autumn sowing of einkorn with predecessor sunflower

<table>
<thead>
<tr>
<th>Interphase periods</th>
<th>Number of days</th>
<th>∑ ef. t</th>
<th>∑ Rainfall, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing-Germination</td>
<td>21.00</td>
<td>228.7</td>
<td>53</td>
</tr>
<tr>
<td>Germination-Third leaf</td>
<td>15.00</td>
<td>49.2</td>
<td>0</td>
</tr>
<tr>
<td>Third leaf-Tillering</td>
<td>75.00</td>
<td>356.8</td>
<td>90.4</td>
</tr>
<tr>
<td>Tilling-Spindle</td>
<td>49.00</td>
<td>616.31</td>
<td>70.6</td>
</tr>
<tr>
<td>Spindle-Heading</td>
<td>24.00</td>
<td>357.8</td>
<td>124.9</td>
</tr>
<tr>
<td>Heading-Flowering</td>
<td>9.00</td>
<td>163.6</td>
<td>15.3</td>
</tr>
<tr>
<td>Flowering-Milk maturity</td>
<td>14.00</td>
<td>285.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Milk maturity-Wax maturity</td>
<td>14.00</td>
<td>280.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Wax maturity-Full maturity</td>
<td>15.00</td>
<td>376.1</td>
<td>19.8</td>
</tr>
<tr>
<td>Duration of vegetation period</td>
<td>236.00</td>
<td>2714.71</td>
<td>400.9</td>
</tr>
</tbody>
</table>
occur at the end of tillering and the beginning of the spindle. During this phase it is necessary to provide einkorn with sufficient nutrients and moisture in the soil. Until the occurrence of the spindle phase, the root system grows predominantly; the root and the adventitious roots grow in depth and width and effectively use nutrients and the available moisture in the soil. The length of the phenophase depends on the sowing time and the soil nutrient content. Autumn sowing, as well as predecessors that deplete the soil, prolong this phase, while spring sowing and bean predecessors shorten the duration and accumulation of higher effective temperature sums. Spinning lasts 15-57 days and accumulation of an effective temperature sum of 242.0-616.3°C (Tables 1-6). It is characterized by the appearance of the first knee on the central brother.

Interphase spindle - heading is 17-37 days depending on the sowing period. The temperature sum required for that interphase period is between 275.1 and 599.2°C (Tables 1-6).

Interphase period heading – flowering is the shortest as it lasts 6-14 days and accumulation of an effective temperature sum of 147.0-349.5°C (Tables 1-6). The duration of the flowering phase depends on regular and even germination. All the conditions that

<table>
<thead>
<tr>
<th>Table 3. Winter sowing of einkorn with predecessor peas</th>
</tr>
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<tbody>
<tr>
<td>Interphase periods</td>
</tr>
<tr>
<td>Sowing-Germination</td>
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<tr>
<td>Germination-Third leaf</td>
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<tr>
<td>Third leaf-Tillering</td>
</tr>
<tr>
<td>Tillering-Spindle</td>
</tr>
<tr>
<td>Spindle-Heading</td>
</tr>
<tr>
<td>Heading-Flowering</td>
</tr>
<tr>
<td>Flowering-Milk maturity</td>
</tr>
<tr>
<td>Milk maturity-Wax maturity</td>
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<tr>
<td>Wax maturity-Full maturity</td>
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<td>Duration of vegetation period</td>
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<th>Table 4. Winter sowing of einkorn with predecessor sunflower</th>
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<tr>
<td>Interphase periods</td>
</tr>
<tr>
<td>Sowing-Germination</td>
</tr>
<tr>
<td>Germination-Third leaf</td>
</tr>
<tr>
<td>Third leaf-Tillering</td>
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<tr>
<td>Tillering-Spindle</td>
</tr>
<tr>
<td>Spindle-Heading</td>
</tr>
<tr>
<td>Heading-Flowering</td>
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<tr>
<td>Flowering-Milk maturity</td>
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<tr>
<td>Milk maturity-Wax maturity</td>
</tr>
<tr>
<td>Wax maturity-Full maturity</td>
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<tr>
<td>Duration of vegetation period</td>
</tr>
</tbody>
</table>

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<th>Table 5. Spring sowing of einkorn with predecessor peas</th>
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<tr>
<td>Interphase periods</td>
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<tr>
<td>Sowing-Germination</td>
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<tr>
<td>Germination-Third leaf</td>
</tr>
<tr>
<td>Third leaf-Tillering</td>
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<tr>
<td>Tillering-Spindle</td>
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<tr>
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<tr>
<td>Heading-Flowering</td>
</tr>
<tr>
<td>Flowering-Milk maturity</td>
</tr>
<tr>
<td>Milk maturity-Wax maturity</td>
</tr>
<tr>
<td>Wax maturity-Full maturity</td>
</tr>
<tr>
<td>Duration of vegetation period</td>
</tr>
</tbody>
</table>
favor this lead to shortening of the flowering period. The phase is characterized by the appearance of blossoms - the sticks go out of the weeds.

Flowering – milk maturity is an interphase period that is critical in terms of yield. During this phase the grain fills and the productive potential of the crop is revealed. It is absolutely necessary during this phase to provide the einkorn with nutrients and moisture in the soil. The phase lasts 9-15 days and accumulation of an effective temperature sum of 280.4-413.2°C (Tables 1-6). It goes quickly both with winter and spring sowing when it gains a sufficiently effective temperature sum for the shortest time and is extended in autumn sowing. Soil moisture and rainfall during the period favor the longer period of this phase.

The interphase period of milk-wax maturity is a continuation of the previous one with regard to the criticality of the period. The need for nutrients and moisture in the soil is extremely high. It lasts 7-14 days and accumulation of an effective temperature sum of 243.0-317.0°C (Tables 1-6). It goes quickly both with winter and spring sowing when it gains a sufficiently effective temperature sum for the shortest time and is extended in autumn sowing. Soil moisture and rainfall during the period favor the longer period of this phase.

The interphase period of milk-wax maturity is a continuation of the previous one with regard to the criticality of the period. The need for nutrients and moisture in the soil is extremely high. It lasts 7-14 days and accumulation of an effective temperature sum of 243.0-317.0°C (Tables 1-6). It goes quickly both with winter and spring sowing when it gains a sufficiently effective temperature sum for the shortest time and is extended in autumn sowing. Soil moisture and rainfall during the period favor the longer period of this phase.

The influence of the studied factors - number of days, effective temperature sum and rainfall on the yield of einkorn in both feeding options - no nitrogen input and nitrogen input into the planting phase of the plants are presented in Tables 7 and 8. The yield from plants with additional nitrogen fertilization is influenced by the number of days of the vegetation period, the sum of the effective temperatures and the amount of rainfall. Yield increases with the increase of the three factors (Table 7). In fertilized variants, however, the added nitrogen eliminates the effect of the sum of the effective temperatures. It is evident from the deduced dependencies that its importance in the set of factors is negligible (Table 8).

**Conclusion**

The growing season of einkorn lasts 114-238 days with accumulation of effective temperature of 2266.0-2714.71°C. The duration of the growing season and the necessary temperature sum depends on the time of sowing, the predecessor, presence of nutrient substances and soil moisture. The influence of the effective
temperatures reduces with the application of additional N fertilization.

Acknowledgements
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The title needs to be as concise and informative about the nature of research. It should be written with small letter/bold, 14/without any abbreviations.

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**Keywords:** Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

**The introduction** must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal?

**Material and methods:** The objects of research, organization of experiments, chemical analyses, statistical and other methods and conditions applied for the experiments should be described in detail. A criterion of sufficient information is to be possible for others to repeat the experiment in order to verify results.

**Results** are presented in understandable tables and figures, accompanied by the statistical parameters needed for the evaluation. Data from tables and figures should not be repeated in the text. Tables should be as simple and as few as possible. Each table should have its own explanatory title and to be typed on a separate page. They should be outside the main body of the text and an indication should be given where it should be inserted.

**Figures** should be sharp with good contrast and rendition. Graphic materials should be preferred. Photographs to be appropriate for printing. Illustrations are supplied in colour as an exception after special agreement with the editorial board and possible payment of extra costs. The figures are to be each in a single file and their location should be given within the text.

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**Conclusion:** The most important consequences for the science and practice resulting from the conducted research should be summarized in a few sentences. The conclusions shouldn’t be numbered and no new paragraphs be used. Contributions are the core of conclusions.

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**Todorov N and Mitev J.** 1995. Effect of level of feeding during dry period, and body condition score on reproductive performance in dairy cows.IX** International Conference on Production Diseases in Farm Animals, September 11-14, Berlin, Germany.

**Thesis:**
Hristova D. 2013. Investigation on genetic diversity in local sheep breeds using DNA markers. Thesis for PhD, Trakia University, Stara Zagora, Bulgaria, (Bg).

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