

VARIATION OF PLANT HEIGHT AND EAR INSERTION HEIGHT IN EARLY RIPENING MAIZE HYBRIDS UNDER THE OPTIMAL AND LATE SOWING DATES

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Topicality. In light of the intensification of agriculture towards more rational utilisation of land resources and the growing season, given the importance of stubble and postcut fodder maize crops in fodder production and maize adaptability to the conditions of the Steppe zone, it is important to study the growth processes of maize under late sowing. Namely, the study of the influence of late sowing date on such traits as plant height and height of first productive ear insertion for early ripening hybrids, the share of which in maize grain production is increasing. **Purpose.** To establish the most stable hybrid combinations by studying the variation of plant height and ear insertion height in early ripening maize hybrids under two sowing dates. **Methods.** Hybridization was used for developing hybrid material; laboratory and field method – to determine morphobiological traits of maize hybrids; measuring weight – to determine metric traits of plants; mathematical and statistical method – to determine the reliability of results, indicators of trait variation, and the correlation of traits. **Results.** The study of early ripening maize hybrids developed by crossing the most common germplasms under two sowing dates revealed that hybrids of heterotic models Iodent×Flint and Iodent×Mix had stably high values of the plant height trait at both sowing dates; hybrids of heterotic models Iodent×Flint and Iodent×Mix and Mix×Flint had stably high values of the height of first productive ear insertion at both sowing dates. **Conclusions.** We have identified the hybrid combinations DK4173SVZM×DK367, DK4172×DK367, MS381MV×DK367, MS555×DK367 (heterotic model Iodent×Mix), and DK4173SVZM×DK2073 (heterotic model Iodent×Flint), which were characterised by stably high values of the plant height trait, as well as the hybrid combinations DK4172×DK4538 (heterotic model Iodent×Flint), DK4172×DK367 (heterotic model Iodent×Mix), and DK2659×DK4538 (heterotic model Mix×Flint), which were characterised by stably high values of the height of first productive ear insertion at both sowing dates. The correlation between plant height and the ear insertion height of maize hybrids was confirmed for both sowing dates in all heterotic models studied.

Key words: common maize, breeding, prematurity, plant height, ear insertion height, sowing dates, line, single-cross hybrid

Introduction. In the market economy, the issue of intensification of agriculture as the main means of forming sustainable agricultural production is gaining special relevance [1].

Intensification of agriculture is possible by increasing production due to cultivation of two crops per year on the same area using stubble and postcut crops.

A long frost-free period with a sufficient amount of active temperatures in the Steppe zone of Ukraine, after harvesting the main crops, makes it possible to use stubble and postcut fodder crops, which provide two harvests per year.

Scientists A.P. Hyrenko, A.I. Livenskyi and K. P. Demydenko reported that maize is the best postcut crop in terms of green mass, dry matter, yield of feed units and digestible protein [2].

Ukrainian breeders do not pay sufficient attention to the development of maize hybrids for growing as a stubble and postcut crops. At the same time, the experience of foreign producers and scientists proves the prospects of this area. For example, in Hungary, ultra-early ripening maize hybrids (FAO 100–150) are used for stubble and postcut crops for grain and silage [3].

The prospects for cultivation of early ripening maize hybrids in stubble and postcut crops are determined by studying the influence of stressful conditions of late sowing on biometric parameters of maize plants, such as plant height and height of first productive ear insertion, in order to find the most stable hybrid combinations for late sowing.

The purpose of the research is to examine the variation of such traits as plant height and

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ear insertion height in early ripening maize hybrids at two sowing dates for establishing the most stable hybrid combinations based on these traits.

Materials and Methods. The research was carried out in the experimental breeding crop rotation of the Institute of Grain Crops of NAAS of Ukraine during 2016–2017.

In the course of the research, 161 single-cross hybrids of the Iodent×Flint heterotic model, 101 hybrids of the Iodent×Mix heterotic model, and 92 hybrids of the Mix×Flint heterotic model were studied under two sowing dates. The optimal sowing date was the third ten-day period of April, and the late sowing date was the third ten-day period of May. The experiments were laid out in accordance with the recommendations in the "Methodology for field experiments with maize" [4]. Plot area was 5 m². We conducted biometric measurements on 10 plants from each plot.

In the years of the study, meteorological conditions were typical for the Steppe, with a nonuniform distribution of precipitation and air temperature. In 2016, precipitation was 60.7 mm higher than the long-term data (332.7 mm), the maximum precipitation fell in the third ten-day period of April, the second ten-day period of June and July. The average daily air temperatures in the spring and autumn months of the growing season were close to the long-term average, but in summer, the temperatures exceeded the norm by an average of 1.1, 2.0 and 3.1 °C.

The growing season of 2017 was characterised by a moisture deficit. In total, 251.4 mm of precipitation in the form of showers fell between April and September, compared to the long-term average of 272 mm. The average daily air temperatures in May and July were close to the long-term average, however, June, August and September were very hot, and in the last two months the excess was 4.6 and 3.4 °C compared to the long-term average. Soil drought occurred from the second ten-day period of July to the end of August.

Contrasting weather conditions during the years of research allowed us to correctly evaluate the breeding material.

Results and Discussion. According to the analysis of maize plant height over the years of

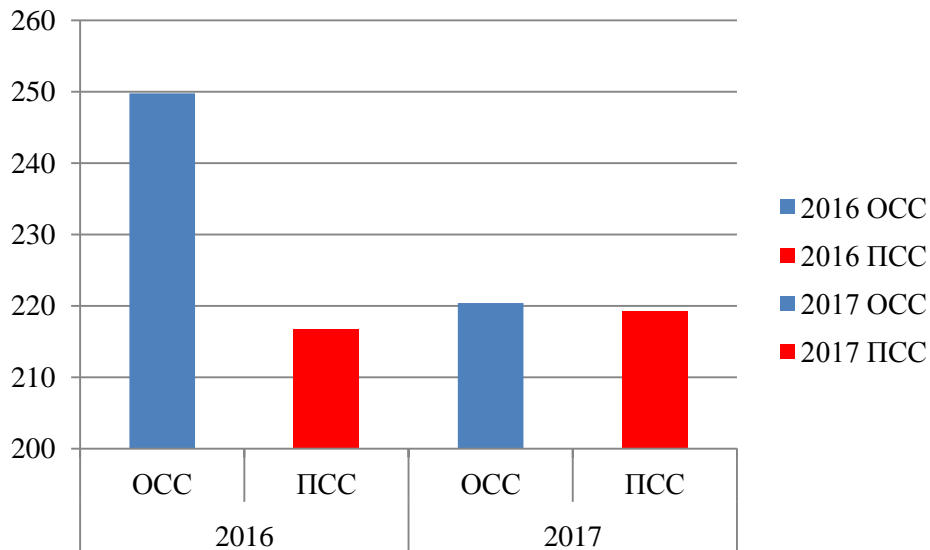
research, the tallest plants were in 2016 at the optimal sowing time, and the plant height was 249.8 cm, which was significantly higher than in 2017 (Fig.1). However, in 2016, the late sowing had the most negative effect, the plants were shorter (by 33 cm) compared to the optimal sowing date, and in 2017 the difference in plant height between the two sowing dates was not significant and was only 1.2 cm.

Over the years of research, the maximum average plant height was 242.9 and 220.6 cm in hybrids of the heterotic model Iodent×Flint, respectively, by sowing dates (Table 1).

It should be noted that the hybrids of the heterotic model Iodent×Flint had significantly higher plant height compared to the hybrids of the Mix×Flint model at both sowing dates for years of research. However, for heterotic model Iodent×Flint and Iodent×Mix, under both sowing dates, no significant differences in plant height were found. As a rule, maize hybrids at late sowing date formed shorter plants, but the significant difference between sowing dates was only in 2016.

Analysis of the obtained hybrids allowed us to identify combinations with high values of the plant height. In 2016, at the optimal sowing dates, according to the heterotic model Iodent×Flint, we identified the following hybrids: DK4173SVZM × DK2073 (293.5 cm), DK2637 × DK2073 (285.5 cm), DK4172×DK2073 (291.5 cm), DK5510×DK2073 (290.0 cm), and according to the heterotic model Iodent×Mix: DK4173SVZM×DK367 (295.0 cm), DK4172 × DK367 (291.0 cm), MS381MV×DK367 (290.0 cm), DK2637×DK367 (289.0 cm), MS555×DK367 (284.5 cm), and according to the heterotic model Mix×Flint: DK367×DK2073 (289.0 cm). According to this trait, these hybrids outperformed the standard DN Pyvykha, which formed a plant height of 251.4 cm at the optimal sowing date.

It should be noted that the most tall-growing hybrids, at the optimal sowing date, significantly reduced the plant height by 35.5–61.5 cm at late sowing, however, these hybrids were significantly taller than the standard HU0008, the significant difference ranged from 16.6–39.1 cm, and hybrids DK4173SVZM×DK367, DK4172×DK367, DK5510×DK2073, and MS555×DK367 had significantly higher



Note*. OSD* – optimal sowing date; LSD* – late sowing date

Fig. 1 Plant height of early ripening single-cross hybrids at two sowing dates.

Table 1. Variation of plant height in single-cross maize hybrids of different heterotic models, cm

Indicator	Heterotic-model	2016		2017		Average	
		OSD*	LSD*	OSD*	LSD*	OSD*	LSD*
$\bar{x} \pm t_{s(\bar{x})}$	Iodent×Flint	252.5 ± 2.3	220.3 ± 1.8	223.1 ± 3.0	221.8 ± 3.0	242.9 ± 2.3	220.6 ± 1.7
	Iodent×Mix	250.6 ± 3.5	216.9 ± 3.4	223.7 ± 5.0	221.6 ± 5.0	242.1 ± 2.9	218.4 ± 2.3
	Mix×Flint	244.2 ± 3.5	210.7 ± 3.2	210.7 ± 5.7	211.0 ± 5.9	236.4 ± 3.5	212.5 ± 2.4
Lim (min–max)	Iodent×Flint	217.0–293.5	186.5–248.5	185.8–264.0	188.5–258.0	204.5–293.5	185.0–252.3
	Iodent×Mix	214.5–295.0	176.5–271.0	181.0–265.0	181.5–261.0	193.5–291.0	181.5–255.0
	Mix×Flint	200.0–289.0	166.0–242.0	162.0–245.5	164.0–249.0	181.0–289.0	166.0–242.0
V, %	Iodent×Flint	5.9	5.2	6.5	6.5	6.4	5.4
	Iodent×Mix	7.1	7.9	8.7	8.8	7.7	6.8
	Mix×Flint	6.8	7.4	9.3	9.6	8.6	7.1
Standard							
	HU0008	227.6	213.4	207.2	200.8	217.4	207.1
	DN Harant	257.0	224.8	224.1	228.7	240.6	226.8
	DN Pyvykha	251.4	228.4	237.2	238.1	244.3	233.3

Note. OSD* – optimal sowing date; LSD* – late sowing date

values of the plant height, compared to the most tall-growing standard DN Pyvykha under late sowing. The hybrids DK4173SVZM×DK367, DK4172×DK367, MS381MV×DK367, MS555×DK367 (the heterotic model Iodent×Mix), and DK4173SVZM×DK2073 (the heterotic model Iodent×Flint) showed some of the highest values of plant height at both sowing dates in 2017. Therefore, we can conclude that these hybrid combinations are stable for this trait both according to the sowing dates and years of the experiment.

The research also revealed hybrid combi-

nations that are not susceptible to deterioration in growing conditions caused by late sowing, as follows: MS252VM3sp×F2, MS252VM3sp×DK4538, DK305×DK2275 (the heterotic model Iodent×Flint), and MS252BM3sp×DC247, DK216×DC6381, DK2637×DC2668 (the heterotic model Iodent×Mix). The plant height of these hybrids at optimal sowing in 2016 varied in the range of 215.0–265.0 cm, and at late sowing – in the range of 203.5–271.0 cm. The decrease in the trait values did not exceed 13.5 cm and was not significant. Under conditions of late sowing, plant height of the hybrid combination

DK216×DK6381 insignificantly increased by only 6.0 cm. In 2017, the difference between the values of plant height at the optimal and late sowing dates in these hybrids ranged from 3.0–13.0 cm, which was not significant. It should be noted that both DN Harant and DN Pyvykha responded more significantly to the deterioration of growing conditions at late sowing in 2016. Thus, with late sowing, the plant height of these hybrids decreased by 32.2 and 23.0 cm, respectively, the difference was significant.

In the course of research, it was noted that for all hybrids of the studied heterotic models, the range of variation in the height of first productive ear insertion was greater than in the plant height (Tables 1 and 2). In particular, the coefficients of variation were almost 2 times higher for the first trait, regardless of the sowing date. The corresponding tendency was noted in other studies [5], which indicate a significant variation in the height of first productive ear insertion.

Table 2. Height of first productive ear insertion in single-cross maize hybrids of different heterotic models at different sowing dates, cm

Indicator	Heterotic model	2016		2017		Average	
		OSD*	LSD*	OSD*	LSD*	OSD*	LSD*
$\bar{x} \pm t_{s(\bar{x})}$	Iodent×Flint	104.2 ± 1.9	83.6 ± 1.8	82.7 ± 2.2	76.2 ± 2.3	97.4 ± 1.9	81.7 ± 1.7
	Iodent×Mix	103.2 ± 2.8	86.3 ± 2.6	84.1 ± 3.2	80.1 ± 3.9	97.5 ± 2.2	84.4 ± 1.9
	Mix×Flint	96.4 ± 2.6	75.0 ± 2.3	74.9 ± 3.6	68.6 ± 3.2	91.5 ± 2.5	75.5 ± 1.9
Lim (min–max)	Iodent×Flint	74.5–133.5	57.5–117.0	53.0–111.6	52.5–104.6	66.5–133.5	56.0–117.0
	Iodent×Mix	71.5–140.5	60.0–119.0	57.0–101.5	48.5–118.9	64.3–140.5	55.8–119.0
	Mix×Flint	63.5–123.5	50.0–105.0	47.3–101.4	43.0–94.0	51.0–123.5	46.5–105.0
V, %	Iodent×Flint	11.5	13.5	12.7	14.8	13.1	14.4
	Iodent×Mix	13.9	15.6	14.5	18.5	14.2	14.9
	Mix×Flint	13.3	14.8	16.4	16.7	15.7	15.3
Standard							
	HU0008	73.1	57.4	52.2	50.2	62.7	53.8
	DN Harant	110.8	89.6	90.0	90.5	100.4	90.0
	DN Pyvykha	101.2	84.4	88.5	81.5	94.8	82.9

Note. OSD* – optimal sowing date; LSD* – late sowing date

On average, the ear insertion height was the highest in hybrids created by the Iodent×Flint model - 97.4 and 81.7 cm, and Iodent×Mix - 97.5 and 84.4 cm, respectively, by sowing time. The hybrids of the heterotic model Mix×Flint were characterised by slightly lower values of this trait – 91.5 and 75.5 cm, respectively, by sowing dates. It was noted that under the condition of late sowing, the ear insertion height decreased on average within 13.1–16.0 cm, and the sampling variation increased by 1.8–2.5 % due to the different resistance of hybrids to stress conditions.

Under the conditions of optimal sowing date in 2016, we identified hybrids of different heterotic models that had the maximum values of the ear insertion height, in particular DK4172×DK4538 (133.5 cm), DK4172×DK367 (140.5 cm), and DK2659×DK4538 (123.5 cm), and at late sowing – DK2637×DK673 (117.0 cm), DK4172×DK367 (119.0 cm), and DK3902×

DK2073 (105.0 cm).

In 2017, DK4172×DC4538, DK4172×DK367, and DK2659×DK4538 hybrids also showed the maximum ear insertion height at both sowing dates; values ranged from 101.4–123.6 cm (for optimal sowing date), and 94.0–118.9 cm (for late sowing date).

The hybrids DK2285×DK2732, DK2285×DK212, DK2613×DK2323MV (heterotic model Iodent×Mix), DK6356×DK673 (heterotic model Mix×Flint), and DK7174×DK2275 (heterotic model Iodent×Flint) were characterised by a slight decrease in the height of first productive ear insertion at late sowing date. In 2016, the difference between the values of the height of first productive ear insertion of these hybrids at two sowing dates ranged from 3.0–6.0 cm; in 2017 - from 7.0–13.0 cm, the difference was not significant for two years of research. In the hybrid combination DK7174×DK2275 at late sowing in 2017, a slight (4.0 cm) increase in the ear

insertion height was observed.

It was found that the plant height of these hybrids is closely correlated with the ear insertion height at both sowing dates. Thus, in 2016, the correlations between the ear insertion height and plant height at both sowing dates were significant and slightly variable, $r = 0.75-0.82$ (for the optimal sowing date) and $r = 0.69-0.77$ (for the late sowing date). In 2017, there was a certain reduction in correlations at the optimal sowing date ($r = 0.56-0.81$), while at the late sowing date, on the contrary, there was an increase in the correlation between these traits in most of the heterotic models ($r = 0.64-0.89$). Also, at both sowing dates in 2017, the variation of correlation values increased.

It should be noted that the correlations between the plant height and the ear insertion height of the experimental hybrids weakened in 2016 due to the deterioration of growing conditions caused by late sowing. It should be noted that the correlations between the plant height and the ear insertion height of the experimental hybrids weakened in 2016 due to the deterioration of growing conditions caused by late sowing. These traits are formed at different stages of plant ontogeny under the influence of different weather conditions. A similar phenomenon was observed in his research by M. M. Fedko [6].

In 2017, with a late sowing date, on the contrary, these correlations were strengthened, i.e., under better conditions of plant development, the correlation was weaker. I. P. Chuch-

miy and V. V. Morhun provide results indicating a similar trend in their experiments [7]. In our opinion, such a different response of correlations to late sowing date indicates the genetic diversity of the source material.

Conclusions. Therefore, as a result of the assessment of the influence of late sowing data on plant height and height of first productive ear insertion in hybrids of different heterotic models, the following conclusions can be drawn:

- the hybrid combinations with consistently high values of plant height at both sowing dates were established: DK4173SVZM×DK367, DK4172×DK367, MS381MV×DK367, MS555×DK367 (heterotic model Iodent×Mix), and DK4173SVZM×DK2073 (heterotic model Iodent×Flint).;

- the hybrid combinations with consistently high values of the height of attachment of the first productive cob at both sowing dates were established: DK4172×DK4538 (heterotic model Iodent×Flint), DK4172×DK367 (heterotic model Iodent×Mix), and DK2659×DK4538 (heterotic model Mix×Flint).;

- the correlation between the plant height and the ear insertion height of maize hybrids was confirmed for both sowing dates in all heterotic models studied (In 2016, $r = 0.75-0.82$ for the optimum sowing date, and $r = 0.69-0.77$ for late sowing date; in 2017, $r = 0.56-0.81$ - for optimal sowing date, and $r = 0.64-0.89$ - for late sowing date).

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Актуальність. В світлі спрямування процесів інтенсифікації сільського господарства у напрямку більш раціонального використання земельних ресурсів та вегетаційного періоду, враховуючи важливість поживних та поукісних посівів кукурудзи для кормовиробництва та її пристосованість до умов Степової зони, набувають важливості дослідження ростових процесів кукурудзи в умовах пізнього строку сівби. Особливе значення, має вивчення впливу пізнього строку сівби на ознаки “висота рослин”, та “висота прикріплення першого продуктивного качана” у скоростиглих гібридів, частка яких у виробництві зерна кукурудзи зростає. **Мета роботи.** Вивчення мінливості ознак “висота рослин” та “висота прикріплення качана” у скоростиглих гібридів кукурудзи за умов двох строків сівби, для встановлення найбільш стабільних гібридних комбінацій. **Методи.** Гібридизація – у процесі створення гібридного матеріалу; лабораторно-польовий – для визначення морфобіологічних ознак гібридів кукурудзи; вимірювально-ваговий – для визначення метричних ознак рослин; математично-статистичні – для визначення достовірності результатів, показників варіабельності ознак, кореляційної залежності ознак. **Результати.** За результатами дослідження скоростиглих гібридів кукурудзи, отриманих від схрещування найбільш поширених зародкових плазм, в умовах двох строків сівби, було встановлено: стабільно високі значення ознаки “висота рослин” за обох строків сівби у гібридів гетерозисних моделей Iodent×Flint та Iodent×Mix; стабільно високі значення ознаки “висота прикріплення першого продуктивного качана” за обох строків сівби у гібридів гетерозисних моделей Iodent×Flint та Iodent×Mix, Mix×Flint. **Висновки.** Встановлені гібридні комбінації які характеризувалися стабільно високими значеннями ознаки «висота рослин» за обох строків сівби – ДК4173СВЗМ×ДК367, ДК4172×ДК367, МС381МВ×ДК367, МС555×ДК367 – гетерозисної моделі Iodent×Mix, та ДК4173СВЗМ×ДК2073 – гетерозисної моделі Iodent×Flint; та комбінації які характеризувалися стабільно високими значеннями ознаки «висота прикріплення першого продуктивного качана» за обох строків сівби – ДК4172×ДК4538 – гетерозисної моделі Iodent×Flint, ДК4172×ДК367 – гетерозисної моделі Iodent×Mix, та ДК2659×ДК4538 – гетерозисної моделі Mix×Flint. Підтверджено кореляційний зв’язок висоти рослин гібридів кукурудзи з висотою прикріплення качана за умов обох строків сівби, в усіх гетерозисних моделей що вивчалися.

Ключові слова: кукурудза звичайна, селекція, скоростиглість, висота рослин, висота прикріплення качана, строки сівби, лінія, прості гібриди