Faculty of Agriculture
University of Banja Luka

XIII INTERNATIONAL SYMPOSIUM ON AGRICULTURAL SCIENCES

AgroReS
2024

BOOK OF PROCEEDINGS

27-30 May 2024, Trebinje, Bosnia and Herzegovina

ISSN 2831-1248

XIII International Symposium on Agricultural Sciences "AgroReS 2024"

27-30 May 2024, Trebinje, Bosnia and Herzegovina

BOOK OF PROCEEDINGS

Publisher

University of Banja Luka
Faculty of Agriculture
University City, Bulevar vojvode Petra Bojovića 1A
78000 Banja Luka, Republic of Srpska, Bosnia and Herzegovina

Editor in Chief

Boris Pašalić

Technical Editor

Marinko Vekić

Edition

Electronic edition
Available at: https://agrores.agro.unibl.org/en/proceedings/

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

631(082)(0.034.2)

INTERNATIONAL Symposium on Agricultural Sciences (13 ; Trebinje ; 2024)
Book of Proceedings [Електронски извор] / XIII International Symposium on Agricultural Sciences "AgroReS 2024", 27-30 May, 2024, Trebinje, Bosnia and Herzegovina ; [editor in chief Boris Pašalić]. - Onlajn izd. - El. zbornik. - Banja Luka : Faculty of Agriculture = Poljoprivredni fakultet, 2024. - Ilustr. - (AgroRes, ISSN 2831-1248)

Sistemski zahtjevi: Nisu navedeni. - Dostupno i na: https://agrores.agro.unibl.org/en/proceedings/. - Nasl. sa nasl. ekrana. - Opis izvora dana 23.5.2024. - El. publikacija u PDF formatu opsega 287 str. - Bibliografija uz radove

ISBN 978-99938-93-99-8

COBISS.RS-ID 140613121

Original scientific paper | DOI 10.7251/ZARS2401113J

Growing season conditions and planting density impact on some morphological characteristics on different maize (*Zea mays* L.) hybrids

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Abstract

The field study was conducted during 2014, 2016 and 2017 at the Agriculture school in Leskovac. Six maize hybrids from three different maturity groups were planted, two from each group. FAO400 group included ZP434 and NS4023, FAO500 included ZP555 as well as NS5051 and FAO600 included ZP 666 and NS 6030. Maize was planted on april 15th in each year at three planting densities 71429 (70 × 20 cm), 57143 (70 × 25 cm) and 47619 plants per hectare 70 × 30 cm). The plant height and first cob height varied in all three years among hybrids and planting densities. Among hybrids ZP666 was in average the highest with 262.64 cm while NS4023 was in average the smallest in all planting densities with and average height of 227.32 cm. The highest first cob was noticed on NS6030 and presented 112.65 cm while the lowest was measured on NS4023 with 108.96 cm far from the soil. All three years were different, whereby 2014 had the most precipitation followed by 2016 and 2017 respectivly. In all three years the highest plants and cobs were noticed in the highest planting density and vice versa. The goal of this study was to see the variation of these two growing parameters for each of these six maize hybrids planted in three different densities among years.

Key words: maize, planting density, weather conditions, plant height, first cob height

INTRODUCTION

Weather factors such as air temperature, distribution and amount of precipitation are in a close relation with maize growth and development. In combination with weather factors, planting density plays a crucial role for reaching a high and constant yield due to variations between years (Sher et al, 2017; Xu C. et al, 2017; Xu W. et al, 2017), and must be adjusted by the genotype characteristics. The planting density of maize is based on weather conditions, soil type and soil quality as well as the genotype. On poorer and sandy soils with less nutrients and a bad water regime the planting density should be reduced while on soils with better mechanical characteristics, more nutrients, a higher percent of organic matter and a better water regime planting density should be increased, especially in irrigated maize. Short season hybrids because of their smaller habitus are usually planted in higher densities compared to mid and long season hybrids (Jaramaz, 2015). Insufficient number of plants per square meter usually represents a huge issue and is one of the most common limitating factors for reaching a high yield (Mandić, 2011). Starčević i Latković (2005) point out that the planting density should be adjusted by the agroecological conditions of the area where maize is grown. In a study where different maize hybrids were constantly grown without crop rotation Jovanovic et al. (1997) point out that the number of plants per square meter is based on the weather conditions and morphological characteristics of the hybrid. Based on the plant height and first cob height, different maize maturity groups act different to the amount of precipitation. Marić (2013) points out a difference in plant height between hybrids from different maturity groups. In years with more precipitation the highest first cob was noticed in denser populations and vice versa (Jaramaz, 2015). The goal of this study was to determine the impact of weather conditions and planting densities on plant and first cob height among different maize hybrids.

MATERIAL AND METHODS

The field study was conducted during 2014, 2016 and 2017 as a randomized complete block design. Six different maize hybrids were planted, two from each of the following maturity groups: FAO400 (ZP434 and NS4023), FAO500 (ZP555 and NS5051) and FAO600 (ZP666 and NS6030). The planting destinies were 71429, 57143 and 47619 plants per hectar. Each plot was seven meters long and had four rows in three replications. 500 kg ha^{-1} of fertilizer was applied in autumn based on the soil test results (16:16:16). The field was plowed in October at 25 centimeter depth with a plough and prepared immediately before planting with a field disc. The recommended amount of nitrogen fertilizer, 200 kg ha^{-1} KAN was splited and applied twice. 120 kg ha^{-1} KAN was widespread at four leaves stage – BBCH14 and 80 kg ha^{-1} KAN was applied at eight leaves growth stage – BBCH18. A preemergence herbicide program was applied after planting Basar (S-metolachlore 1344 g a.i. ha^{-1} – Galenika Fitofarmacija, Batajnički drum BB, 11080 Zemun, Serbia) plus Rezon (terbuthylazine 750 g a.i. ha^{-1} – Galenika Fitofarmacija, Batajnički drum BB, 11080 Zemun, Serbia). At six leave growth stages – BBCH16 a tank mix of Callisto WG® (mesotrione 125 g a.i. ha^{-1} – Syngenta, Rosentalstrasse 67, 4058 Basel, Switzerland) plus Motivell extra 6 OD® (nicosulfuron 45 g a.i. ha^{-1} – Certis Belchim, Technologielaan 7, 1840 Londerzeel, Belgium) was applied for postemergence weed control. The data was analyzed with ANOVA SAS Institute (2000): User's guide, Version 9.1.3. Cary: SAS Institute Inc.

The weather data was collected at the local weather station and is shown in Table 1.

Table 1. Average air temperatures and amount of precipitation in 2014, 2016 and 2017.

Month	IV	V	VI	VII	VIII	IX	X	XI	Average
Year	Average air temperature (°C)								
2014	11.54	15.55	19.59	21.60	21.50	17.00	11.50	8.08	15.79
2016	13.73	14.70	21.90	22.80	21.40	17.90	11.90	6.80	15.67
2017	11.30	16.70	21.90	23.50	23.30	18.70	12.60	7.00	16.87
	Amount of precipitation (mm^2)								Total
2014	214.00	117.61	64.30	86.00	47.10	121.20	63.70	57.00	770.91
2016	24.20	69.60	63.00	114.00	30.00	56.00	82.00	131.00	569.80
2017	69.00	82.00	19.00	34.00	20.00	20.00	117.00	73.00	434.00

The weather conditions were different among years whereby in 2016 the average air temperature in combination with the amount and distribution of precipitation was more favorable compared to 2014 and especially 2017. With the lowest total amount of precipitation, by as much as 336.91 mm m^{-2} less than in 2014 and an unfavorable distribution of precipitation during the growing season combined with a lack of precipitation from June to September and with a higher average air temperature per month from May to October compared to 2014 and 2016, 2017 was the least optimal for maize growth and development.

RESULTS AND DISCUSSION

Hybrid selection and planting density play an important role on plant and cob height (Lashkari et al., 2011). The plant height results are shown in the table 2. The highest average plant height was recorded in 2016 followed by 2014 and 2017 respectively. In each year the highest plants were noticed in the highest planting density plots, followed by the mid-one and the lowest respectively. The differences in plant height for all hybrids in the same season across all growing season are minor in rainy and dry year compared to 2016 as the year with the best growing conditions. This means that all tested hybrids, because of the better growing conditions were much taller and reached out their maximum plant height for each planting density. Regardless of the weather conditions during the growing season and the planting density, hybrids from FAO600 group were the tallest compared to all other hybrids. NS4023 was the smallest in all years and planting densities, but ZP434 as a hybrid from the same maturity group was under some growing conditions taller than ZP555 as a hybrid from FAO500 group.

Table 2. Average plant height per year in centimeter

Year	Hybrid	D1	D2	D3	Average
2014	ZP434	246.44	235.78	228.22	236.81
	NS4023	232.22	230.11	226.78	229.70
	ZP555	237.11	234.89	226.78	232.92
	NS5051	244.33	240.99	237.77	241.03
	ZP666	258.22	253.33	251.44	254.33
	NS6030	261.55	258.55	254.78	258.29
	Average	246.64	242.26	237.62	**242.17**
2016	ZP434	250.00	244.77	242.77	245.88
	NS4023	244.33	236.66	233.55	238.17
	ZP555	252.44	247.66	243.77	247.55
	NS5051	266.10	264.44	259.99	263.51
	ZP666	270.11	266.11	264.21	266.78
	NS6030	271.99	267.77	264.88	268.21
	Average	259.16	254.50	251.30	**255.06**
2017	ZP434	228.99	226.66	222.66	226.10
	NS4023	216.77	213.66	211.88	214.10
	ZP555	223.44	221.21	216.33	220.33
	NS5051	229.66	226.44	224.33	226.80
	ZP666	232.11	226.10	226.44	228.21
	NS6030	229.88	228.44	226.22	228.18
	Average	226.80	223.77	221.31	**223.96**
Three year average	ZP434	241.81	235.73	231.21	236.25
	NS4023	231.10	226.80	224.06	227.32
	ZP555	237.66	234.25	228.95	233.62
	NS5051	246.69	243.95	240.69	243.77
	ZP666	266.14	261.84	259.95	262.64
	NS6030	254.47	250.10	248.62	251.06
	Average	246.31	242.11	238.91	**242.44**

*D1 – 71429 plants per hectare; D2 – 57143 plants per hectare; D3 – 47619 plants per hectare

Table 3. Variance analysis of plant height (three year average)

Factor	df	Mean sqr Effect	Mean sqr Error	F	p-level
Growing season	2.483	39417.9	130.893	301.146^{***}	0.000
Hybrid	5.480	7362.60	219.259	33.579^{***}	0.000
Planting density	2.483	2075.17	285.521	7.268^{***}	0.001
Growing season x Hybrid	10.468	697.940	41.515	16.812^{***}	0.000
Growing season x Planting density	4.477	32.051	123.570	0.259^{ns}	0.904
Hybrid x Planting density	10.468	26.240	215.452	0.122^{ns}	0.999

Average influence on plant hight of all three factors separately – growing season, hybrid selection and planting density was statistically very significant (respectively - 301.146***, 33.579*** and 7.268***). The interaction between growing season × hybrid selection showes also statistically very significant differences in plant height (16.812***). Variance analysis showes that the interaction between growing season x planting density as well as hybrid selection x planting density is not statistically significant (F = 0.259^{ns} and 0.122^{ns}) (P > 0,05).

In addition other authors also reported statistically very significant differences in plant height between maize planted in different planting densities (Ilić, 2002; Silva et al., 2014; Greveniotis et al., 2019 and Mandić et al., 2016) confirming that the highest plants were recorded in the population with the highest planting density. The plant height is determined by the genotype, but according to Živanović (2005) plant height may vary to some degree as influenced by growing conditions during tasseling stage. This hypothesis has been proved by many other authors (Božić, 1992; Živanović, 2005; Živanović, 2012) who claimed that growing practice has a significant impact on maize height, while other authors (Božić, 1992; Mandić, 2011) add that maize height is a resault of a complex interaction between hybrid, weather and growing conditions. In addition, Marić (2013) proved that maize height varies among hybrids from different maturity group. Generally, in our study hybrids from FAO600 group were the highest with 224.2 cm, followed by FAO500 group with 219.6 and FAO400 with 215.4 cm. In conclusion, our research agrees with the results and hypothesis from similar studies that have been done by other researchers.

Table 4. Average cob height (cm) among hybrid, growing season and planting density

Year	Hybrid	D1	D2	D3	Average
2014	ZP434	113.44	111.66	110.33	111.81
	NS4023	113.11	111.66	110.11	111.63
	ZP555	115.44	113.55	112.33	113.77
	NS5051	117.88	116.33	114.22	116.14
	ZP666	117.10	115.55	113.55	115.40
	NS6030	119.10	117.44	116.77	117.77
	Average	116.01	114.44	112.88	**114.44**
2016	ZP434	115.99	114.33	113.33	114.55
	NS4023	117.66	116.55	115.10	116.43
	ZP555	112.77	111.66	110.99	111.88
	NS5051	115.21	113.44	115.21	114.88
	ZP666	115.55	114.22	112.33	114.02
	NS6030	116.55	115.77	113.55	115.29
	Average	115.62	114.32	113.41	**114.45**
2017	ZP434	104.44	103.66	102.55	103.55
	NS4023	101.99	101.33	98.33	100.55
	ZP555	106.88	104.77	102.44	104.70
	NS5051	108.77	106.99	104.66	106.81
	ZP666	104.77	102.33	99.88	102.32
	NS6030	101.66	105.44	101.88	104.19
	Average	105.75	104.08	101.62	**103.80**
Three year average	ZP434	111.28	109.88	108.12	109.76
	NS4023	110.27	109.40	107.21	108.96
	ZP555	111.69	109.99	108.58	110.08
	NS5051	113.95	112.95	110.36	112.42
	ZP666	113.03	110.69	108.69	110.80
	NS6030	114.36	112.88	110.73	112.65
	Average	112.31	110.84	108.95	**110.70**

*D1 – 71429 plants per hectare; D2 – 57143 plants per hectare; D3 – 47619 plants per hectare;

Cob height was in average the highest in 2015 (114.45 cm) followed by 2014 (114.44 cm) and 2017 (103.80) respectively. In 2014 the highest cob was noticed in hybrid NS6030 and the lowest in hybrid NS4023, which were at the same time the highest and the smallest hybrids in 2014. In a year with less precipitation such as 2017, cob height on all hybrids was much lower than in 2016 and 2014. 2014 and 2016 were years with more precipitation than 2017, which has reflected on the cob height especially in plots with the lowest planting rate e.g. ZP666 and NS4023. The difference between the highest and lowest cob for all hybrids was 8.99, 6.67 and 7.78 cm in rainy (2014), average (2016) and dry (2017) year respectively which showes that hybrid selection can minimize the impact of weather conditions on cob height.

Table 5. Average corncob hight (cm) among hybrid, growing season and planting density

Factor	df	Mean sqr Effect	Mean sqr Error	F	p-level
Growing season	2.483	5964.1	17.133	348.111**	0.000
Hybrid	5.480	124.700	40.791	3.057*	0.010
Planting density	2.483	464.93	39.904	11.651**	0.000
Growing season × Hybrid	10.468	109.55	14.009	7.820**	0.000
Growing season × Planting density	4.477	7.367	15.337	0.480ns	0.750
Hybrid × Planting density	10.468	2.979	39.787	0.075ns	0.999

The weather conditions impact during the growing season on the first cob height was statistically very significant (348.111**). The weather conditions amog years have an enormus impact on cob height because of the variation among resaults by each year. The planting density has likewise a statistically very significant impact on cob height (11.651**). The interaction between growing season × hybrid selection had a statistically very significant impact on cob height (7.820**), whereby the interection of year x planting density and hybrid selection × planting density had statistically not a significant impact on cob height (P>0,05). The cob height is a characteristic which has been determined by plant lenght (Živanović, 2013). Planting density impact on plant height among the three year period was statistically very significant but not significant for the cob height. The data showes that different weather conditions in each year interrect different with all tested genotypes both on the plant height and cob height which has already been proved by other authors. The highest plants and cobs were recorded in plots with the highest density which has been claimed earlier by Pandurović i sar. (2009, 2010); Ilić (2002), Zamir et al. (2011); Silva et al. (2014), Mandić et al. (2016) and Greveniotis et al. (2019). In dry years with less precipitation like 2017 plants were heigher in low dense population compared to mid and high dense populations because of the limited growing factors like water and increased intraspecies competition (Jarmaz, 2015).

CONCLUSION

Over the three year period, weather conditions and planting density had statistically very significant impact on maize growth and development and therefore on plant and cob height. In the year with the highest amount of precipitation (2014) the tallest plants and the heighest corn cobs were measured in the densest planted maize population. The optimum amount and the best distribution of precipitation as well as the optimum average monthly temperatures were recorded in 2016 whereby the plants reached the highest average height from 255.06 cm and cob height from 114.45 cm, compared to 242.17 centimeter plant height and similar 114.44 cm cob height in 2014 and 223.96 cm plant and 103.80 centimeter cob height in 2017 which was the least optimum year in terms of precipitation amount and distribution. The highest average height for all three years was measured at hybrid ZP666 with 262.64 cm and the highest average cob height was measured by NS6030 with 112.65 centimeter, compared to NS4023 which was in average the smallest hybrid with 227.32 cm and had the lowest average corn cob height with 108.96 cm. In conclusion, it is important to test hybrids for morphological and productive characteristics in a given area across years with different weather conditions for having a better and more constant yield and minimizing yield losses.

ACKNOWLEDGMENTS

The research presented in this article is part of the research project number 451-03-66/2024-03/200216 and 451-03-65/2024-03/200383 funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia

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