

THE EFFECT OF CROP DENSITY ON YIELD OF FORAGE MAIZE

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Abstract: The aim of this investigation was to estimate the effects of crop density on the plant height (PH), stem diameter (SD), number of leaves per plant (NL), forage yield hectare⁻¹ (FY), dry matter yield hectare⁻¹ (DMY), stem percentage (SP), leaf percentage (LP) and ear percentage (EP) in two maize hybrids of FAO maturity group 600 (ZP 684 and NS 6010). Field trials were carried out in rainfed farming in the Srem region (location Putinci: 44° 59' 19" North and 19° 58' 11" East) during years 2007 and 2008. Three crop densities were compared: G1 – 51,020 plants ha⁻¹, G2 – 59,524 plants ha⁻¹ and G3 – 71,429 plants ha⁻¹ (corresponding to spacing of 70 × 28, 70 × 24, and 70 × 20 cm). Plots were organized as completely randomized block system design in four replications. PH (265.45 cm), SD (2.40 cm), FY (68.63 t ha⁻¹) and DMY (24.63 t ha⁻¹) were significantly higher in 2007 than in 2008 (261.78 cm, 2.32 cm, 61.17 t ha⁻¹ and 21.04 t ha⁻¹, respectively). Hybrid NS 6010 had significantly higher PH (266.23 cm), SD (2.39 cm) and NL (14.75) than hybrid ZP 684 (261.0 cm, 2.33 cm and 13.99, respectively). Increasing crop density significantly increased the PH, FY, DMY and SP, and significantly decreases the SD and EP. Therefore, crop density of 71,429 plants ha⁻¹ (70 x 20 cm) can be recommended for growing hybrids of FAO 600 maturity group in climatic conditions of Srem in order to achieve high yields of forage and dry matter.

Key words: crop density, dry matter yield, forage yield, maize

Introduction

Maize is multipurpose crop. It is used for human food, animal feed and as industrial raw material. In Serbia, maize is largely used for feeding livestock, an estimated 80% of the total production. In the complete forage mixtures, maize is present with 50-80%, depending on the type and categories of animals (*Randjelovic et al., 2011*). In animal nutrition grain or silage (grain silage and forage silage) is

used. Maize is a very convenient crop for forage production due to the high production of green mass per unit area (12-25 t total dry matter per hectare), high energy content of dry matter and quality of biomass for silage (Mandić et al. 2013). Selection of maize is focused on maize hybrids that produce high grain yields and good quality silage combined with agronomic traits. Silage maize hybrids are certified based on fresh and dry matter yield and the proportion of the ear (Tóthné Zsubori, 2011). Hybrids are grown for the maximum amount of dry matter per hectare. In many environments in Serbia, the loss of plants from sowing to harvest is around 30% and the maize yield is decreased by 1.5 to 2.2 t ha⁻¹. In Serbia, maize is sown in 70 cm inter-row, while the distance between seeds in a row determines the number of plants per unit area (Mandić, 2011). At supra-optimal crop density, maize reduces the total biomass per plant, increases barrenness, and decreases harvest index (Boomsma et al., 2009). The distance between the plants should be ideal so that the plants are competing minimally for nutrients, sunlight and other factors (Lauer 1994). Çarpıcı et al. (2010) established that dry matter yield and stem percentage increased, leaf number plant⁻¹, stem diameter and ear percentage decreased as crop density increased. Karaşahin (2014) concluded that the silage and dry matter yield increased as plant density increased, while decreased stem diameter, and fresh ear ratio. While forage yield and dry matter yield increases with increasing plant densities, stem diameter decreases (Baghdadi et al. 2012; Moosavi et al., 2012).

This research is focused to find optimal crop density to enhance maize forage and dry matter yield. We examined the effect of three crop densities (51,020 plants ha⁻¹, 59,524 plants ha⁻¹ and 71,429 plants ha⁻¹) on the plant height (PH), stem diameter (SD), number of leaves per plant (NL), forage yield hectare⁻¹ (FY), dry matter yield hectare⁻¹ (DMY), stem percentage (SP), leaf percentage (LP) and ear percentage (EP) in maize hybrids ZP 684 and NS 6010 in different environmental conditions.

Materials and Methods

Field trials were carried out in rainfed conditions in the Srem region (location Putinci: 44° 59' 19" North and 19° 58' 11" East) during years 2007 and 2008. The experiment was carried out on calcareous chernozem soil type, with pH in H₂O 7.6, pH in KCl 7.18, 12.99% CaCO₃, 2.69% humus, 0.18% total N, 19.12 mg 100g soil⁻¹ P₂O₅ and 21.8 mg 100g soil⁻¹ K₂O, respectively. Two maize hybrids of FAO maturity group 600, ZP 684 and NS 6010, were used as material. Three crop densities were tested: G1 – 51,020 plants ha⁻¹, G2 – 59,524 plants ha⁻¹ and G3 – 71,429 plants ha⁻¹ (corresponding to spacing of 70 × 28, 70 × 24, and 70 × 20 cm). Sowing was carried out manually with 2 seeds in seedbed. After sowing, rolling was applied. After germination thinning was carried out at a steady, planned

number of plants. Maize sowing was done on in the optimal time (from 16-18 April). Sub-plot area was 16.8 m² having 4 rows each per hybrid with row length of 6 m. Plots were organized as completely randomized block system design in four replications. Preceding crop was winter wheat in both seasons. The N-P-K fertilizer (10-30-20) in quantity 300 kg N ha⁻¹ was incorporated into the soil during primary soil tillage. In spring during additional soil tillage was applied KAN - 27% in quantity 90 kg ha⁻¹. One half of the KAN was applied at the stage of 3 leaves, the remaining half at the stage of 7-9 leaves. A standard cultivation practice was applied.

The amount of rainfall and monthly air temperature during the growing season of maize (April-August) were 265.4 mm and 19.7°C in 2007, and 236.6 mm and 19.2°C in 2008, respectively (Figure 1). Climate diagram showed that in 2007 drought period was in July at the flowering stage (anthesis and silking), and in 2008 in August at the stage of grain filling.

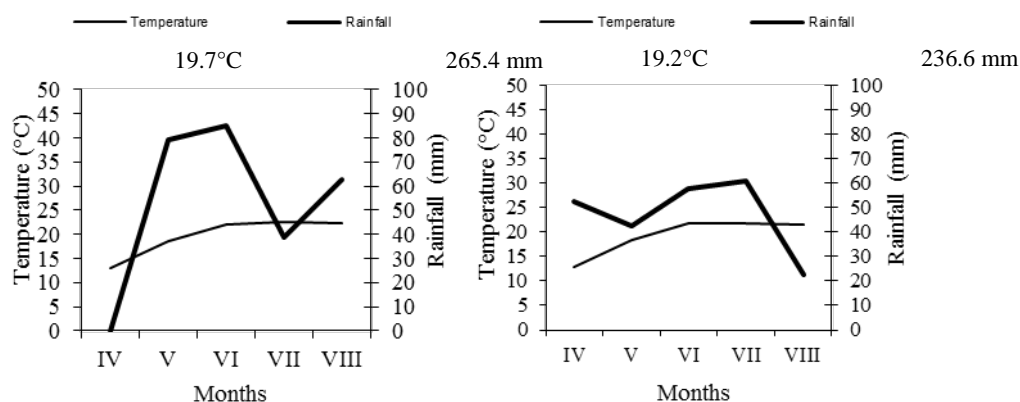


Figure 1. Climate diagram according to Walter in the 2007 and 2008 for Sremska Mitrovica, Serbia

Maize harvest was performed manually when the dry matter was 34-36% during second half of August and the beginning of September. Plants from central two rows from each sub plot were cut on height 20 cm at harvest time and forage yield was measured (FY). The yield was converted into t ha⁻¹. At maize harvest, plant height (PH), stem diameter (SD), number of leaves per plant (NL), dry matter yield hectare⁻¹ (DMY), stem percentage (SP), leaf percentage (LP) and ear percentage (EP) were measured from 10 random plants from each sub plot.

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

Results

Results showed that the year had highly significant effect on PH, SD, FY and DMY (Table 1). PH (265.45 cm), SD (2.40 cm), FY (68.63 t ha⁻¹) and DMY (24.63 t ha⁻¹) were higher in the 2007 than in the 2008 (261.78 cm, 2.32 cm, 61.17 t ha⁻¹ and 21.04 t ha⁻¹, respectively).

Table 1. The effect of year, hybrid, and crop density on forage yield, dry matter yield and some morphological traits of maize

Factor		PH	SD	NL	FY	DMY	SP	LP	EP
Year (A)	2007	265.45 ^a	2.40 ^a	14.43	68.63 ^a	24.63 ^a	47.48	28.10	24.41
	2008	261.78 ^b	2.32 ^b	14.31	61.17 ^b	21.04 ^b	46.88	29.14	23.98
Hybrid (B)	ZP 684	261.00 ^b	2.33 ^b	13.99 ^b	65.18	22.99	46.28	28.80	24.92
	NS 6010	266.23 ^a	2.39 ^a	14.75 ^a	64.61	22.69	48.09	28.44	23.47
Crop density (C)	51020	259.52 ^b	2.43 ^a	14.39	61.90 ^c	21.80 ^c	43.28 ^c	29.76	26.97 ^a
	59524	264.21 ^a	2.36 ^a	14.38	65.28 ^b	23.04 ^b	46.61 ^b	28.05	25.34 ^a
	71429	267.12 ^a	2.29 ^b	14.34	67.51 ^a	23.67 ^a	51.65 ^a	28.06	20.29 ^b
F test	A	**	**	ns	**	**	ns	ns	ns
	B	**	*	**	ns	ns	ns	ns	ns
	C	**	**	ns	**	**	**	ns	**
	A × B	ns	ns	ns	**	**	ns	*	ns
	A × C	ns	ns	ns	ns	ns	ns	ns	ns
	B × C	*	ns	ns	ns	ns	ns	ns	ns
	A × B × C	**	ns	ns	*	ns	ns	ns	ns
M		263.62	2.36	14.37	64.9	22.84	4.18	28.62	24.20

Note: PH, plant height (cm); SD, Stem diameter (cm); NL, number of leaves per plant; FY, Forage yield hectare⁻¹ (t ha⁻¹); DMY, Dry matter yield hectare⁻¹ (t ha⁻¹); SP, Stem percentage (%); LP, Leaf percentage (%); EP, percentage (%); Means followed by the same letter within a column are not significantly different by Duncan's Multiple Range Test at the 5% level ($p \leq 0.05$); ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

The hybrid had significant effect on PH, SD and NL. Hybrid NS 6010, in average for years and crop densities, produced significantly higher PH (266.23 cm), SD (2.39 cm) and NL (14.75) than hybrid ZP 684 (261.0 cm, 2.33 cm and 13.99, respectively).

The crop density had highly significant effect on PH, SD, FY, DMY, SP and EP. The lowest values of PH (259.52 cm), FY (61.90 t ha⁻¹), DMY (21.80 t ha⁻¹) and SP (43.28%) were measured in the lowest crop density (51,020 plants ha⁻¹), and the highest values (267.12 cm, 67.51 t ha⁻¹, 23.67 t ha⁻¹ and 51.65%, respectively) in the highest crop density (71,429 plants ha⁻¹). By contrast, the highest values of SD (2.43 cm) and EP (26.97%) were measured in the lowest crop density (51,020 plants ha⁻¹), and the lowest values (2.29 cm and 20.29%, respectively) in the highest crop density (71,429 plants ha⁻¹).

The interaction of year and hybrid had significant effect on FY, DMY and LP. The interaction of hybrid and crop density had significant effect on PH. The interaction of year, hybrid and crop density had significant effect on PH and FY.

Discussion

PH, SD, FY and DMY were affected by year. Values for these traits were significantly higher in 2007 than in 2008. The amount of rainfall during growing period in 2007 was higher for 28.8 mm than in 2008 (236.6 mm). *Tóthné Zsubori et al. (2010)* reported that maize hybrids have the higher PH and DMY per plant in years with favorable climatic conditions. The better distribution of rainfall during vegetative stage of maize, i.e. greater amount was in May and June of 2007, especially in June, when the maize was at the stage of intensive stem growth. In 2008, the lower amount of rainfall and the higher air temperature in June reduced stem cell expansion resulting in reduced PH. *Çakir (2004)* reported that short drought stress in the vegetative stage of maize reduces PH, leaf area development and dry matter content of maize for 28-32%. High FY and DMY resulted in years with well distributed rainfall from June to August. In 2007, the amount of rainfall from June to August was higher for 44.6 mm than in 2007 (141.8 mm) which resulted in higher FY and DMY. Also, *Randjelovic et al. (2011)* stated that the amount of rainfall in this period is crucial factor for maize biomass production and grain yield. In 2007, drought period present was in July at the stage of flowering (anthesis shed and silking), and in 2008, in August at the stage of grain filling. However, results of *Mandić (2011)* showed that drought stress in July in 2007 in that location had no influence on flowering and pollination of hybrids ZP 684 and NS 6010, because there was rainfall in anthesis-silking period (lasts for five days). Also, author reported that the drought in August in 2008 reduced the grain weight per ear, 1,000 grain weight and grain yield. Different climatic conditions (temperature and quantity and rainfall distribution) significantly influence yield of maize grown under similar conditions (*Huzsvai and Nagy, 2005*).

Hybrids significant differed for PH, SD and NL. Hybrid NS 6010 had the higher PH, SD and NL than hybrid ZP 684. The same results were obtained by *Mandić (2011)* at the same location. *Randjelović (2009)* stated that the PH depends on the genetic basis of hybrid and growing conditions. The studied hybrids have stay green trait, i.e. leaves and stem stay green longer than the cob rapidly matures. These hybrids are suitable for the production of grain and silage. According to *Randjelovic et al. (2011)* hybrid NS 6010 produced higher DMY and grain yield than hybrid ZP 684, as well as hybrids from maturity groups FAO 400 (ZP 434 and NS 444 ultra) and FAO 700 (ZP 735 and Dunav) in region Srem at location Ruma. *Terzić et al. (2012)* reported that ZP maize hybrids (ZP 158, ZP 173/8, ZP 377, ZP

440, ZP 555 and ZP 679) of different genetic backgrounds produces DMY from 14.0 (ZP 158) to 21.3 t ha⁻¹ (ZP 679).

PH, SD, FY, DMY, SP and EP were affected by crop density. PH, FY, DMY and SP were significantly increased parallel with crop density. Also, many research have showed that increasing crop density consistently increases PH (Yilmaz et al., 2008; Moosavi et al., 2012; Şafî et al., 2012; Silva et al., 2014), FY (Yilmaz et al., 2007; Baghdadi et al. 2012; Moosavi et al., 2012; Karaşahin, 2014), DMY (Yilmaz et al., 2007; Stanton et al., 2007; Çarpıcı et al., 2010; Baghdadi et al. 2012; Moosavi et al., 2012; Ferreira et al., 2014; Karaşahin, 2014) and SP (Oktem and Oktem, 2005; Çarpıcı et al., 2010). Contrary, SD and EP were significantly decreased with increasing crop density. At high crop densities, PH increased due to competition for light (longer internodes and longer stem), while SD decreased. SD is strongly influenced by climatic conditions during stem elongation. Considering that at high densities inter-plant competition for environmental parameters (light, water, and space) increased, and hence photosynthesis was reduced, it finally caused SD reduction. The increase in DMY with the increasing crop density indicates the favorable response of biomass produced per maize population. EP decreased with increasing crop density. This can be explained by the presence of high intraspecific competition between maize plants for light, water and nutrients. In the highest crop density plants form shorter ears, number of kernels per row, the number of grains per ear, grain weight per ear, 1,000 grain weight, ear diameter, cob diameter and rachis diameter (Mandić, 2011). Conforming to our results, Widdicombe et al. (2002), Turgut et al. (2005), İptaş and Acar (2006), Yilmaz et al. (2007), Çarpıcı et al. (2010), Baghdadi et al. (2012), Moosavi et al. (2012) and Karaşahin (2014) reported that SD decrease with increasing crop density. Baron et al. (2006), Stanton et al. (2007), Yilmaz et al. (2007), Çarpıcı et al. (2010) and Karaşahin (2014) also observed that EP decreased with increasing crop density. Crop densities had not affected NL ranging from 14.34 to 14.39. Similar results were found in research by İptaş and Acar (2006), Moosavi et al. (2012) and Baghdadi et al. (2012). Also, LP (ranging from 28.05% to 29.76%) was not affected by crop density. Similar results reported Çarpıcı et al. (2010).

Conclusions

Results of the study showed that the hybrids ZP 684 and NS 6010 can be recommended for production of forage in Srem region. Maize hybrids responded positively to high crop densities with maximum forage and dry matter yields occurring at crop density 71,429 plants ha⁻¹ (70x20 cm). Also, higher crop density can be recommended because of the increase in usage of solar radiation and other inputs for the production of biomass per hectare. PH, FY, DMY and SP are

increased; SD and EP are decreased, while LP did not change as crop densities increased.

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Uticaj gustine useva na prinos krme kukuruza

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Cilj ovog istraživanja bio je da se ispita uticaj gustine useva na visinu biljke (VB), prečnik stabla (PS), broj listova po biljci (BL), prinos krme po hektaru (PK), prinos suve materije po hektaru (PSM), udeo stabla (US), udeo lista (UL) i udeo klipa (UK) dva hibrida kukuruza FAO 600 grupe zrenja (ZP 684 and NS 6010). Ogledi su izvedeni u suvom ratarenju u regionu Srema (lokacija Putinci 45° 00' SGŠ, 19° 58' IGD) tokom 2007. i 2008. godine. Upoređivane su tri gustine biljaka: G1 – 51,020 biljaka ha⁻¹, G2 – 5,9524 biljaka ha⁻¹ i G3 – 71,429 biljaka ha⁻¹ (odgovara razmaku 70 × 28, 70 × 24 i 70 × 20 cm). Ogledi su postavljeni po slučajnom blok sistemu u četiri ponavljanja. VB (265.45 cm), PS (2.40 cm), PK (68.63 t ha⁻¹) i PSM (24.63 t ha⁻¹) bili su značajno veći u 2007. godini nego u 2008. (261.78 cm, 2.32 cm, 61.17 t ha⁻¹ and 21.04 t ha⁻¹). Hibrid NS 6010 imao je značajno veću VB (266.23 cm), PS (2.39 cm) i BL (14.75) nego hibrid ZP 684 (261.0 cm, 2.33 cm and 13.99). Povećanje gustine biljaka značajno je povećalo VB, PK, PSM i US, i značajno smanjilo PS i UK. Gustina biljaka 71,429 biljaka ha⁻¹ (70 x 20 cm) može se preporučiti za gajenje hibrida FAO 600 grupe zrenja u klimatskim uslovima Srema u cilju postizanja visokih prinosa krme i suve materije.

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