

THE EFFECT OF CROP DENSITY ON MAIZE GRAIN YIELD

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Abstract: The aim of this investigation was to estimate the effects of crop density on the plant height (PH), ear height (EH), leaf number per plant (LN), ear length (EL), number of rows per ear (NRE), number of grain per row (NGR), number of grain per ear (NGE), grain weight per ear (GWE), cob weight (CW), 1000-grain weight (1000-GW), ear diameter (ED) and grain yield (GY) in staygreen maize hybrid Dijamant 6 (FAO maturity group 600). Three crop densities (51020 plants ha⁻¹, 59524 plants ha⁻¹ and 71429 plants ha⁻¹) were tested. The field experiment was carried out during 2006 and 2007 at Srem region (Putinci: latitude 44° 59' 19" N; longitude 19° 58' 11" E). Plots were organized as completely randomized block system design in four replications. PH (284.3 cm), EH (119.9 cm), LN (13.9), EL (20.8 cm), GWE (232.5 g), CW (56.4 g), 1000-GW (378.4 g) and GY (13.56 t ha⁻¹) were significantly higher in 2006 (favorable climatic conditions) than in 2007 (258.5 cm, 112.8 cm, 13.2, 17.9 cm, 192.9 g, 46.9 g, 232.7 g and 11.50 t ha⁻¹, respectively). Increasing crop density significantly increased the PH, EH and GY, and significantly decreases the EL, NGR, NGE, GWE, CW and 100-GW. The crop density of 71429 plants ha⁻¹ is the optimal for growing this hybrid in Srem region. On that crop density hybrid more efficiently used available resources and achieved the highest grain yield.

Key words: crop density, grain yield, maize, morphological traits

Introduction

In Serbia, maize (*Zea mays* L.) is very important agricultural plant which is grown on 1.2 million hectares of land. The total annual production of maize is about 6 million tons and an average grain yield of 4.9 t ha⁻¹. It is used for feeding livestock (80% of the total production), human food and as industrial raw material. Grain yield of maize depends upon variability of the rainfall and temperature

regimes during summer seasons (Mandić et al., 2013). However, irregular schedule and an insufficient number of plants per unit area is a major problem in the production of maize and one of the most common reasons for poor production results (Mandić, 2011). The number of plants per unit area is the most important component of yield because if there are not enough plants cannot be expected high number of ear per unit area and yield. In many regions in Serbia, the maize grain yield is reduced by 1.5 to 2.2 t ha⁻¹ due to the loss about 30% of plants from sowing to harvest. Plants will produce smaller ears, fewer kernels per ear and/or less grain weight per year in densely sown crops, but greater number of ear will result in a higher yield. Mandić (2011) found that the ear length, number of grain per row, number of grain per ear, grain weight per ear, cob weight, 1000-grain weight decreases, grain yield increases and number of rows per ear and leaf number per plant did not change with the increase of plant density. Sharifi et al. (2009) reported that the highest grain yield obtained from plant density of 10 plants m⁻², number of grain per ear, number of grain per row, ear length, number of grain per ear at plant density of 8 plants m⁻², while plant height at plant density of 12 plants m⁻². Amiri et al. (2014) concluded that increasing crop density increases grain yield, decreases number of grain per ear, and not change ear length, number of rows per ear, 1000-grain weight and ear diameter. Plant height, ear height and grain yield is greater under high density and ear length and number of grain per row decreases with increase in plant density in maize (Silva et al., 2014). However, maize grain yield rises with planting density to some maximum value and then declines because of water supply, plant nutrients and other available resources, become limiting. Maize grain yield declines due to a decline in the harvest index, total biomass per plant and increased stem barrenness (Boomsma et al., 2009; Mandić, 2011).

The aim of this study was to determine the effects of crop density on morphological traits, yield components and grain yield of maize hybrid Dijamant 6.

Materials and Methods

The field experiment was carried out during 2006 and 2007 at Srem region (Putinci: latitude 44° 59' 19" N; longitude 19° 58' 11" E). The tests were carried out in dry land farming on calcareous chernozem soil type. Soil analysis in the layer of 0-30 cm showed: in 2006 - pH in water of 7.38; pH in n/1KCl of 7.16; CaCO₃ of 16.8%; humus of 3.61%; total N of 0.23%; P₂O₅ of 17.18 mg/100 g soil and K₂O of 28.20mg/100 g soil; in 2007 - pH in water of 7.67; pH in n/1KCl of 7.46; CaCO₃ of 10.08%; humus of 2.79%; total N of 0.12%; P₂O₅ of 21.86 mg/100 g soil, and K₂O of 22.2 mg/100 g soil.

Maize hybrid Dijamant 6 (FAO maturity group 600) was used as material. It is hybrid with stay green trait, recommended for grain and silage production.

Preceding crop was winter wheat in both seasons. An elementary plot was 16.8 m² (consisting of 4 rows of 6 m length) with plant densities of 51020 plants ha⁻¹, 59524 plants ha⁻¹ and 71429 plants ha⁻¹. The field experiment was arranged in a randomized block system design with 4 replications. Sowing was carried out manually between the 16th and 18th of April, with 2 seeds in seed bed to spacing of 70 × 28, 70 × 24, and 70 × 20 cm. Land rolling was applied after sowing, and thinning seedlings after germination on planned number of plants. A standard cultivation practice was applied. Basic fertilization with N-P-K fertilizer 10:30:20 at the rate of 300 kg ha⁻¹ in autumn and 90 kg ha⁻¹ of KAN - 27% in two doses (1/2 at the stage of 3 leaves and 2/2 at the stage of 7-9 leaves) in spring were applied.

The amount of rainfall and monthly air temperature from April to September were 398.4 mm and 18.0°C in 2006, and 358.8 mm and 18.8°C in 2007, respectively (Table 1). In 2006, higher rainfall amount were in April for 63.9 mm, June for 7.1 mm and August for 93.8 mm than in 2007. In 2006, lower rainfall amount was in May for 47.6 mm than in 2007. In 2006, average month temperatures were lower than in 2007.

Table 1. Monthly meteorological data in 2006 and 2007

Year	Month							Σ / (IV-IX)
	X-III	IV	V	VI	VII	VIII	IX	
	Rainfall (mm)							
2006	211.8	63.9	31.4	92.3	39.0	156.2	15.6	398.4
2007	254.8	0	79	85.2	38.7	62.5	93.4	358.8
	Relative humidity (%)							
2006	-	78	70	78	68	81	76	75.2
2007	-	56	67	69	66	73	80	68.2
	Temperature (°C)							
2006	-	12.5	16.4	19.6	22.8	19.1	17.5	18.0
2007	-	13.0	18.5	22.0	22.6	22.3	14.3	18.8

Maize harvest was performed manual on 15th October in 2006, and 16th in 2007. The central two rows from each plot were used to determine grain yield (GY). GY is calculated on a 14% moisture basis. Ten plants from each plot were taken for measuring plant height (PH), ear height (EH), leaf number plant⁻¹ (LN), ear length (EL), number of rows per ear (NRE), number of grain per row (NGR), number of grain per ear (NGE), grain weight per ear (GWE), cob weight (CW), 1000-grain weight (1000-GW) and ear diameter (ED).

Data were processed using analysis of variance (ANOVA). The statistical tests were carried out using STATISTICA (version 10; StatSoft, Tulsa, Oklahoma, USA). The significance level was set at P≤0.05 and P≤0.01. Differences between traits means were assessed using Duncan's Multiple Range Test at P≤0.05 level.

Results and Discussion

Results showed that the year had highly significant effect on PH, EH, LN, EL, GWE, CW, 1000-GW and GY (Table 2).

Table 2. Effects of year and crop density on morphological traits, yield components and grain yield of maize

Factor		PH	EH	LN	EL	NRE	NGR	NGE	GWE	CW	1000-GW	ED	GY
Year (A)	2006	284.3 ^a	119.9 ^a	13.9 ^a	20.8 ^a	15.1	39.2	594.0	232.5 ^a	56.4 ^a	378.4 ^a	4.8	13.56 ^a
	2007	258.5 ^b	112.8 ^b	13.2 ^b	17.9 ^b	14.8	38.5	570.9	192.9 ^b	46.9 ^b	232.7 ^b	4.6	11.50 ^b
Crop density (B)	51020	266.7 ^b	112.7 ^b	13.5	21.3 ^a	15.2	42.4 ^a	645.5 ^a	250.6 ^a	60.3 ^a	341.1 ^a	4.8	11.79 ^b
	59524	270.8 ^b	116.8 ^{ab}	13.6	19.4 ^b	15.0	38.6 ^b	579.7 ^b	210.8 ^b	51.2 ^b	300.7 ^b	4.8	12.51 ^{ab}
	71429	276.8 ^a	119.6 ^a	13.6	17.4 ^c	14.7	35.7 ^b	522.1 ^b	176.7 ^c	43.5 ^c	275.0 ^c	4.5	13.30 ^a
F test	A	**	**	**	**	ns	ns	ns	**	**	**	ns	**
	B	**	*	ns	**	ns	*	**	**	**	**	ns	*
	A × B	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
M		271.4	116.4	13.6	19.4	15.0	38.9	582.4		51.7	305.6	4.7	12.53

Note: PH, Plant height (cm); EH, Ear height (cm); LN, Leaf number per plant; EL, Ear length(cm); NRE, Number of rows per ear; NGR, Number of grain per row; NGE, Number of grain per ear; GWE, Grain weight per ear(g); CW, cob weight (g); GW, 1000-grain weight (g); ED, Ear diameter (cm); GY, Grain yield (t ha⁻¹); Means followed by the same letter within a column are not significantly different by Duncan's Multiple Range Test at the 5% level (p≤0.05); ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

PH (284.3 cm), EH (119.9 cm), LN (13.9), EL (20.8 cm), GWE (232.5 g), CW (56.4 g), 1000-GW (378.4 g) and GY (13.56 t ha⁻¹) were significantly higher in 2006 than in 2007 (258.5 cm, 112.8 cm, 13.2, 17.9 cm, 192.9 g, 46.9 g, 232.7 g and 11.50 t ha⁻¹, respectively). However, in 2007 we have noticed slow initial growth of seedlings and uneven initial plant growth. The initial population of plants and adequate development affected maize grain yield (Mandić, 2011). Pommel et al. (2002) concluded that difference in seedlings emergence affect canopy development of maize plant. Egli and Rucker (2012) have concluded that plants with a delay of emergence were responsible for reducing crop growth than plants with early emergence. In June maize is in stage of intensive growth of the stem. Although amount of rainfall in June in 2007 (Table 1) was higher than in 2006 the lagging of growth at the beginning of the growing season influenced that plants are lower. During the 2006, the amount of rainfall in August (156.2 mm) was above conditional-optimal for grain filling (95 mm). The grain filling stage of maize is in August. Thus, GWE and GW were higher in this year than in 2007 when amount of rainfall in August was lower (62.5 mm). Mandić et al. (2013) reported that drought stress in August reduced GWE and the share grain in ear was which leads to a reduction in the yield.

The crop density had significant effect on PH, EH, EL, NGR, NGE, GWE, CW, 1000-GW and GY. PH increased 266.7 to 276.8 cm, EH increased 112.7 to 119.6 cm, and GY increased 11.79 to 13.30 t ha⁻¹ with increasing crop densities. EL decreased 21.3 to 17.4 cm, NGR decreased 42.4 to 35.7, NGE decreased 645.5 to 522.1, GWE decreased 250.6 to 176.7 g, CW decreased 60.3 to 43.5 g and 1000-GW decreased 341.1 to 275.0 g with increasing crop densities. The increased plant populations intensified interplant competition for light and stimulate apical dominance and lengthening internodes. Accordingly PH and EH is greater under high density. EL, NRE, NGR, NGE, GWE, CW and 1000-GW decreased linearly as crop density increased because the resources, light, water and nutrients are limited. Interplant competition for sunlight, soil nutrients and soil water increases with increasing crop density. Increasing crop density reduces the quantity of resources available for each individual, and intraspecific competition becomes more intense (Mandić 2011). Also, Sangakkara *et al.* (2004) reported that the interspecific competition for nutrients uptake and sunlight interception increased with increasing plant population of maize. The interplant competition for light, water and nutrients induces barrenness, decreases the number of ears per plant, NKE and GY (Sangoi and Salvador, 1998). Also, Ottman and Welch (1989) reported that high plant population increases barrenness and decreases kernel number per plant and kernel size. EL was reduced which resulted in fewer NGR and NGE. Higher planting densities increase plant sterility and the interval between pollen shed and silk emergence, reducing the NGE (Sangoi *et al.*, 2002). However, the lower values of the traits of the ear shall be compensated larger number of plants per unit area, and a large number of ears per unit area. Many research showed that increasing crop density increases PH and EH (Shafi *et al.*, 2012; Sharifi *et al.*, 2009; Silva *et al.*, 2014), decreases EL (Gozubenli *et al.*, 2004, Sharifi *et al.*, 2009; Mandić, 2011; Khah *et al.*, 2012; Silva *et al.*, 2014; Ijaz *et al.*, 2015; Imran *et al.*, 2015), decreases NGR (Sharifi *et al.*, 2009; Abuzar *et al.*, 2011; Silva *et al.*, 2014; Ijaz *et al.*, 2015), decreases NGE (Abuzar *et al.*, 2011; Mandić, 2011; Amiri *et al.*, 2014), decreases GWE (Gozubenli *et al.*, 2004; Mandić, 2011; Ijaz *et al.*, 2015), decreases CW (Azam *et al.*, 2007; Mandić, 2011), decreases 1000-GW (Mandić, 2011; Zamir *et al.* 2011; Ijaz *et al.*, 2015), increases GY (Mandić, 2011; Shafi *et al.*, 2012; Amiri *et al.*, 2014; Silva *et al.*, 2014; Mahdi and Ismail, 2015).

Different crop density had no significant effects on LN (ranging from 13.5 to 13.6), NRE (ranging from 14.7 to 15.2), and ED (ranging from 4.5 to 4.8). NRE is genetic traits that depend primarily on the genotype, rather than growing conditions (Mandić 2011). Also, many researchers showed that crop density did not significantly affect NRE (Sharifi *et al.* 2009; Ashrafi and Seiedi, 2011; Mandić, 2011; Amiri *et al.*, 2014; Ijaz *et al.*, 2015; Mahdi and Ismail, 2015), LN (Mandić, 2011; Rahmani *et al.*, 2015) and ear diameter (Amiri *et al.*, 2014; Rahmani *et al.*, 2015).

Year and plant density interactions were not observed for investigated traits.

Conclusions

Results of the study showed that the hybrid Dijamant 6 responded positively to high plant densities. In our study grain yields increased about 0.72-1.51 t ha⁻¹ by increasing plant density. The maximum PH, EH, and GY were recorded at highest crop density (71429 plants ha⁻¹). Contrary, the maximum EL, NRE, NGR, NGE, GWE, CW and 1000-GW were recorded in the lowest crop density (51020 plants ha⁻¹). LN, NRE and ED did not change with increasing crop density. The crop density of 71429 plants ha⁻¹ is the optimal for growing this hybrid in region Srem. This hybrid more efficiently uses available resources and achieves the highest grain yield with above mentioned crop density.

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Uticaj gustine useva na prinos zrna kukuruza

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Rezime

Cilj ovog istraživanja bio je da se ispita uticaj gustine biljaka na visinu biljke (VB), visinu klipa (VK), broj listova po biljci (BL), dužinu klipa (DK), broj redova zrna na klipu (BRZ), broj zrna u redu (BZR), broj zrna po klipu (BZK), prinos zrna po klipu (PZK), masu koćanke (MK), masu 1000 zrna (MHZ), prečnik klipa (PK) i prinos zrna (PZ) u hibrida Dijamant 6 (FAO 600 grupa zrenja). Tretmani su bili: 51020 biljaka ha⁻¹, 59524 biljaka ha⁻¹ i 71429 biljaka ha⁻¹. Poljski ogledi izvedeni su 2006. i 2007. godine u regionu Srema (Putinci 44° 59' 19" SGŠ, 19° 58' 11" IGD). Ogledi su postavljeni po slučajnom blok sistemu u četiri ponavljanja. VB (284.3 cm), VK (119.9 cm), BL (13.9), DK (20.8 cm), PZK (232.5 g), MK (56.4 g), MHZ (378.4 g) i PZ (13.56 t ha⁻¹) bili su značajno veći u 2006 godini (povoljni klimatsku uslovi) nego u 2007. (258.5 cm, 112.8 cm, 13.2, 17.9 cm, 192.9 g, 46.9 g, 232.7 g i 11.50 t ha⁻¹). Povećanje gustine useva značajno je povećalo VB, VK i PZ, i značajno smanjilo DK, BZR, BZK, PZK, MK i MHZ.

Gustina useva 71429 biljaka ha⁻¹ je optimalna za gajenje ovog hibrida u regionu Srema. Na toj gustini hibrid najefikasnije koristi raspoložive resurse i postiže najveći prinos zrna.

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