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# THE SUM OF TEMPERATURE UNITS IN DIFFERENT PHENO-PHASES OF DEVELOPMENT OF SEED MAIZE REGARDING THE PRODUCTION YEAR

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## Abstract

The aim of this study was to determine variability of temperature sums for the occurrence of pheno-phases of silking, tasselling and pollination of seed maize. Nine maize inbred lines were tested in two production years. Compatibility and overlapping of silking, tasselling and pollination of parental components in a seed crop are important for achieving high yields. According to obtained data, the degree of accumulation of temperature sums was higher in the first year than in the second production year for all stages, except for the beginning of tasselling. The differences were statistically significant: the greatest and smallest differences were obtained for tasselling (t2 - 70.9$^{o}$C) and the beginning of silking (s1- 20.86$^{o}$C), respectively. The effect of genotypes on differences in temperature sums was the greatest for all pheno-phases, $p<0.005$. The effect of the production year on the number of temperature units necessary for silking and pollination was also high, but there was no high statistical effect on the beginning of tasselling. Since maize is a plant species that is grown in different regions, maize growing practices should be adjusted to the main aim of maize production, to achieving high and stable yields.

**Key words:** *grow degree units (GDU), maize, silking, tasselling, pollination*

## Introduction

According to its morphological, physiological and other traits, maize belongs to the most variable crop. There are several classifications related to maize, and one of them is the classification according to the duration of the growing season. The decision on the introduction of vegetative groups in Europe was made as long ago as 1954 and was based on the FAO regulations with the US hybrids used as checks *(*Derieux and Bonhome, 1982*).*

The classification of maize into maturity groups, as well as, the determination of the duration of the growing season are done based on temperature sums as the most reliable method. The establishing of pheno-phases according to temperature sums has initially applied to peas (Katz, 1952), and afterwards to maize with the application of various methods for calculation of heat sums *(*Marton *et al.,* 2007). The temperature, humidity and mineral nutrition affect the length of the growing season. The information about temperature sums of developmental pheno-phases provides the appropriate planning of the production for achieving high yields. In order to get high yields in seed production it is necessary to achieve full pollination and kernel filling. The kernel number per plant and their size, i.e. their weight, determines the grain yield. The kernel number per plant is a trait that varies and is more strongly related to the yield than to the kernel size is (Peltonen-Sainio *et al.*, 2007). The kernel size has a significant role in modulating genetic and external control of the kernel number, Egli (2006).

Otegui *et al.* (1995) have established that the kernel number per plant also affected the water deficit in the period of tasselling and silking of maize.
High temperatures affect production and pollen viability. Dry and warm weather postpones the occurrence of silk and increases the number of days between tasselling and silking. According to results gained by Chassot (2000) and Stone *et al.* (1999) temperatures of soil and air are the principal physiological stress factor in the early development of maize plants.

## Material and Methods

Nine maize inbred lines were used in the trail, which was set in the plots of the Maize Research Institute, Zemun Polje in the two production years (2013 and 2015). The plot size amounted to 0.09 ha. Each inbred was sown in three 50-m long rows with the inter-row distance of 70 cm. Standard growing practices for cultivating seed maize were applied during the growing season (the Regulation on control of the seed production, the content and the method of keeping records on production of seedlings of agricultural crops and the form on the report on the production of mycelia of edible and medicinal fungi, Oficial Gazette of RS 60/2006). Temperature sums were estimated based on meteorological data of the Maize Research Institute, Zemun Polje according to the GDU (Growing Degree Unit) method: mean daily temperature minus minimum maize growth rate ($10^0$C), extreme values below $10^0$C and above $30^0$C (maximum maize growth rate), were calculated as $10^0$C and $30^0$C (Shaw, 1975; McMaster and Wilhelm, 1997).

$$GDU = (T_{max}+T_{min}/2)-T_{base}$$

Where $T_{max}$ is the daily maximum air temperature, $T_{min}$ is the daily minimum air temperature and $T_{base}$ is the minimum maize growth rate.
Based on visual observation, the dates of the beginning and ending of silking, tasselling and pollination were estimated. The first date was estimated when 5% of plants occurred in all three pheno-phases: beginning of silking (s1), beginning of tasselling (t1), and beginning of pollination (p1). The second date was when silk, tassels and anthers occurred on 100% of plants: end of pheno-phases of silking (s2), tasselling (t2) and pollination (p2).
Results were processed by the statistical program *IMB SPSS 2010*. The descriptive statistics was done for each parameter at the annual level; two factorial analysis of variance was performed to determine differences, while their significance was estimated by the t-test (Hadživuković, 1991).
Meteorological data in the trial period were equal regarding temperature sums and water regime. The average air temperatures during pollination (mid June - end of July) were approximately the same in both years of investigation (Table 1). Comparing with the official standard temperature period (1961-1990), we have an increase in temperature in both years of research, which is in line with climatic changes that move towards global warming.
Precipitation sums in 2015 were higher by 60.9 $Lm^{-2}$ than in 2013. During pollination (June-July) precipitation sums were almost equal (31 L in June, while there were a bit more precipitation in July of 2013 - 16 L $m^{-2}$) (Table 1). As with temperature, changes in schedule and amount of precipitation were also determined. In the period of research, the amount of precipitation is less than the standard period (1961-1990) . The visible decrease was in the period June-July, ie at the time of the observed pheno-phases.

Table 1. Monthly values of precipitation and mean air temperature (weather station Zemun Polje)

| | Monthly mean air temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | April | May | June | July | Aug. | Sept. | Oct | Average |
| 2013 | 14.9 | 19.7 | 21.9 | 23.8 | 23.7 | 16.9 | 15.3 | 22.7 |
| 2015 | 12.9 | 19.1 | 22.1 | 26.4 | 25.7 | 20.2 | 12.4 | 23.1 |
| 61-90 | 12,3 | 17,1 | 20,0 | 21,7 | 21,3 | 17,6 | 12,4 | 20.4 |
| | Monthly sum of growing degree units (GDU) | | | | | | | Sum |
| 2013 | 147.0 | 300.7 | 357.0 | 427.8 | 424.7 | 207.0 | 164.3 | 2028.5 |
| 2015 | 87.0 | 282.1 | 363.0 | 508.4 | 486.7 | 306.0 | 74.4 | 2107.6 |
| | Monthly sum of precipitation (mm) | | | | | | | |
| Year | April | May | June | July | Aug. | Sept. | Oct | Sum |
| 2013 | 14.9 | 93.9 | 37.8 | 16.0 | 12.7 | 70.1 | 21.9 | 367.3 |
| 2015 | 19.7 | 97.8 | 31.1 | 7.2 | 56.0 | 73.6 | 65.1 | 350.5 |
| 61-90 | 57.6 | 69.3 | 89.3 | 70.0 | 54.3 | 51.3 | 41.0 | 433.0 |

*61-90 (1961-1990)-official standard period, GDU = ($T_{max}$+$T_{min}$/2)-$T_b$ (extreme values below $10^0$C and above $30^0$C, were calculated as $10^0$C and $30^0$C)

## Results and Discussion

Mean values of temperature sums were established over production years with the aim to observe variability of these sums. The lowest temperature sum was obtained in the first year (2013) at the time of tasselling, while the highest sum was detected also in the first year (2013) in the pheno-phase of pollination (p2) (Figure 1). In 2013, the temperature sums were higher for all pheno-phases. The exception was the beginning of tasselling in 2013, when values were a little bit lower than in 2015 (t1 in 2013 with GDU-621.23°C, t2 in 2015 with GDU-627.73°C). According to Çakir (2004), tasselling and ear formation were especially affected by soil water deficiency. A lower precipitation sum postponed tasselling in 2015. Tasselling (t1) expressed the greatest variability in performed trials, with the coefficient of variation of 7.04%. The smallest differences in means of coefficients of variation of temperature sums were detected in the pheno-phase of silking (s2 - CV 4.85%).

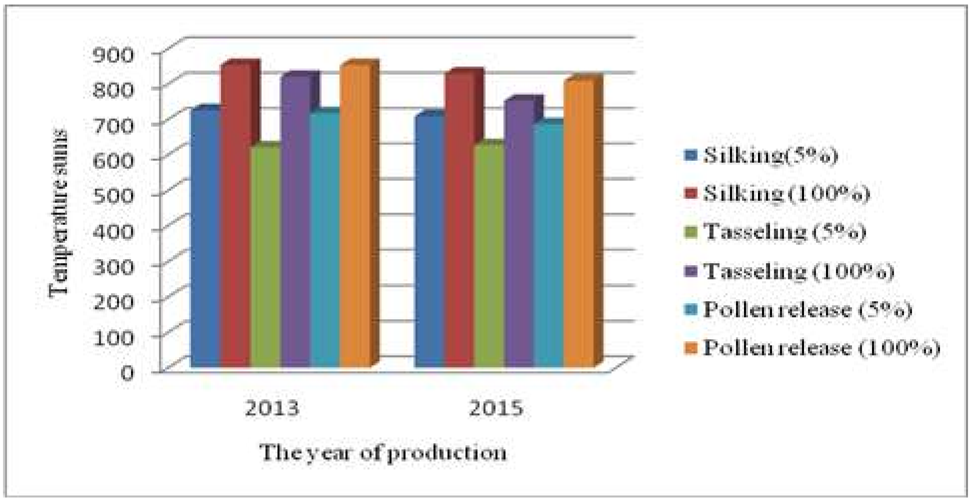


Figure 1. Temperature sums of phenol-phases over production years

According to the t-test, the differences in the time of the beginning of silking, tasselling and pollination over the two production years were significant (Table 2). The effect of the production year on the duration of the periods of silking (s2), tasselling (t2) and pollination p(2) was significant. The beginning of the stated pheno-phase differed in the two production years, but with no statistical significance. The amount and distribution of precipitation during flowering and kernel filling have a significant role in the expressing of plant potential (Bello et al., 2014).

Table 2. The t-test for the significance of differences in temperature sums over production years

| | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 95% Confidence Interval of the Difference | |
| | t | df | Sig. | Mean Difference | Std. Error Difference | Lower | Upper |
| s1 | 1.67 | 16.16 | 0.11 | 20.86 | 12.50 | -5.62 | 47.34 |
| s2 | 3.26* | 27.00 | 0.00 | 35.95 | 11.02 | 13.34 | 58.56 |
| m1 | -0.31 | 27.00 | 0.76 | -5.19 | 16.84 | -39.74 | 29.35 |
| m2 | 5.58* | 27.00 | 0.00 | 65.78 | 11.78 | 41.61 | 89.95 |
| p1 | 1.68 | 20.37 | 0.11 | 25.29 | 15.08 | -6.12 | 56.70 |
| p2 | 2.58* | 27.00 | 0.02 | 48.48 | 18.79 | 9.94 | 87.03 |

The pollination period in maize inbreds is a very specific trait and is attributed to genotypic structure, $p<0.05$ (Table 3). Whether any particular pheno-phase will vary more or less also depends on environmental conditions. According to presented results, the production year was significant for all pheno-phases except for the beginning of tasselling. The beginning and the duration of the tasselling period were not statistically significant even in the genotype × production year interaction ($p>0.05$). On the other hand, silking and pollination depended on the interaction of both factors.

According to Kang (1998, 2004), the genotype by environment interaction implies the response of genotypes to conditions of the environment they are cultivated in. Since conditions under which the trials were carried out were similar, the effects of these two factors did not have any significant results for all studied traits.

Table 3. Two factorial analysis of variance

| Source of variation | F | | | | | |
|---|---|---|---|---|---|---|
| | s1 | s2 | t1 | t2 | p1 | p2 |
| Genotype | 35,03* | 17,85* | 4,06* | 4,19* | 3,51* | 17,61* |
| Year | 24,04* | 35,82* | 0,22 | 65,45* | 5,99* | 36,91* |
| Genotype × Year | 19,82* | 8,86* | 0,88 | 2,01 | 1,2* | 8,12* |

## Conclusions

The temperature sums for seed maize inbreds during the two production years similar in temperature and humidity conditions, pointed out variations in all of three observed pheno-phases. The influence of factors on occurense pheno- phasis was different which is also confirmed by coefficients of variation - the lowest (4.85%) and highest (7.04%) for silking and tasselling, respectively. Despite similar weather conditions over both production years, the year significantly affected only the beginning of tasselling (t1) $p>0.05$. It is necessary to know about the degree of variability in occurrences in stages during pollination, and conditions under which the production is planned, so the probability of incongruity between tasselling and pollination will be lower.

Since maize is a crop grown in various regions, the maize growing practices should be adjusted to conditions under which the seed production will be performed.

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