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INFLUENCES OF SOWING DATE AND CLIMATE CONDITIONS ON THE PHENOLOGICAL PHASES OF DIFFERENT MAIZE HYBRIDS

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Abstract: The experiment was set up during 2016 and 2017 in the Leskovac area on an alluvial soil. For research purposes, the duration of certain phenological phases, the entire vegetation period of 6 maize hybrids, and three FAO maturity groups (400–600) were monitored. The research aims to determine the duration of each phenological phase and the entire growing season based on the number of days, the sum of the total, and the sum of the effective temperatures, and to recommend suitable hybrids for the investigated area. In terms of years and sowing dates, the difference in vegetation period between the hybrid with the longest and the hybrid with the shortest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. On average over two years, the lowest sum of effective temperatures was measured at 1158.8°C for the FAO hybrid group 400, ZP 434, and the highest at 1398.9°C for the FAO hybrid group 600, NS 6030. Depending on the temperature conditions, the year in the first sowing period of the individual phases was shortened with increasing temperature. The onset of periods with lower air temperatures and the length of the phenological phases lasted longer. The method of the sum of effective temperatures proved to be the most reliable method for determining the vegetation length of the maize hybrids examined.

Key words: maize, length of vegetation, number of days, total air temperature, effective temperature.

Introduction

Maize is a field crop that, along with wheat and rice, occupies the largest production areas in the world's total crop production. In the Republic of Serbia,

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maize has been the most widely cultivated crop for years, and in 2023, 922.980 ha were sown under this crop (SORS, 2023). The constant work on breeding maize has resulted in various phenotypic changes, leading to a large number of hybrids with good agronomic properties (Popović et al., 2022; Akintunde, 2024). To achieve high and stable yields, a large number of researchers studied the vegetation length of different maize hybrids under different production conditions from germination to maturation. The duration of a certain phenological phase of various hybrids differs in length (Junyan et al., 2023). Crop phenology characterises the physiological stages of crop development, spanning from sowing to harvest (Gao et al., 2021). In production areas with less rainfall, hybrids of FAO group 300–500 should be produced, as hybrids with a longer vegetation period (Glamočlija and Prijić, 2004; Biberdžić et al., 2018a). The possibility of using heat units has been extensively studied in the production of maize, and different methods are used to calculate them. Calculating the sum of heat units to determine the vegetation period of various cultivated crops was first used in the production of peas (*Pisum sativum* L.). The classification of the length of the maize vegetation according to the required number of days from sprouting to ripening has proven to be unreliable in practice, because it mainly depends on the agrometeorological conditions of the year, but also on the edaphic and orographic conditions of the relief (Jovanović et al., 2013). The goal of these studies was to determine the duration of certain phenological phases of different maize hybrids, depending on the time of sowing and the climatic conditions of the year.

Material and Methods

The two-year experiment was based on the property of the Secondary Agricultural School in Leskovac, on alluvial soil at an altitude of 225 m above sea level. The experiment included 6 maize hybrids from three FAO maturity groups, namely: H1 – ZP 434, H2 – NS 4023, (FAO 400); H3 – ZP 555, H4 – NS 5051 (FAO 500); H5 – ZP 666, H6 – NS 6030 (FAO 600). During the production process, the standard agricultural practices were applied in the production of maize, characteristic of the examined area. Sowing was done during April in two sowing periods: I – early April; II – mid-April. The trial was set up in 3 repetitions in a randomised block system. Four rows of each hybrid were sown. To provide the plants with an optimal density, sowing was done at an inter-row distance: 70 cm x 20 cm (FAO group 400), 70 cm x 25 cm (FAO group 500) and 70 cm x 30 cm (FAO group 600) (Figure 1). The meteorological station in Leskovac, which is located in the immediate vicinity of the trial field, was used to obtain data on the mean, minimum and maximum daily air temperatures and on the amount and distribution of precipitation. The following phenological phases were monitored on all hybrids from both sowing periods: from sowing to sprouting; from sprouting to the phase of the 10th leaf; from the phase of the 10th leaf to silking; from silking to the appearance of a black layer at the base of the grain; from the appearance of a black layer at the base of the grain to full maturity; from sowing to full maturity (harvest). To determine the phenological phases, a visual assessment was made when 70% of the plants entered into the observed phenological phase. For each phenological phase, the duration was determined based on the number of days, the sum of effective air temperatures (SET) and the sum of total air temperatures (SUT). The accuracy of each method was determined based on the standard deviation (Sd) and the coefficient of variation (Cv). During the two-year research period, the lowest average air temperature was recorded in 2016, and the highest average air temperature in 2017. Figure 1 shows the average monthly air temperatures (°C) and the distribution and amount of precipitation (mm) by month of the maize vegetation period in both years of the study. During the two-year research based on the data on the mean monthly air temperatures, it was observed that the temperature increased from April to July, while a decrease in temperature was recorded from August onwards. The highest amount of precipitation was recorded in 2016, with 569.8 mm in the period from April to November, and the lowest in 2017 (434.0 mm). Analysing the mean monthly air temperatures, as well as the amount and distribution of precipitation by month, during the research period, it can be seen that the temperature conditions were more advantageous during the production year of 2016, especially in the period from June to August, which is very important during the maize vegetation period, and especially for yield formation. The second year of the research was characterised by a much lower amount of precipitation and was characterised as less favourable for maize production.

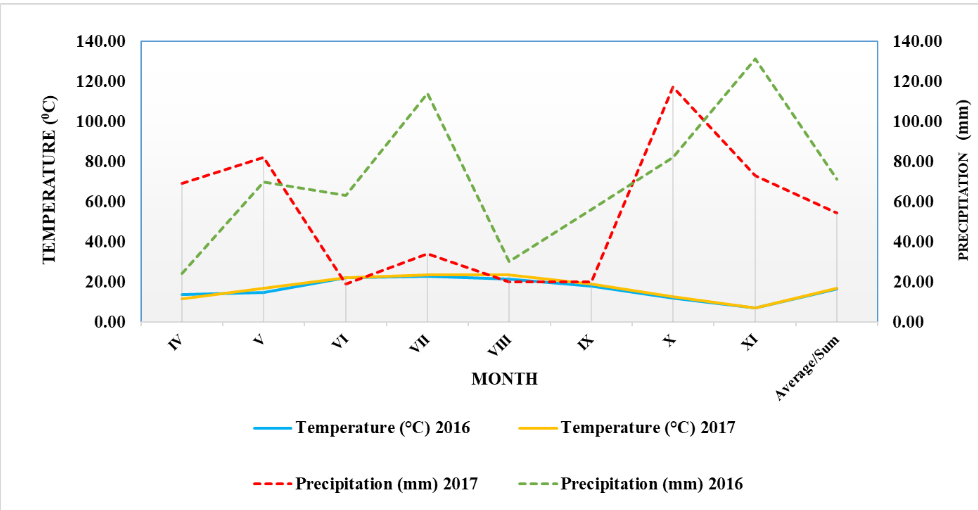

Figure 1. Average monthly air temperatures (°C) and sums of monthly precipitation (mm) and their distribution in the examined years.

Results and Discussion

Table 1 shows the duration of individual maize phenological phases and the sowing date in 2016. In the first sowing period, the phase from sowing to sprouting in all hybrids lasted 13 days. During this period, the sum of total air temperatures (SUT) was measured at 140.5°C, and the sum of effective temperatures (SET) at 55.8°C. The phenological phase from sprouting to the appearance of the 10th leaf in all hybrids lasted 41 days with a total air temperature of 615.6°C and an effective temperature of 312.2°C.

Table 1. Duration of certain phenological phases in the first sowing date of different maize hybrids in 2016.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	13.0	140.5	55.8	41.0	615.6	312.2	22.0	400.2	210.1
H 2	13.0	140.5	55.8	41.0	615.6	312.2	22.0	400.2	210.1
H 3	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
H 4	13.0	140.5	55.8	41.0	615.6	312.2	24.0	422.1	231.1
H 5	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
H 6	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
Average	13.0	140.5	55.8	41.0	615.6	312.2	22.8	409.5	219.1
Sd	0.00	0.00	0.00	0.00	0.00	0.00	0.75	8.18	7.97
Cv	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.04
Sowing date I – 2016									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	39.0	827.4	368.5	24.0	439.0	231.2	139.0	2422.7	1177.8
H 2	40.0	831.9	375.6	26.0	458.6	240.3	142.0	2446.8	1194.0
H 3	42.0	864.5	397.4	28.0	487.4	260.0	147.0	2518.8	1246.5
H 4	44.0	893.1	435.2	32.0	531.2	286.4	154.0	2602.5	1320.7
H 5	44.0	879.8	437.3	35.0	549.6	294.2	156.0	2596.1	1320.6
H 6	46.0	919.7	445.4	36.0	562.1	302.6	157.0	2648.5	1332.9
Average	42.5	869.4	409.9	29.8	504.6	269.1	149.1	2539.2	1265.4
Sd	2.66	35.76	33.76	4.49	50.51	29.67	7.63	91.34	68.98
Cv	0.06	0.04	0.08	0.15	0.10	0.11	0.05	0.04	0.05

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The phenological phase from the 10th leaf to silking in the first sowing period lasted 22–24 days, depending on the hybrid. The measured sum of the total air temperatures was 400.2–422.1°C, and the sum of the effective temperatures was

210.1–231.1°C. The phase from silking to the appearance of a black layer at the base of the grain in the first sowing period lasted 39–46 days, with the measured sum of total temperatures being 827.4–919.7°C, or 368.5–445.4°C, depending on the hybrid. The phase from the appearance of the black layer at the base of the grain to full maturity lasted 24–36 days, while the total temperatures measured were 439.0–562.1°C, and the effective temperatures were 231.2–302.6°C. The total vegetation period (from sowing to full maturity) in the first sowing period of 2016 (Table 1), depending on the hybrid, lasted 139–157 days, with the sum of total temperatures being 2422.7–2648.5°C, and the sum of effective air temperatures 1177.8–1332.9°C. Biberdžić et al. (2018b) state that despite the recorded difference in the length of the vegetation period in the number of days, no major differences were found in the sum of the effective temperatures for the same hybrid, regardless of the influence of the year and sowing dates.

During the first sowing period, the ZP 434 hybrid had the shortest vegetation period. The vegetation period lasted 139 days, the measured sum of total air temperatures was 2422.7°C, while the sum of effective temperatures was 1177.8°C. The hybrid with the longest vegetation period in the first sowing period (Figure 2) was NS 6030 (157 days). The sum of total air temperatures was 2648.5°C, and the sum of effective temperatures was 1332.9°C. In the second sowing period in 2016, the phase from sowing to sprouting lasted the same as in the first sowing period, namely 13 days for all hybrids (Table 2). The measured sum of total air temperatures was 129.3°C, and the sum of effective temperatures was 60.9°C.

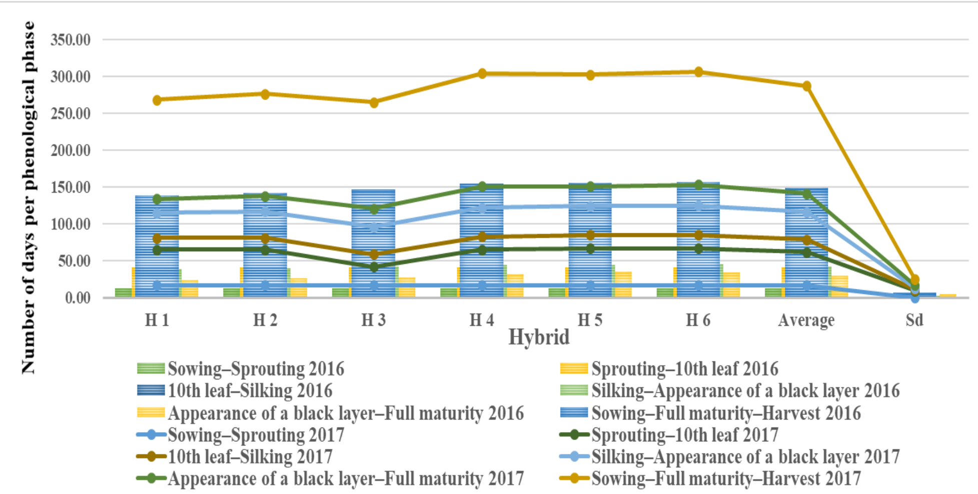

Figure 2. Number of days per phenological phase of maize hybrids in the first sowing date in both examined years.

Table 2. Duration of certain phenological phases in the second sowing date of different maize hybrids in 2016.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (⁰C)	SET (⁰C)	No. of days	SUT (⁰C)	SET (⁰C)	No. of days	SUT (⁰C)	SET (⁰C)
H 1	13.0	129.3	60.9	42.0	660.6	311.9	22.0	390.5	204.3
H 2	13.0	129.3	60.9	42.0	660.6	311.9	22.0	390.5	204.3
H 3	13.0	129.3	60.9	42.0	660.6	311.9	23.0	405.2	217.3
H 4	13.0	129.3	60.9	42.0	660.6	311.9	24.0	421.5	238.3
H 5	13.0	129.3	60.9	42.0	660.6	311.9	24.0	421.5	238.3
H 6	13.0	129.3	60.9	42.0	660.6	311.9	25.0	435.3	246.2
Average	13.0	129.3	60.9	42.0	660.6	311.9	23.3	410.8	224.8
Sd	0.00	0.00	0.00	0.00	0.00	0.00	1.21	18.36	18.54
Cv	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.08
Sowing date II – 2016									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (⁰C)	SET (⁰C)	No. of days	SUT (⁰C)	SET (⁰C)	No. of days	SUT (⁰C)	SET (⁰C)
H 1	38.0	805.0	381.4	25.0	470.6	239.1	140.0	2456.0	1197.1
H 2	39.0	814.3	391.5	26.0	486.2	246.4	142.0	2480.0	1215.0
H 3	42.0	852.0	419.7	31.0	518.0	269.7	151.0	2565.1	1279.0
H 4	43.0	869.7	430.7	36.0	570.6	292.8	158.0	2651.7	1335.2
H 5	43.0	890.0	448.5	37.0	586.7	300.3	159.0	2688.1	1359.9
H 6	45.0	909.7	463.1	39.0	609.0	316.8	164.0	2743.9	1398.9
Average	41.7	846.2	414.4	32.3	540.1	277.5	152.3	2597.4	1297.5
Sd	2.66	41.42	31.78	5.92	56.70	30.99	9.73	116.15	81.03
Cv	0.06	0.05	0.08	0.18	0.10	0.11	0.06	0.04	0.06

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 42 days for all hybrids. The sum of total air temperatures was 660.6°C, while the sum of effective temperatures was 311.9°C. In the second sowing period, the phase from the appearance of the 10th leaf to silking lasted 22–24 days, depending on the hybrid, with the sum of total temperatures being 390.5–435.5°C, while the sum of effective temperatures was 204.3–246.2°C. The phase from silking to the appearance of a black layer at the base of the grain in the second sowing period lasted 38–45 days depending on the hybrid, with the measured sum of total air temperatures being 805.0–909.7°C, and the sum of effective temperatures 381.4–663.1°C. The phase from the appearance of the black layer at the base of the grain to full maturity lasted 25–39 days. During this period, the sum of total temperatures was measured at 470.6–609.0 °C, while the sum of effective temperatures was 239.1–316.8°C. The vegetation period from sowing to full maturity in the second sowing period in 2016, depending on the hybrid, lasted 140–164 days (Figure 3) with a sum of total temperatures of 2456.0–2743.9°C, and the measured sum of effective temperatures was 1197.1–1398.9°C. The ZP 434 hybrid also showed the shortest vegetation period in the second sowing period. Expressed in days, the vegetation period lasted 140 days, with a total temperature of 2456.0°C, and the sum of effective temperatures in this period amounted to 1197.1°C. The hybrid NS 6030 (H6) had the longest vegetation period in the second sowing period (164 days with the measured sum of total air temperatures 2743.9°C), while the measured sum of effective temperatures was 1398.9°C. During the second year of research, in the first sowing period, the phenological phase from sowing to sprouting lasted 17 days for all hybrids. The sum of the total temperatures measured during this period was 183.6°C, and the sum of the effective temperatures was 60.2°C.

The phase from emergence to the appearance of the 10th leaf lasted 48–50 days, depending on the hybrid. During this phenological phase, the sum of total temperatures was measured at 750.8–767.2°C and the sum of effective temperatures at 310.6–327.0°C. During this period, the sum of total temperatures was measured at 384.0–436.0°C, that is, the sum of effective temperatures at 204.0–236.0°C. The phase from silking to the appearance of a black layer in the grain in the first sowing period lasted 34–40 days, depending on the hybrid, with the sum of total air temperatures being 592.7–731.6°C and the sum of effective temperatures 356.0–429.8°C. The period from the 10th leaf to silking in the first sowing period lasted 16–18 days. The phase from the appearance of the black layer in the grain to full maturity lasted 19–28 days, depending on the hybrid. The measured sum of total temperatures was 420.0–588.7°C. In the first sowing period, in 2017, the vegetation period lasted 134–153 days, with the sum of total temperatures being 2331.0–2707.1°C, while the sum of effective temperatures was 1169.0–1368.0°C, depending on the hybrid. The ZP 434 hybrid (134 days, SUT 2331.0°C, SET 1169.0°C) had the shortest vegetation period in the first sowing period in 2017 (Table 3). In the same period, the NS 6030 hybrid had the longest growing season (153 days, SUT 2707.1°C, SET 1368.4°C).

In the second sowing period (Table 4), the phase from sowing to sprouting lasted 15 days for all hybrids. During this period, the sum of total air temperatures was measured at 199.7°C, while the sum of effective temperatures was 61.6°C. The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 40–43 days, depending on the hybrid. The sum of total air temperatures was 682.8–741.2°C, and the sum of effective temperatures was 310.1–336.5°C. The phenological phase from the 10th leaf to silking lasted 16–18 days, depending on the hybrid, with a sum of total temperatures of 378.8–433.6°C.

Table 3. Duration of certain phenological phases in the first sowing date of different maize hybrids in 2017.

Phenological phase	Sowing–Sprouting			Sprouting –10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (0C)	SET (0C)	No. of days	SUT (0C)	SET (0C)	No. of days	SUT (0C)	SET (0C)
H1	17.0	183.6	60.2	48.0	750.8	310.6	16.0	384.0	204.0
H 2	17.0	183.6	60.2	48.0	750.8	310.6	16.0	384.0	204.0
H 3	17.0	183.6	60.2	48.0	750.8	310.6	17.0	409.2	219.2
H 4	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
H 5	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
H 6	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
Average	17.0	183.6	60.2	44.8	759.0	318.8	17.2	414.2	222.5
Sd	0.00	0.00	0.00	9.77	8.98	8.98	0.98	25.59	15.76
Cv	0.00	0.00	0.00	0.22	0.01	0.03	0.06	0.06	0.07
Sowing date I – 2017									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (0C)	SET (0C)	No. of days	SUT (0C)	SET (0C)	No. of days	SUT (0C)	SET (0C)
H 1	34.0	592.7	356.0	19.0	420.0	238.4	134.0	2331.0	1169.0
H 2	36.0	623.3	380.4	21.0	441.3	257.3	138.0	2383.0	1212.8
H 3	37.0	648.3	349.9	25.0	510.3	281.2	144.0	2502.2	1265.6
H 4	39.0	702.4	394.4	29.0	600.0	325.6	153.0	2689.2	1361.0
H 5	39.0	702.4	394.4	27.0	571.3	290.7	151.0	2660.6	1326.1
H 6	40.0	731.6	429.8	28.0	588.7	315.4	153.0	2707.1	1368.4
Average	37.5	653.8	334.2	24.8	521.9	284.8	145.5	2545.5	1283.8
Sd	2.26	53.78	141.30	4.02	77.48	33.34	8.17	163.89	81.80
Cv	0.06	0.08	0.42	0.16	0.15	0.12	0.06	0.06	0.06

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The sum of effective temperatures in the same period was 204.6–225.8°C. In the second sowing period of 2017, the phase from silking to the appearance of a black layer at the base of the grain lasted 34–40 days, depending on the hybrid. The measured sum of total temperatures during this period was 618.1–757.9°C, while the sum of effective temperatures was 354.8–421.0°C. The phenological phase from the appearance of the black layer at the base of the grain to full maturity lasted 21–32 days, depending on the hybrid, with the measured sum of total temperatures being 448.9–622.3°C and the sum of effective temperatures 250.1–389.5°C. The period from sowing to full maturity in the second sowing period of 2017, depending on the hybrid, lasted 126–148 days (Figure 4), with the sum of total air temperatures being 2328.3–2754.0°C, and the measured sum of effective temperatures being 1158.9–1434.4°C. The ZP 434 hybrid (H1) had the shortest vegetation period, 126 days with a total temperature of 2328.3°C, while the sum of effective temperatures in this period was 1158.9°C. The longest vegetation period was recorded for the NS 6030 (H6) hybrid. The vegetation period lasted 164 days with a measured sum of total temperatures of 2754.0°C, while the measured sum of effective temperatures amounted to 1245.7°C. As the most accurate method for determining the length of the maize vegetation period, the method of the sum of the effective temperatures of the GDU (Biberdžić et al., 2000) was used. The average duration of certain phenological phases of maize in the first sowing period in days during the two years is shown in Figure 2, as well as SUT and SET (Figure 3). The phase from sowing to emergence in the first sowing period in all hybrids lasted 16 days on average (SUT – 162.1°C, and SET – 58.0°C). The phase from sprouting to the appearance of the 10th leaf in the first sowing period for all hybrids lasted an average of 42.9 days with a measured SUT of 687.3°C, while the measured SET was 331.4°C.

Table 4. Duration of certain phenological phases in the second sowing date of different maize hybrids in 2017.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	15.0	199.7	61.6	40.0	682.8	310.1	16.0	378.8	204.6
H 2	15.0	199.7	61.6	40.	682.8	310.1	16.0	378.8	204.6
H 3	15.0	199.7	61.6	42.00	720.6	325.9	17.0	405.6	225.8
H 4	15.0	199.7	61.6	42.0	720.6	325.9	17.0	405.6	225.8
H 5	15.0	199.7	61.6	43.0	741.2	336.5	18.0	433.6	225.8
H 6	15.0	199.7	61.6	43.0	741.2	336.5	18.0	433.6	225.8
Average	15.0	199.7	61.6	41.7	714.9	321.7	17.0	406.0	218.7
Sd	0.00	0.00	0.00	1.37	26.49	11.88	0.89	24.51	10.95
Cv	0.00	0.00	0.00	0.03	0.04	0.04	0.05	0.06	0.05
Sowing date II – 2017									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	34.0	618.1	354.8	21.0	448.9	250.1	126.0	2328.3	1158.9
H 2	36.0	657.0	385.5	22.0	461.3	265.8	129.0	2379.6	1227.6
H 3	37.0	669.3	394.3	27.0	530.7	342.6	138.0	2525.9	1350.8
H 4	39.0	739.1	407.9	30.0	589.4	360.0	143.0	2653.7	1381.2
H 5	39.0	737.6	406.4	32.0	615.0	385.3	147.0	2727.1	1385.4
H 6	40.0	757.9	421.0	32.0	622.3	389.5	148.0	2754.0	1434.4
Average	37.5	696.5	394.9	27.3	544.6	332.2	138.5	2411.3	1245.8
Sd	2.26	52.91	23.15	4.89	76.54	60.22	9.27	102.54	97.23
Cv	0.06	0.08	0.06	0.18	0.14	0.18	0.07	0.04	0.08

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

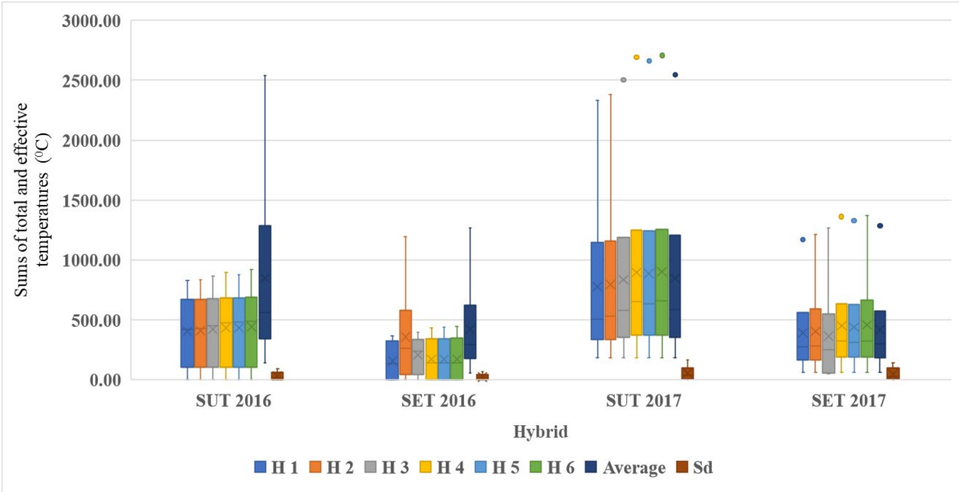

Figure 3. SUM (^{0}C) and SET (^{0}C) in the first sowing period of the maize hybrid in both examined years.

In the first sowing period, during the two years, the phase from the 10th leaf to silking lasted an average of 19.9 days, with the sum of total temperatures being 407.8°C and the sum of effective temperatures being 220.8°C. The phenological phase from silking to the appearance of the black layer at the base of the grain lasted an average of 40 days (SUT 761.6°C and SET 372.0°C). During the two years, the phase from the appearance of the black layer at the base of the grain to full maturity lasted an average of 27.3 days, with a sum of total temperatures of 513.2°C, and SET of 276.9. The total vegetation period during the first sowing period lasted 147.3 days. During this period, SUT was measured at 2542.3°C. In the first sowing period, the shortest period of vegetation was observed in the ZP 434 hybrid (136.5 days, SUT – 2376.9°C and SET – 1173.4°C).

The duration of each phenological phase of maize in days, in the second sowing period during the two years, is shown in Figure 4, and the SUT and the SET are calculated in Figure 5. The phase from sowing to sprouting in the first sowing period in all hybrids lasted an average of 14 days (SUT – 164.5°C, and SET – 61.3°C). The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 41.8 days on average for all hybrids, while the SUT was measured at 687.7°C and the SET at 316.8°C. During the two-year experiment, in the second sowing period, the phase from the 10th leaf to silking lasted an average of 20.1 days, with the sum of total temperatures being 408.4°C and the sum of effective temperatures 221.8°C. The phase from silking to the appearance of a black layer at the base of the grain lasted an average of 39.6 days (SUT – 771.4°C and SET – 404.7°C). On average, the phase from the appearance of the black layer at the base of the grain to full maturity lasted 29.8 days, with the sum of total air temperatures 542.3°C, and SET 304.9. The vegetation period during the two years in the second sowing period lasted an average of 39.2 days, with SUT – 2504.3°C and SET – 1271.7°C. The ZP 434 hybrid (133 days, SUT 2392.0°C and SET 1177.5°C) had the shortest vegetation period in the second sowing period, during both years. The NS 6030 hybrid (156 days, SUT 2748.9°C, and SET 1416.5°C) had the longest vegetation period in the second sowing period during both years. During the two-year research period, in terms of sowing dates, the vegetation period varied, depending on the hybrid. Observed by years and sowing dates, the difference in vegetation length between the hybrid with the longest and the hybrid with the shortest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. The period from sowing to sprouting was the same for all hybrids in terms of years and sowing dates. Depending on the duration and year of the research, the number of days and SUT differed. In the observed period, the sum of effective temperatures had the most approximate values. In the second year of testing, the phenological phases of all maize hybrids lasted shorter than in 2016, except for the period from sowing to sprouting and from sprouting to the 10^{th} leaf. This difference is particularly evident in the total vegetation period of the second sowing period. In 2016, in the second sowing period, the total vegetation period lasted 152.3 days, and in 2017, 138.5 days.

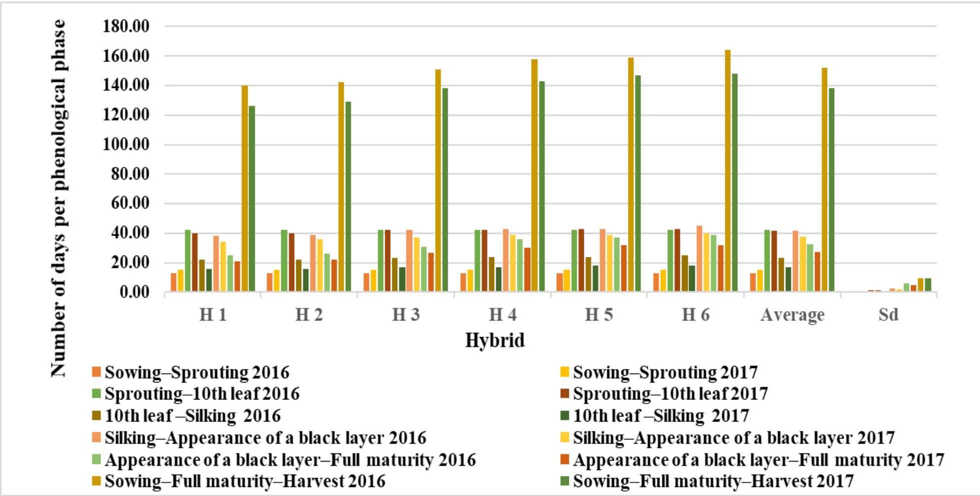

Figure 4. Number of days per phenological phase of maize hybrids in the second sowing date in both investigated years.

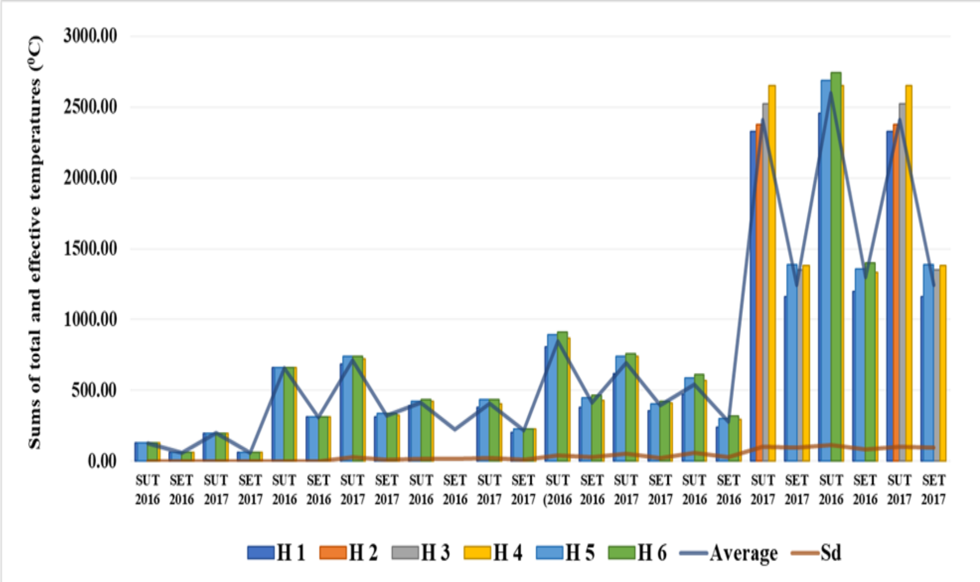

Figure 5. SUM (0C) and SET (0C) in the second sowing date of maize hybrids in both investigated years.

In a five-year study of the length of vegetation of individual ZP hybrids, Jovanović et al. (2013) determined that the average length of vegetation of a mid-early hybrid (FAO 400) lasted 121 days, with a sum of effective temperatures of 1315.0°C. In medium-sized hybrids (FAO 500), the vegetation period lasted 125–128 days, with a sum of effective temperatures of 1315.0–1365.0°C. Medium-late hybrids (FAO 600) had a vegetation length of 130–134 days with a SET of 1425.0–1452.0°C. In this research, the method of the sum of heat units proved to be effective. In the Republic of Serbia, the old, already outdated classification of the length of the maize vegetation according to the required number of days from sprouting to maturity has been accepted. Over time, this method has proven to be unreliable in practice, because it depends on the agrometeorological conditions during the year, but also on the area where the tests were conducted (Jovanović et al., 2002). Based on five years of research with different hybrids and sowing dates, Penčić (1996) states that the number of days is the least accurate method for determining the length of the vegetation period or certain phenological phases of maize. The biggest variations in the number of days between the years were found in the periods with the biggest temperature oscillations. Similar results were obtained by other authors (Drezgić et al., 1981; Biberdžić et al., 2000). Svečnjak et al. (2012) also state in their research that they have observed that the sum of heat units from sowing to physiological maturity is 1270.0°C for hybrids of FAO group

200 and 1490.0°C for hybrids of the latest FAO maturity groups. They determined that the studied hybrids differed significantly both in the number of days of vegetation and in the sum of heat units from sowing to silking and from silking to physiological maturity. From the phenological stage of the appearance of the 10^{th} leaf to full maturity, depending on the hybrid, the date of sowing and the year of production, the differences were noticeable. Depending on the year (temperature conditions and the amount and distribution of precipitation) and the time of sowing, the period of certain phases was shortened when the increase in temperature was recorded. When the period with lower temperatures was recorded, the length of the phenological phases lasted longer. The research is in agreement with the research of Biberdžić et al. (2000), who state that the length of certain phenological phases is related to the height of the temperature and very often shortens linearly with the increase in temperature. The duration of certain phenological phases and the entire length of the maize vegetation has been the subject of numerous studies. It has been found that the lower the daily air and soil temperature, the longer a particular phenological phase lasts (Čirkov, 1972). Following the results of research on the influence of sowing date on the yield of different maize hybrids, Starčević et al. (1981) observed a mutual dependence between the height of soil or air temperatures and the length of the period from sowing to sprouting. The duration of certain phenological phases depends on the climatic conditions of the area and the year (air and water temperature), the choice of hybrids, the time of sowing, the type of soil and agrotechnical measures. Starčević et al. (1986) experimented with different sowing dates and different hybrids for research purposes and monitored the phenological stages of maize. They have also stated that the duration of the studied phenological phases depends on the height of the air temperature and shortens linearly with the increase in air temperature. Similarly, they have noticed that the dependence between the duration of a certain phenological phase and the height of the air temperature is more significant in those phases in which the temperature fluctuations are greater.

Conclusion

Observed by years and sowing dates, the difference in vegetation length between the hybrids with the shortest and the hybrids with the longest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. During both years, the lowest sum of effective temperatures was 1158.8°C recorded in the FAO hybrid group 400, ZP 434 (H1), and the highest 1398.9°C in the FAO hybrid group 600, NS 6030 (H6). In 2017, for all maize hybrids, the phenological phases lasted shorter compared to 2016, except for the period from sowing to sprouting and from sprouting to the tenth leaf. This difference is particularly evident in the total vegetation period of the second sowing period. In 2016, the total vegetation period in the second sowing period lasted 152.3 days, and in 2017, 138.5 days. Depending on the date of sowing and the year of the research, the number of days and the sum of total air temperatures differed. In the observed period, the sum of effective temperatures had the most approximate values. The period after silking was more susceptible to temperature oscillations compared to the phenological stages up to silking. Depending on the temperature conditions, according to the years and the sowing dates, the period of certain phases was shortened with the increase in the air temperature. When there was a period with lower temperatures, the length of the phenological phases lasted longer. When selecting hybrids, it should be noted that there are large oscillations in the length of vegetation in hybrids of different FAO maturity groups. Depending on the sowing plan and the next crop, hybrids of the appropriate vegetation period should be selected.

Acknowledgments

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UTICAJI ROKA SETVE I KLIMATSKIH USLOVA NA FENOLOŠKE FAZE RAZLIČITIH HIBRIDA KURUZA

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R e z i m e

Ogled je postavljen tokom 2016. i 2017. godine na području Leskovca, na zemljištu tipa aluvijum. Za potrebe istraživanja praćena je dužina trajanja pojedinih fenoloških faza, kao i celog perioda vegetacije 6 hibrida kukuruza, tri FAO grupe zrenja (400–600). Istraživanje ima za cilj da se na osnovu broja dana, sume ukupnih, kao i sume efektivnih temperatura odredi dužina trajanja pojedinih fenoloških faza i cele vegetacije i preporuče odgovarajući hibridi za ispitivano područje. Posmatrano po godinama i rokovima setve razlika u dužini vegetacije između hibrida sa najdužim i hibrida sa najkraćim periodom vegetacije bila je 38 dana, razlika u SUT iznosi 414.70°C, a razlika u SET iznosi 240.00°C. Prosečno, za dvogodišnji period, najmanja suma efektivnih temperatura od 1158.80°C je zabeležena kod hibrida FAO grupe 400 ZP 434, a najveća 1398.90°C kod hibrida FAO grupe 600, NS 6030. Zavisno od temperaturnih uslova, po godinama i roku setve, period pojedinih faza se skraćivao sa porastom temperature. Sa nastupanjem perioda sa nižim temperaturama vazduha, dužina fenoloških faza je trajala duže. Kao najpouzdaniji metod za određivanje dužine vegetacije ispitivanih hibrida kukuruza pokazao se metod sume efektivnih temperatura.

Ključne reči: kukuruz, dužina vegetacije, broj dana, ukupne temperature vazduha, efektivne temperature.

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