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Effects of Maize Density and Sowing Pattern on Weed Suppression and Maize Grain Yield

Milena Simić and Lidija Stefanović
Maize Research Institute „Zemun Polje", Belgrade, Serbia
(smilena@mrizp.co.yu)

SUMMARY

Plant competition in its basic sense can be defined as competition for resources such as light, water and nutrients. The intensity of crop competition, especially competition of row crops such as maize, mostly depends on population density and plant arrangement. A better use of maize plant density and row spacing may be one way of developing crops that would be more competitive against weeds. An IWM programme should attempt to exploit effectively the competitive ability of crops in suppressing weed growth. Weed suppression is one potential benefit of altered population density and sowing pattern of maize. Another one is an increase in grain yield.

Keywords: Maize population; Density; Sowing pattern; Weed suppression; Grain yield

INTRODUCTION

Crop yield losses due to weeds are mainly explained in terms of competition. Competition has different meanings to ecologists, geneticists and agronomists as a result of confusing the process of competition, results of competition, and relationships among the competing individuals. In its basic sense, plant competition can be defined as competition for resources such as light, water and nutrients (Cousens, 1985; Håkansson, 1997). In a broader sense, any plant activity resulting in a reduced growth of all or individual plants in a stand, compared with the growth of comparable solitary individuals, is ascribed to competition (Håkansson, 1997).

The competitive ability of crops works in two basic ways. The first is the ability of a crop to compete with weeds by reducing their biomass and seed production. The second one is the crop's toleration of competition from weeds while maintaining high yields (Bussan et al., 1997). The intensity of crop competition, especially the competition of row crops such as maize, is mostly defined by population density and the arrangement of plants (Kropff and van Laar, 1993; Murphy et al., 1996; Mohler, 2001). A better use of maize plant density and row spacing may be one way of developing crops more competitive with weeds (Swanton and Weise, 1991; Teasdale, 1995; Swanton and Murphy, 1996). The effect of plant arrangement, i.e. uniformity of crop plants, on the level of weed infestation has been investigated mostly in cereal crops (Lemerle et al., 1996; Weiner et al., 2001) and much less in maize, which is a row crop. The effects of population density and sowing pattern (row spacing or spatial arrangement) on weed suppression were not separated in earlier research.

EFFECTS OF MAIZE DENSITY ON WEED SUPPRESSION

Under an integrated weed management (IWM) programme, an attempt should be made to exploit effectively the competitive ability of crops to suppress weed growth. Wide-row crops, such as maize, are less competitive with weeds, which is particularly evident in the early stages of growth (Kovačević, 2003; Simić, 2004). The optimum sowing dates, rates, cultivars, i.e. plant breeding for the highest competitive ability against weeds, irrigation and use of herbicides at such a level as to enhance the role of the edificators and weaken the weed plants, are the main agrophytocenological methods for weed suppression (Vorobjev et al., 1985). These methods anticipate optimal crop structure, i.e. coverage, in order to enhance the dominant role of the cultivated plants and make an important part of complex measures of weed control (Božić et al., 1996; Simić et al., 2004). Competition is a dynamic process determined by the ability of competing species to exploit effectively the crucial resources - both those necessary for growth (light, vegetative space) and those whose lack can inhibit growth (water and mineral matters) (Kropff et al., 1997). Differences in weed coverage are primarily explained by the effects of density and growth rate of both crops and weeds (Muminović, 1990). Greater crop density significantly affects the vegetative and generative development of individual weed species, as well as the composition and structure of the entire weed association, and is a very reliable cropping practice applied to enhance the competitive ability of a certain genotype (Tollenaar et al., 1994; Doll et al., 1995; Wilson et al., 1995; Murphy et al., 1996; Hashem et al., 1998; Knežević and Horak, 1998; Stanojević, 1999; Korres and Froud-Williams, 2002; Simić, 2004). Increasing maize plant density is another way of reducing light transmittance through the canopy (McLachlan et al., 1993). Weed height and biomass in narrow-stand crops are significantly lower, pointing to the fact that crop density is significant in the competition for living space, light, water and mineral matters (Muminović, 1990; Stanojević et al., 1996).

In the last 30-year period, maize plant density has been changed in keeping with a tendency to increase plant numbers per ha. Today, it is generally accepted that maize should be grown in densities greater than 60000 or 70000 plants ha^{-1}, as previously recommended. Maize density achieved by timely sowing an optimum number of plants, according to conditions in any given location and the variety and hybrid, directly affects the formation of a good crop coverage, and consequently an improved competitive ability of the crop against weeds. According to results obtained by Teasdale (1998), a 1.5-2-fold maize density increase in relation to the initial number (64000 plants ha^{-1}) caused not only a decrease in the number of *Abutilon theophrasti* plants and their vegetative mass, but the species' seed production as well (Table 1).

Maize cultivation at increased density was also found to reduce vegetative biomass of *Amaranthus retroflexus* (McLachlan et al., 1993) and biomass of annual weeds (Murphy et al., 1996; Tollenaar et al.,

Table 1. Velvetleaf survival, growth, and seed production in response to maize density (Teasdale, 1998)
Tabela 1. Uticaj gustine kukuruza na procenat preživelih biljaka, razviće i produkciju semena abutilona (Teasdale, 1998)

Year Godina	Maize density Gustina kukuruza	Plant survival Preživele biljke (%)	Weight of surviving plants Masa preživelih biljaka (g)	Plants producing seed Biljke sa produkcijom semena (%)	Seed number per producing plant (seed plant^{-1}) Broj semena po biljci (broj biljka^{-1})
1994	1 x	37 b	4.19 a	7	253
	1.5 x	64 a	0.81 b	0	-
	2 x	77 a	0.31 b	0	-
1995	1 x	36 a	9.55 (1.47)	33	95
	1.5 x	15 b	3.97 (0.84)	13	74
	2 x	1 b	0.60 (0.60)	1	42
1996	1 x	100 a	19.9 a	100	601
	1.5 x	89 a	3.4 b	48	70
	2 x	89 a	1.5 b	13	20

Values of means followed by the same letter within year are not significantly different (P= 0.05) according to the LSD test. Standard error of the mean is shown in parentheses when analysis of variance was not appropriate
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno (P=0.05) prema LSD testu. Standardna greška sredine je naznačena u zagradama ako analiza varijanse nije bila odgovarajuća

1994). Murphy et al. (1996) reported that, by increasing maize density from 7 to 10 plants m^{-2} or decreasing maize row spacing fr om 75 to 50 cm, the biomass of late emerging weeds was reduced. Previous studies had shown that maize cultivation at increased density and ″narrower inter-row spacing could reduce weediness and increase efficiency of herbicides, hence their lower rates could be applied (Teasdale, 1995).

The results obtained under our local conditions show that maize density can reduce total maize weediness, as well as the biomass of certain troublesome weed species (Stanojević et al., 1998; Oljača et al., 2000, 2002). In a four-year study by Simić (2004), increased maize density resulted in a significant reduction in total weed biomass (Table 2).

In these studies (Simić et al., 2003a; Simić, 2004), high maize density was found to reduce all weeds during the entire growing period, but this was more evident in the summer and autumn aspects of the weed community than the spring one (Table 3). Hence, weed biomass reduction under the highest maize density, compared to the initial and lowest density, was

Table 2. Effects of maize density (plants ha^{-1}) on weed fresh weight (g m^{-2}) (Simić, 2004)
Tabela 2. Uticaj gustine useva kukuruza (biljaka ha^{-1}) na svežu masu korova (g m^{-2}) (Simić, 2004)

Maize density Gustina kukuruza	Year – Godina				Mean Prosek
	1996	1997	1998	1999	
40.816	755.04 a	952.54 a	1012.70 a	1292.18 a	1003.11 a
69.686	553.92 b	463.98 b	573.48 b	408.59 b	499.99 b
98.522	397.45 c	315.28 b	315.34 c	291.01 b	329.77 c
	$LSD_{0.01}$= 133.0	$LSD_{0.01}$= 172.0	$LSD_{0.01}$= 202.2	$LSD_{0.01}$= 279.0	$LSD_{0.01}$= 99.63

Values of means followed by the same letter within year are not significantly different (P= 0.01) according to the LSD test
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno (P=0.01) prema LSD testu

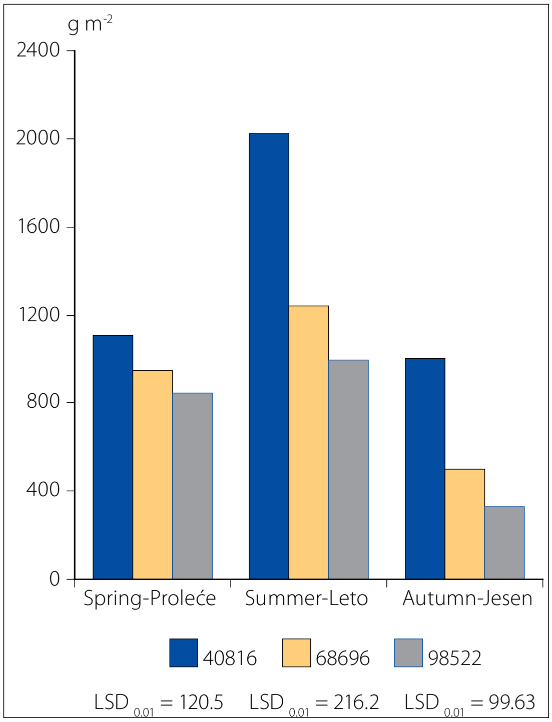
Table 3. Effects of maize density on the weed association according to seasonal dynamics (average for 1996-1999) (Simić, 2004)
Tabela 3. Uticaj gustine useva kukuruza na sezonsku dinamiku korovske zajednice (prosek 1996-1999) (Simić, 2004)

Parameters of weeds Parametri korova	Maize density (plants ha^{-1}) Gustina kukuruza (biljaka ha^{-1})			Statistical analysis Statistička analiza
	40.816	68.696	98.22	
No. of weed species 1 Broj vrsta korova 1	8.30 a	7.81 b	7.61 b	$LSD_{0.05}$ = 0.35
No. of weed species 2 Broj vrsta korova 2	7.78 a	7.01 b	6.25 c	$LSD_{0.05}$ = 0.31
No. of weed species 3 Broj vrsta korova 3	8.20 a	6.40 b	5.56 c	$LSD_{0.05}$ = 0.33
No. of weed individuals 1 Broj jedinki korova 1	122.70 a	103.10 b	98.47 b	$LSD_{0.05}$ = 17.15
No. of weed individuals 2 Broj jedinki korova 2	79.26 a	62.61 b	56.03 b	$LSD_{0.05}$ = 10.16
No. of weed individuals 3 Broj jedinki korova 3	56.36 a	40.52 b	32.42 c	$LSD_{0.05}$ = 5.34
Dry biomass of weeds 1 Suva masa korova 1	154.10 a	133.90 b	119.20 c	$LSD_{0.05}$ = 13.88
Dry biomass of weeds 2 Suva masa korova 2	346.60 a	217.90 b	185.10 c	$LSD_{0.05}$ = 30.56
Dry biomass of weeds 3 Suva masa korova 3	222.30 a	115.30 b	73.00 c	$LSD_{0.05}$ = 18.26

Values of means followed by the same letters are not significantly different (P= 0.05) according to the LSD test; 1- spring aspect, 2- summer aspect, 3- autumn aspect
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno (P=0.05) prema LSD testu; 1- prolećni aspekt, 2- letnji aspekt, 3-jesenji aspect

26.31%, 50.81% and as much as 67.12% in spring, summer and autumn, respectively (Figure 1).

Reduced weed biomass in high-density systems has been related to an increase in leaf area index (LAI),



Values of means followed by the same letter within year are not significantly different (P = 0.01) according to the LSD test
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno (P = 0.01) prema LSD testu

Figure 1. Effect of maize density (plants ha^{-1}) on weed fresh weight (g m^{-2}) during the maize growing period (Simić, 2004)
Slika 1. Uticaj gustine useva kukuruza (biljaka ha^{-1}) na svežu masu korova (g m^{-2}) tokom vegetacionog perioda (Simić, 2004)

(Tollenaar et al., 1994). The results obtained also show that maize density increased from 41000 to almost 99000 plants ha^{-1} significantly reduced weed fresh weight, and increased leaf area per plant and leaf area index of maize from 2.85 to 6.26, which is 54.5% (Sim ić et al., 2003b; Simić, 2004) (Table 4).

In addition to crop density, appropriate choice of maize hybrids also has a significant role in increasing maize competitiveness against weeds. Although selection of crops for heightened competitive ability against weeds is quite difficult, cultivation of competitive crops and genotypes is a principal component of integrated weed management (Lemerle et al., 1996). Different crops and cultivars can reduce weed biomass between 4% and 83% during a full season of competition (Malik, 1990). The possibility of reducing weed coverage by increasing the competitive activity of crops through cultivation of high-yielding hybrids that tolerate high density depends on the traits of each hybrid and environmental conditions in the cultivation region (Graybill et al., 1991). Increased competitive ability of cultivars has been attributed to early emergence, seedling vigour, an increased rate of leaf expansion, rapid formation of dense canopy, leaf area and increased plant height (Minotti and Sweet, 1981; Forcella, 1987; Joenje and Kropff, 1987; Berkovitz, 1988; Blackshaw, 1994; Knežević et al., 1995).

The use of specific-purpose genotypes and their sowing at different denisities in order to control weeds requires special attention, particularly under conditions of limited water supply (Korres and Froud-Williams, 2002). Breeding and variety testing programmes should consider the factors of crop competitive ability. Information on the degree of competitiveness of recommended varieties need to be collected. This information could contribute to optimising herbicide use efficiency through factor-adjusted dose rec-

Table 4. Data on the effects of crop density (plants ha^{-1}) on maize leaf area index (Simić, 2004)
Tabela 4. Rezultati delovanja gustine useva (biljaka ha^{-1}) na indeks lisne površine kukuruza (Simić, 2004)

Crop density Gustina kukuruza	Year – Godina				Mean – Prosek (1996-1999)
	1996	1997	1998	1999	
40816	2.72 c	2.56 c	3.11 c	3.00 c	2.85 c
68696	4.81 b	4.06 b	5.12 b	4.41 b	4.60 b
98522	6.51 a	5.58 a	6.64 a	6.30 a	6.26 a
	$LSD_{0.01}$ = 0.388	$LSD_{0.01}$ = 0.424	$LSD_{0.01}$ = 0.394	$LSD_{0.01}$ = 0.413	$LSD_{0.01}$ = 0.198

Values of means followed by the same letters are not significantly different (P = 0.01) according to the LSD test
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno (P = 0.01) prema LSD testu

ommendations (Swanton and Weise, 1991). A genotype's height is its essential trait that contributes to greater competitiveness in relation to weeds (Wicks et al., 1986; Lemerle et al., 1996). Short early-maturing varieties of soybean in Ontario were less competitive than tall and later maturing varieties (Barrie, 1969; cit. Swanton and Weise, 1991). The results of contemporary studies point to a fact that new types of maize hybrids can favourably respond to increased density (Tollenaar, 1991, 1992; Dong and Hu, 1993; Cox, 1996). Conversely, Westgate et al. (1997) found that canopies with a greater LAI intercepted more incident light earlier in the season, regardless of row spacing or height of a hybrid.

As far as our domestic conditions are concerned, the data obtained by Gotlin et al. (1980) are interesting as they show that the NS and ZP hybrids of the FAO maturity group 600-700 tolerate high densities of as much as 90000 plants ha^{-1}. On the average, optimum density of our hybrids is 60000 plants ha^{-1} and higher, as there has been certain progress in our growing practices (Videnović et al., 2005).

Increasing plant density beyond the recommended rate for maximum maize growth (7-8 plants m^{-2}) may not, however, translate into a significant improvement in light interception and weed suppression (Tollenaar et al., 1994). Moreover, Tollenaar et al. (1994) reported no difference in weed biomass when maize density was between 7 and 10 plants m^{-2}.

EFFECTS OF MAIZE SOWING PATTERN ON WEED SUPPRESSION

Sowing a crop with more uniform and dense plant distribution may result in better utilization of light, water and nutrients, which leads to greater crop competitive ability (Minotti and Sweet, 1981; Berkowitz, 1988). A more equidistant arrangement of maize plants, achieved by manipulating row spacing and plant density, is thought to play a role in reducing the potential for weed interference by increasing the amount of light that is intercepted by the crop canopy (Gunsolus, 1990; Teasdale, 1995). Moreover, Bullock et al. (1988) noted that a relative growth rate of maize was greater for narrow-row than wide-row systems early in the growing season. In a completely uniform crop stand with equal distance between plants in a row and between rows, the competition against weeds will start earlier than in conventional row cultivation, while intraspecies competition will occur latter (Fisher and Miles, 1973; Légère and Schreiber, 1989; Olsen et al., 2005). Enhancing the competitive ability of crops may allow for a reduction in the amount of herbicides used. Forcella et al. (1992) found that narrow-row maize competed well enough with weeds to eliminate effectively the need for cultivation and two-thirds of a normally applied herbicide rate. Manipulation of the sowing pattern for greater weed suppression should also allow for inter-row cultivation where applicable, should not increase the incidence of diseases and insects, should ensure harvesting efficiency, and provide optimum crop yields (Swanton and Weise, 1991).

Differences in maize plant architecture (leaf orientation and angle) among hybrids also need to be re-examined with respect to reducing an early season light penetration through the canopy in narrow-row systems. According to results obtained in studies carried out at Zemun Polje during 2004 and 2005, the lowest weed fresh weight was recorded in the variant of 35x50 cm between rows and plants in a row compared to the variants of 50x35 cm and 70x25 cm. The number of maize plants ha^{-1} remained the same in all variants. The difference in fresh weight between the variants of 35x50 cm and 50x35 cm occurred due to different plant orientation, leaf position and amount of light, as plant orientation was east-west in the first variant and north-south in the second (Table 5).

Westgate et al. (1997) suggested that hybrids with a greater capacity of altering leaf display angles or with a whorled leaf display might be better suited for efficient light interception in narrow rows. Moreover, the advantages of narrow maize row spacing may stem from an enhanced competitive ability with the more shade-intolerant weed species. The predominant weed species in the Westgate et al. (1997) study (i.e. giant foxtail and common ragweed) had greater shade tolerance.

Sowing pattern also affects the critical period of weed control (Swanton and Weise, 1991). The use of a narrow maize row spacing to reduce weed competitiveness appears more risky, especially at optimal plant densities (7-8 plants m^{-2}). To enhance crop competitiveness by using a narrow row spacing, optimisation of all other crop growth variables is required (Tollenaar et al., 1994).

Table 5. Effects of maize plant arrangements and herbicide application on weed fresh weight (g m^{-2}) (2004-2005)
Tabela 5. Uticaj raspreda biljaka kukuruza i primene herbicida na svežu masu korova (g m^{-2}) (2004-2005)

Herbicide rate Količina herbicida (HR)	Plant arrangement – Raspored biljaka (PA)			Mean Prosek
	70x25 cm	50x35 cm	35x50 cm	
Full rate – Preporučena količina	127.9*	91.9*	83.4*	101.3*
Half rate Polovina preporučene količine	297.2*	324.7*	233.1*	285.0*
Without herbicide Bez herbicida	5147.7	5213.6	4052.1*	4804.5
Mean – Prosek	1857.6	1876.7	1456.2	$LSD_{0.05}$ HR = 413.3
	$LSD_{0.05}$ interaction PA x HR = 698.8			
	$LSD_{0.05}$ PA = 527.0			

* Significant difference at 0.05 level
* Značajna razlika na nivou 0.05

EFFECTS OF CROP DENSITY ON MAIZE GRAIN YIELD

The highest maize yield in modern maize growing practices can be achieved only if crop density is appropriate, i.e. when optimum shape and size of the vegetative space is provided to each plant. Under such conditions maize can be competitive against weeds, reducing as a result weed biomass and increasing yield (Simić, 2004), (Table 6). The coefficient of multiple determination shows that weed biomass was lower under higher maize density, and therefore maize grain yield was higher. This dependence was significant in each of the four years of investigation.

Increasing maize density from 4 to 7 and 10 plants m^{-2} resulted in a maize grain yield increase (Tollenaar et al., 1994) (Table 7).

According to results reported by Teasdale (1998) on effects of population size and inter-row distance on the yield of maize and velvetleaf, maize cultivation at higher densities significantly reduced or even caused absence of seed production in weed plants. Maize density that was 1.5- or 2-fold higher than the initial one (89.5-96.5 thousand or 120.4-127.7 thousand plants ha^{-1}, respectively) led to a reduction in velvetleaf seed production by 69-94% and even 99%, respectively, in the variant with velvetleaf emerging at the same time as maize. Furthermore, maize density that was 1.5-fold higher than the initial one resulted in a total absence of seed production of velvetleaf when weed emergence coincided with the 5-leaf or later stage of maize development. Nevertheless, the author found maize cultivation at densities as high as 120.4-127.7 thousands ha^{-1} unacceptable as the yield decreased and many plants lodged. However, the density that was 1.5-fold higher than the initial one is fully justifiable as it ensures optimum yield provided that water supply is adequate. At the same time, this density lowers seed production of velvetleaf to a rate sufficient to make the application of economic thresholds quite reasonable. Based on the results of economic threshold investigations, a herbicide rate can be lowered in certatin years (Teasdale, 1998).

As far as our domestic conditions are concerned, maize cultivation at densities of approximately 90000 plants ha^{-1} are thought to be efficient not only in reducing weed coverage, but also in achieving higher grain yields (Stanojević et al., 2000a, 2000b; Simić, 2004; Simić et al., 2004; Stefanović et al., 2005) (Table 8).

Table 6. Coefficients of multiple determination of maize grain yield depending on crop density (plants ha^{-1}) (Simić, 2004)
Tabela 6. Vrednosti koeficijenata višestruke determinacije za prinos zrna kukuruza u zavisnosti od gustine useva (biljaka ha^{-1}) (Simić, 2004)

Crop density Gustina useva	Year – Godina			
	1996	1997	1998	1999
40816	$R^2 = 0.7315$**	$R^2 = 0.7293$**	$R^2 = 0.6642$**	$R^2 = 0.6996$**
68696	$R^2 = 0.7013$**	$R^2 = 0.5835$**	$R^2 = 0.7004$**	$R^2 = 0.5762$**
98522	$R^2 = 0.7004$**	$R^2 = 0.6033$**	$R^2 = 0.3069$	$R^2 = 0.3651$

** $P<0.01$

Table 7. Effect of weed pressure and maize plant density on grain yield of maize (3-yr means, 1990 to 1992, Tollenaar et al., 1994)
Tabela 7. Uticaj korova i gustine useva na prinos zrna kukuruza (prosek 1990-1992, Tollenaar et al., 1994)

Maize plant density Gustina kukuruza	Grain yield (by weed pressure: WP) Prinos zrna (zavisno od nivoa zakorovljenosti)			
	Weed free Bez korova	Medium WP Srednje zakorovljeno	High WP Jako zakorovljeno	Mean – Prosek
No. m^{-2}	------------------ t ha^{-1} ----------------------			
4	6.72	6.33	4.98	6.01 a
7	8.16	7.82	6.74	7.57 b
10	8.19	8.10	7.11	7.80 c
Mean – Prosek	7.69 b	7.42 b	6.27 a	

Within columns or rows, means followed by a different letter are significantly different at $P<0.05$
Vrednosti sredina označene različitim slovima u okviru kolona i redova se značajno razlikuju na nivou 0.05

Table 8. Effects of crop density (plants ha^{-1}) on maize grain yield (t ha^{-1}) (Simić, 2004)
Tabela 8. Uticaj gustine useva (biljaka ha^{-1}) na prinos zrna kukuruza (t ha^{-1}) (Simić, 2004)

Crop density Gustina useva	Year – Godina				Mean – Prosek (1996-1999)
	1996	1997	1998	1999	
40816	10.48 b	10.44 b	8.99 c	10.22 b	10.03 b
68696	12.06 a	12.73 a	12.19 a	12.07 a	12.26 a
98522	12.64 a	12.47 a	10.82 b	12.46 a	12.10 a
	$LSD_{0.01}$ = 584.6	$LSD_{0.01}$ = 297.6	$LSD_{0.01}$ = 1281.0	$LSD_{0.01}$ = 710.3	$LSD_{0.01}$ = 392.5

Values of means followed by the same letter are not significantly different ($P = 0.01$) according to the LSD test
Vrednosti sredina označene istim slovima unutar godine ne razlikuju se značajno ($P = 0.01$) prema LSD testu

EFFECTS OF SOWING PATTERN ON MAIZE GRAIN YIELD

Row spacing narrower than the standard 76 cm for most planters has improved maize performance. Yield was increased when maize was grown in 50-cm instead of 75-cm rows in Canada (Murphy et al., 1996) or in 25 to 51 cm instead of 76 cm rows in Minnesota (Porter et al., 1997). Bullock et al. (1998) showed that a crop growth rate was higher early in the season when maize was grown in an equidistant pattern in 38 cm rows than when grown in a rectangular pattern in 76 cm rows. Teasdale (1995) found that the leaf canopy of maize grown in 38 cm rows closed one week earlier than maize grown in 76 cm rows.

Potential increases in maize grain yields have led many producers to consider using narrow maize rows. Narrow row spacing is also thought to play a role in reducing weed interference through enhanced light interception by the crop. However, there is little information on how narrow row spacing and cultivation fit into the integrated weed and crop management strategy.

Weed suppression is only one potential benefit of a narrow-row maize production. Several field studies have suggested a slight to moderate yield advantage when growing maize in narrow rows (<76 cm) compared with wide rows (>76 cm) (Bullock et al., 1988; Murphy et al., 1996; Porter et al., 1997). Porter et al. (1997) investigated the relationship between row spacing, plant density and hybrid on maize grain yield. They observed that maize grain yield increased by 7.2% in 25 and 51 cm row spacing compared with 76 cm row spacing when averaged over plant densities and hybrids. The primary reason for an increase in potential yields by decreasing row spacing or providing a more equidistant planting arrangement is decreased competition between maize plants for light, water, and nutrients (Sprague and Dudley, 1988; Olson and Sander, 1988). Fulton (1970) found that narrow-row spacing improved maize yield relative to wide-row spacing only when soil moisture and plant densities were high. Based on the results of nine experiments, Colville (cit. Sprague and Dudley, 1988) in 1966 reported a grain yield increase of 16% when the same number of maize

Table 9. Effect of maize plant arrangements and herbicide application on maize grain yield (t ha^{-1})
Tabela 9. Uticaj rasporeda biljaka i primene herbicida na prinos zrna kukuruza (t ha^{-1})

Herbicide rate Količina herbicida (HR)	Plant arrangement – Raspored biljaka (PA)			Mean – Prosek
	70x25 cm	50x35 cm	35x50 cm	
Full rate Preporučena količina	12.9	12.2	13.6	12.9*
Half rate Polovina preporučene količine	12.8	12.2	14.0	13.0*
Without herbicide Bez herbicida	8.7	8.0	9.6	8.8
Mean – Prosek	11.5	10.8	12.4*	$LSD_{0.05}$ HR = 0.7
	$LSD_{0.05}$ PA = 0.8			

* Significant difference at 0.05 level
* Značajna razlika na nivou 0.05

plants per ha were grown at 51 cm distance in comparison with the distance of 102 cm and irrigation conditions. Conversely, Ottman and Welch (1989) found no advantage in narrowing row spacing from 76 to 38 cm, not even when plots were irrigated and plant densities were high. However, Westgate et al. (1997) looked at the radiation use efficiency of maize sown in narrow-rows with high plant density and concluded that the narrow row spacing had less of an impact on grain yield than increased plant density. Considerable differences reported by various investigators regarding different sowing patterns are usually due to vastly different growing conditions, yield potential, and interactions with other management factors (Sprague and Dudley, 1988).

The study performed at Zemun Polje during 2004 and 2005 shows that both row spacing and spatial arrangement of maize plants had a significant influence on maize grain yield (Table 9).

Further research of crop growth and development and weed management is needed, particularly of crop interference with weeds (Jordon, 1993; Elmore, 1996). Crops interfere with weed growth, and vice versa (Jordon, 1993). An IWM programme should attempt to exploit effectively the competitive ability of crops to suppress weed growth. The IWM system must enhance the competitive ability of crops and at the same time provide adequate weed control.

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Uticaj gustine kukuruza i načina setve na suzbijanje korova i prinos zrna kukuruza

REZIME

Prema programu integralnog sistema kontrole korova, treba težiti efikasnom iskorišćavanju kompeticijske sposobnosti useva u onemogućavanju porasta korova. Gustina kukuruza koja se postiže pravovremenom setvom optimalnog broja biljaka za date uslove staništa, vrstu i hibrid, direktno utiče na formiranje dobre pokrovnosti useva, a samim tim I na povećanje njegove konkurentske sposobnosti u odnosu na korove. Prema našim rezultatima gajenje kukuruza u povećanoj gustini je dovelo do značajnog smanjenja ukupne biomase korova tokom sve četiri godine istraživanja.

Gajenjem useva sa ujednačenim rasporedom i u većoj gustini postiže se bolje iskorišćavanje svetlosti, vode i hranljivih materija i povećava njegova kompetitivna sposobnost. Prema rezultatima istraživanja sprovedenih u Zemun Polju najmanja sveža masa korova je utvrđena u varijanti sa najmanjim međurednim razmakom (35x50 cm).

Pored delovanja na smanjenje zakorovljenosti, gajenje kukuruza u povećanim gustinama i sa pravilnijim rasporedom biljaka (smanjeni međuredni razmak) uglavnom doprinosi i ostvarenju većih prinosa zrna.

Ključne reči: Populacija kukuruza; gustina; način setve; supresija korova; prinos zrna