EFFECT OF PLANT DENSITY AND ROW SPACING ON MAIZE (*ZEA MAYS* L.) GRAIN YIELD IN DIFFERENT CROP YEAR

Eszter MURÁNYI

Institute of Crop Science, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen H-4032 Debrecen Böszörményi u. 138. E-mail: emuranyi@agr.unideb.hu

Abstract: Nowadays the aim of crop production is to realize the highest possible yield per production area unit by the highest possible crop safety. One of the possible ways for this is to increase of plant density or to decrease row spacing. Therefore, the plant number per unit area can be increased and the potential yield loss of individual plants is compensated by the higher plant density.

The development of yield amounts of eight different genotypes was investigated in a small-plot field experiment with four replications on a calcareous chernozem soil type at the Látókép Research Site of the University of Debrecen in the crop years 2013 and 2014. Row distances of 45 and 76 cm, just as plant densities of 50 000, 70 000 and 90 000 plants per ha were set.

Significant differences were found between the yield amounts of the studied hybrids in both studied crop years, while the effect of plant density on yield amount showed different results. In the crop year of 2013 the hybrids resulted high yields in the treatment with a row distance of 45 cm and plant density of 90 000 plants per ha, however, in 2014 significant yield decrease was found in comparison with the previous year, that can be attributed to the weather conditions in the months April-May and June.

Optimal plant densities of hybrids, just as the corresponding expectable yield amounts were determined with quadratic equations. Optimal plant densities of the hybrids were different in the two studied crop years: in 2013, regarding the treatments set with the row distance of 45 cm, increasing plant densities resulted in higher yields, while in 2014, the yield showed decreasing tendency parallel to the increasing plant densities, that is confirmed by the fact that plant densities of 50 000 and 65 000 plants ha^{-1} proved to be more favourable. Regarding the treatments with a row distance of 76 cm, hybrids obtained their yield maximums by 80 327 plants ha^{-1} in 2013, while in the vegetation of 2014, by higher plant density (85 845 plants ha^{-1}).

Keywords: maize, grain yield, plant density, row spacing

Introduction

According to Pepó and Sárvári (2013), maize is a plant with individual productivity; therefore plant density determines yield significantly. Optimal plant density can be affected by the genetic properties and vegetation time of the given hybrid, just as by the conditions of the production area, by the crop year and the extent of water and nutrient supply. Sárvári et al. (2002) found that different hybrids endure production using higher plant densities in different extent. Plant density is a production factor that affects yield to the greatest extent. Parallel to the increasing plant density the individual production of plants decreases but the yield per unit area increases, however to a certain limit.

Roekel and Coulter (2011) determined a close relationship between maize yield and plant density. The studied hybrid produced maximal yield by a plant densities of 81 700 plants ha^{-1} or even higher. On the basis of their research work Berzsenyi and Lap (2005) have found that optimal plant density varied between 67 483 and 70 161 plants ha^{-1} regarding the average of the involved hybrids.

Nagy (1983) concluded based on his research results that the plant density of 60 000 plants ha^{-1}, which was considered to be optimal, could be effectively increased up to 80 000 plants ha^{-1}, in case row distance would be reduced from 70 cm to 50 cm. According to Shapiro and Wortmann (2006) a yield increment of 4% could be produced by decreasing the row distance from 76 cm to 51 cm. Widdicombe and Thelen (2002) stated that yield increased by 2-4% as the result of decreasing row spacing from 76 cm to 56 and 38 cm. According to the conclusions of Andrade et al. (2002), Lutz

DOI: 10.18380/SZIE.COLUM.2015.1.57.

Table 1. The values of monthly precipitation (mm) and temperature (°C) in maize growing season and in the previous period (Debrecen, 2013. 2014.)

Debrecen: Precipitation and mean air-temperature (61-90: 30-year means 1961-1990)									
Year	**Jan.-March.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**April-Sept.**	
			Precipitation (mm)					Total	
2013	228	48	69	31	16	32	48	243	
2014	77	40	69	8	128	45	96	385	
61-90	**101**	**42**	**59**	**80**	**66**	**61**	**38**	**345**	
			Mean air-temperature (°C)						Mean
2013	1.4	12.0	16.6	19.6	21.2	21.5	14.0		17.5
2014	4.8	12.3	15.4	19.0	21.2	19.8	16.7		17.4
61-90	**0.9**	**10.7**	**15.8**	**18.7**	**20.3**	**19.6**	**15.8**		**16.8**

et al. (1971), the decrease of row spacing resulted in yield increment as well. Fanadzo et al. (2010) found that the application of 45 cm row distance resulted in 11% higher grain yield than in case of the setting of 90 cm rows. Increasing plant density from 40 000 to 60 000 plants ha^{-1} resulted in 30% higher grain yield. In the study of Giesbrecht (1969) row spacing (50, 65, 80 and 90 cm) did not affect grain yield. Varieties showed significant differences in their yield response to increased plant densities.

In their research work Hunter et al. (1970) found that the yield of all studied hybrids increased parallel to each increasing plant density setting and showed low but significant increments when narrowing the row spacing. Gozübenli et al. (2004), just as Lashkari et al. (2011) found that plant density has significant effect on yield.

Yield showed increasing tendency up to a plant density of 90 000 plants ha^{-1} (10 973 kg ha^{-1}), but by any higher density it decreased. Hoshang (2012) also found that there were significant differences between the yields of different plant populations which increased with increasing plant density. In his work Mohseni et al. (2013) confirmed that the increase of plant density from 60 000 plants ha^{-1} (9.09 t ha^{-1}) to 80 000 plants ha^{-1} (11.14 t ha^{-1}) resulted in a yield increment as well.

Materials and methods

The small-plot field experiment was set up with four replications at the Látókép Research Site of the University of Debrecen in the crop years of 2013 and 2014 on a calcareous chernozem experimental soil type which is characterized by good nutrient management due to its favourable nitrogen supply, phosphate mobilization and potassium supply capacity. Water management of the experimental soil is considered to be very good, since all soil layers show excellent water permeability and water storing capacity. Pre-crop was winter wheat in both years; PK fertilization was not performed on the experimental area, while N was applied in an amount of 180 kg ha^{-1}.

In this present research work the effect of different row spacing (45 and 76 cm) and plant densities (50 000, 70 000, just as 90 000 plants ha^{-1}) on yield amounts was studied. Hybrids of the very early (FAO 240-299), early (FAO 300-399) and medium (FAO 400-499) maturity groups were involved in the experiment. The studied hybrids were: Sarolta (FAO 290), DKC 4025 (FAO 330), NK Lucius (FAO 330), PR 37N01 (FAO 380), DKC 4490 (FAO 380), P 9494 (390), Kenéz (FAO 410) and SY Afinity (FAO 470). Weather conditions of the two studied crop years (Table 1.) were different. The amount of precipitation that fell before the vegetation period in 2013 was 332.7

DOI: 10.18380/SZIE.COLUM.2015.1.57.

mm. In contrast in the crop year of 2014 only 167.1 mm precipitation fell between October and April. In the vegetation period of maize the amount of fallen precipitation was 242.9 mm in 2013, while in 2014 it was 385.4 mm. The high amount of precipitation in March (136.3 mm) proved to be determining in 2013 regarding the water supply, which filled the water stock of the soil. In 2014, the amount of precipitation in the vegetation period (396.7 mm) did not differ significantly from the long-term average value (378.6 mm), but its distribution was not appropriate. The greatest water deficit was observed in June (7.9 mm).

For the statistical evaluation of the experimental results, software SPSS 13.0 for Windows and Microsoft Excel 2010 were used. The statistical evaluation, the three-factorial variance analysis and correlation analysis were calculated according to the methods described by Sváb (1981) and using regression equations. During the correlation analysis following types of correlations were determined corresponding to the r values: r<0.4: loose, 0.4-0.7: medium, 0.7-0.9: tight, >0.9: strong.

Results and discussion

In the crop years of 2013 and 2014 the effect of the application of different plant densities and row spacing on grain yield amount was studied in case of 8 hybrids of different genotypes and variant vegetation period lengths.

In the crop year of 2013 yield amounts varied between 12.7 and 14.6 t ha^{-1} in case of a row spacing of 45 cm, while in case of that of 76 cm between 13.0 and 13.9 t ha^{-1}. The highest yields were measured in case of a plant density of 90 000 plants ha^{-1} in the average of the hybrids in case of both row distances (Table 2.). The studied hybrids obtained their yield maximums by plant densities of 70 000 and 90 000plants ha^{-1}. There were significant differences between the yields of the involved hybrids.

The difference between the yield amounts corresponding to the two different row distances was not significant (200 kg ha^{-1}). The increase of plant density resulted in significant differences in the yield in the case of both row spacings. The yield increased parallel to the increasing density of the plant population.

The increase of the plant density resulted in relatively higher yield increment by the application of narrow row spacing (45 cm) compared to the common row spacing (76 cm). In the case of the row spacing of 45 cm, increasing the basic plant density (50 000 plants ha^{-1}) to 70 000 plants ha^{-1} resulted in the highest yield increment: 9.09% (1 283 kg ha$_{-1}$). However, increasing the plant density by further 20 000 plants ha^{-1} (90 000) did not result in any expressed yield increment: 3.80% (615 kg ha^{-1}).The highest yields were measured in case of the hybrid P 9494 regarding all plant densities. Evaluating the studied hybrids it can be stated that the hybrids DKC 4025 and NK Lucius reached their yield maximums by a plant density of 70 000 plants ha^{-1}, while all the others by 90 000 plants ha^{-1}.

In the case of the row spacing of 76 cm, the increase of plant density from 50 000 to 70 000 plants ha^{-1} resulted in a yield increment of 4.12% (581 kg ha^{-1}), while the extent of this increment was 2.46% (353 kg ha^{-1}) when plant density was increased from 70 000 to 90 000 plants ha^{-1}. In case of the plant density of 70 000 plants ha^{-1} highest yield amounts were measured for the hybrids Sarolta and P 9494, while the other hybrids produced maximal yield by plant density of 90 000 plants ha^{-1}.

As a summary it can be concluded that the highest yield increment was produced by increasing plant density from 50 000 to 70 000 plants ha^{-1} in the case of both applied row spacings.Regarding the average of the hybrids, they showed yield decrement when row spacing was decreased (76 to 45 cm) by 50 000 plants ha^{-1}: -2.54% (-323 kg ha^{-1}), however, in case of plant densities of 70 and 90 000 plant ha^{-1} yield increment was observed parallel to

DOI: 10.18380/SZIE.COLUM.2015.1.57.

the decrease of row spacing: 2.72% (380 kg ha^{-1}) and 4.4% (642 kg ha^{-1}), respectively.

Hybrids of different genotypes showed different responses to the changes in the plant density and row spacing. Most of the hybrids showed to produce a yield increment parallel to the increase of the plant density, while in case of the row spacing of 45 cm, hybrids DKC 4025 and NK Lucius, while in case of that of 76 cm hybrids Sarolta and P 9494 responded to the increase of the plant density by 20 000 plants ha^{-1} by yield decrement.

Regarding the average of the involved hybrids yield amounts varied between 10.6 and 11.6 t ha^{-1} in case of the row spacing of 45 cm, while in case of that of 76 cm between 11.6 and 14.1 t ha^{-1} in the average of the hybrids in the crop year of 2014 (Table 2.). The difference between the yields corresponding to the two different row spacings was 14.6% (1800 kg ha^{-1}). In 2014 the application of different row spacings, plant densities and hybrids resulted in significant differences in the yield amounts. In case of the row spacing of 76 cm, significant difference was measured between the yields by plant densities of 50 000 and 70 000 plants ha^{-1}, and similarly in case of both studied row spacings between the yields of the treatments with plant densities of 50 000 and 90 000 plants ha^{-1}. The studied hybrids produced maximum yields by plant densities of 50 000 and 70 000 plants ha^{-1} in the case of the row spacing of 45 cm; while by that of 76 cm, by plant densities of 70 000 and 90 000 plants ha^{-1}. There were significant differences between the yields of the involved hybrids in this crop year as well. The hybrids Sarolta,

Table 2. Impact of row spacing, plant density and hybrid on grain yield of maize

Látókép Exp. Farm: Impact of row spacing (the factor A: 45 and 76 cm), plant density (the factor B: PD in thousand plants ha^{-1}) and genotype (the factor C: hybrids H1-H8) on grain yield of maize

H*	The 2013 growing season								The 2014 growing season							
	Row spacing 45 cm				Row spacing 76 cm				Row spacing 45 cm				Row spacing 76 cm			
	PD				PD				PD				PD			
	50	70	90	x	50	70	90	x	50	70	90	x	50	70	90	x
	Grain yield of maize (t ha^{-1})								Grain yield of maize (t ha^{-1})							
H1	10.8	12.6	12.9	**12.1**	11.9	12.0	11.8	**11.9**	10.3	10.1	9.6	**10.0**	9.6	11.0	12.1	**10.9**
H2	11.9	12.3	11.6	**12.0**	11.9	12.6	13.7	**12.8**	11.8	11.5	10.4	**11.2**	11.0	13.1	13.9	**12.7**
H3	12.1	14.0	13.7	**13.3**	13.4	12.9	13.8	**13.4**	10.8	11.2	10.4	**10.8**	11.1	13.3	14.0	**12.8**
H4	13.3	16.1	17.1	**15.5**	13.8	15.4	16.3	**15.2**	11.9	13.1	13.2	**12.7**	12.6	13.8	16.3	**14.2**
H5	11.7	12.2	12.9	**12.3**	11.9	12.8	13.2	**12.6**	11.3	10.7	9.8	**10.6**	11.3	12.7	13.8	**12.6**
H6	16.7	17.5	17.7	**17.3**	15.1	15.6	14.3	**15.0**	12.4	12.5	12.1	**12.3**	14.3	15.0	14.0	**14.4**
H7	11.3	12.4	13.9	**12.5**	11.4	11.9	12.4	**11.9**	9.8	10.1	10.2	**10.0**	10.2	11.3	13.1	**11.5**
H8	13.6	14.6	16.9	**15.0**	14.7	15.4	15.9	**15.3**	12.5	13.3	9.3	**11.7**	13.2	15.1	15.3	**14.5**
x	**12.7**	**14.0**	**14.6**	**13.7**	**13.0**	**13.6**	**13.9**	**13.5**	**11.3**	**11.6**	**10.6**	**11.2**	**11.6**	**13.2**	**14.1**	**13.0**
	LSD (5% probability level)								LSD (5% probability level)							
	A	B	C	AB		ABC			A	B	C	AB		ABC		
	0.50	0.35	0.51	0.49		1.25			0.85	0.46	0.44	0.65		1.09		

Correlation coefficients		
Grain yield : row spacing	2013 = -0.058;	2014 = 0.448 (**)
Grain yield : plant density	2013 = -0.287 (**);	2014 = 0.184 (*)
	Significance at 0.05 (*) and 0.01 (**) levels	

***H1**: Sarolta; **H2**: DKC 4025; **H3**: NK Lucius; **H4**: PR 37N01; **H5**: DKC 4490; **H6**: P 9494; **H7**: Kenéz; **H8**: SY Afinity

 DOI: 10.18380/SZIE.COLUM.2015.1.57.

DKC 4025 and DKC 4490 responded to the increase of the plant density from 50 000 to 70 000 plants ha^{-1} with yield decrement; while every studied hybrid responded to the increase of the plant density from 70 000 to 90 000 plants ha^{-1} with yield decrease.

In the crop year of 2014 in case of the row spacing of 45 cm yield amount showed decreasing tendency due to the increase of the plant density; while in case of the row spacing of 76 cm the studied hybrids produced the highest yield amounts by the plant density of 90 000 plants ha^{-1}, similarly to the previous crop year.

In case of row spacing of 45 cm the population with a plant density of 70 000 plants ha^{-1} produced higher yield amount 1.71% (229 kg ha^{-1}) compared to that of 50 000 plants ha^{-1}. However, yield decrement (-9.62%, -932 kg ha^{-1}) was observed when plant density was increased from 70 000 to 90 000 plants ha^{-1}. The most balanced yield was produced by the hybrid P 9494. The genotypes Sarolta, DKC 4025 and DKC 4490 showed yield decrement response to the increase of the plant density.

Regarding the row spacing of 76 cm all hybrids but one reached their yield maximums by the plant density of 90 000 plants ha^{-1}. High yield increment was resulted by the increase of plant density: 6.51-11.56% (917-1508 kg ha^{-1}).

Regarding the average of the hybrids increasing yield decrease tendency was observed as the response to the decrease of the row spacing (from 76 to 45 cm) and the increase of plant density ((-2.76)-(-32.39%), (-313) - (-3 442) kg ha^{-1}).

Comparing the two studied crop years, it can be concluded that while hybrids produced high yield amounts by the row spacing of 45 cm even by the plant density of 90 000 plants ha^{-1} in 2013, significant yield decrease was observed in 2014 compared to the previous crop year due to the weather conditions in April-May and June. As a result of the different weather conditions in the two studied crop years the yield amount increased by the application of a narrow row spacing (45 cm) of higher plant density in 2013; while in 2014 the studied hybrids responded with yield decrement to the inappropriate distribution of precipitation.

Difference in the yield amounts between the crop years 2013 and 2014 in an extent of 2.6 t ha^{-1} was measured by a row spacing of 45 cm, while this extent was 0.6 t ha^{-1} by that of 76 cm. The application of narrow row spacing, the unfavourable distribution of precipitation that did not match the demand of the studied hybrids and the increase of the plant density can be evaluated as stress factors in 2014. In contrast, the application of increasing plant densities by the common row distance resulted in yield increment in both studied crop years.

Beside the increase of the plant density, the optimal plant density that is the most favourable for the applied hybrid under the given conditions shall be determined as well. The optimal plant density was determined corresponding to the maximal yield amounts with regression equations in the range between 50 000 and 90 000 plants ha^{-1} (Table 3.).

Optimal plant density of the hybrids and the corresponding expected yield can be determined with quadratic equations. Optimal plant densities of the hybrids were different in the two studied crop years: in case of the row spacing of 45 cm the increase of plant density resulted in higher yields in 2013, while in 2014 yield amount decreased parallel to the increasing plant density, thus plant densities of 50 000 and 65 000 plants ha^{-1} were considered as more favourable. In case of the row spacing of 76 cm hybrids produced maximal yields by a density of 80 327 plants ha^{-1} in 2013, while in the crop year of 2014 by higher plant density (85 845 plants ha^{-1}).

Hybrids that can be produced in a wide or a narrow plant density range can be classified. According to the results of the present research work it can be stated that the hybrids PR 37N01, P 9494 and SY Afinity could be produced in wide, while Kenéz and Sarolta

DOI: 10.18380/SZIE.COLUM.2015.1.57.

Table 3. Optimal densities and maximal yields of maize grain of eight hybrids grown in two different row spacing during two growing seasons

Látókép Exp. Farm: Optimal plant density (OPD: plants number ha^{-1}) and maximal yields (t ha^{-1}) of maize grain									
Maize hybrid									
	OPD	**Yield**	**OPD**	**Yield**	**OPD**	**Yield**	**OPD**	**Yield**	
H1	**Sarolta**	82,225	12.8	61,875	11.8	51,833	10.3	89,500	12.4
H2	**DKC 4025**	67,214	12.3	90,000	13.9	50,727	11.7	89,353	13.6
H3	**NK Lucius**	76,712	13.9	65,875	13.0	66,500	11.2	86,575	13.7
H4	**PR 37N01**	90,000	17.0	90,000	16.1	84,308	13.5	90,000	15.9
H5	**DKC 4490**	90,000	12.6	90,000	13.5	50,500	11.2	89,500	14.0
H6	**P 9494**	84,938	17.6	64,870	15.6	64,250	12.5	67,833	14.9
H7	**Kenéz**	90,000	14.2	90,000	12.4	87,000	10.3	90,000	13.0
H8	**SY Afinity**	90,000	16.5	90,000	16.3	63,653	13.7	84,000	15.5
Average		**83,886**	**14.6**	**80,327**	**14.1**	**64,846**	**11.8**	**85,845**	**14,1**

in a rather narrow plant density range in case of both studied years and both row spacings. Negative correlation was found between the yield amount and the row spacing in 2013, while in 2014, medium positive correlation proved to be determining (Table 2.). Loose correlation was found between yield and the plant density in both studied crop years.

Conclusions

Significant differences were found between the yield amounts of the hybrids in the studied crop years, while plant density showed different effects on yield amounts In the crop year of 2013 hybrids produced high yield amounts even by the row spacing of 45 cm and by plant density of 90 000 plants ha^{-1}, however significant yield decrease was observed in 2014 compared to the previous year and the application of lower plant density proved to be more favourable.

Optimal plant density of the hybrids was different in the studied two crop years: in case of the row spacing of 45 cm, increasing the plant density resulted in higher yields in 2013, while in 2014 the yield amounts showed decreasing tendency due to the increase of plant density; thus plant densities of 50 000 and 65 000 plants ha^{-1} were considered as more favourable. In case of the row spacing of 76 cm hybrids produced maximal yield amounts by a density of 80 327 plants ha^{-1} in 2013, while in the crop year of 2014 by higher plant density (85 845 plants ha^{-1}).

There was negative correlation (-0.058) between the yield amount and the row distance in 2013, while in 2014, medium positive correlation (0.448 (**)) was the determinant. Loose correlation (0.184 (*), 0.287 (**)) was observed between the yield and the plant number in both years.

The yield determined by quadratic equations regarding the average of the hybrids in case of the row spacing of 45 cm was 14.6 t ha^{-1} in 2013, while in case of that of 76 cm it was 14.1 t ha^{-1} as well, while in 2014 in case of the row spacing of 45 cm yield amount of 11.8 t ha^{-1} was calculated. Considering the present results, it can be concluded that high yield safety can be achieved in case of the application of high plant densities (90 000 plants ha^{-1}) by the application of common row distance in crop years with different precipitation supply and distribution. If the distribution of precipitation of the given year is extreme, outstanding yield results cannot be produced even by the application of more closed plant population or in case of a soil type with excellent properties.

DOI: 10.18380/SZIE.COLUM.2015.1.57.

References

Andrade H. F., Calvino P., Cirilo A., Barbieri P. (2002): Yield responses to narrow rows depend on increased radiation interception. 94. (5.) 975-980. DOI: http://dx.doi.org/10.2134/agronj2002.0975

Berzsenyi, Z., Lap, D. Q. (2005): Responses of maize (Zea mays L.) hybrids to sowing date, N fertiliser and plant density in different years. Acta Agronomica Hungarica. 53. (2.) 119-131. DOI: http://dx.doi.org/10.1556/aagr.53.2005.2.1

Fanadzo M., Chiduza C., Mnkeni P. N. S. (2010): Effect of inter-row spacing and plant population on weed dynamics and maize (Zea mays L.) yield at Zanyokwe irrigation scheme, Eastern Cape, South Africa. African Journal of Agricultural Research. 5. (7) 518-523.

Giesbrecht J. (1969): Effect of population and row spacing on the performance of four corn (Zea mays L.) hybrids. Agronomy Journal. 61. (3.) 439-441. DOI: http://dx.doi.org/10.2134/agronj1969.00021962006100030031x

Gozubenli H., Klinic M., Sener O., Konuskan O. (2004): Effects of single and twin row planting on yield and yield components in maize. Asian Journal of Plant Sciences. 3. (2.) 203-206. DOI: http://dx.doi.org/10.3923/ajps.2004.203.206

Hoshang R. (2012): Effect of plant density and nitrogen rates on morphological characteristic grain maize. Journal of Basic and Applied Scientific Research. 2. (5) 4680-4683)

Hunter R. B., Kannenberg L. W., Gamble E. E. (1970): Performance of five hybrids in varying plant populations and row widths. Agronomy Journal. 62. (2.) 255-256. DOI: http://dx.doi.org/10.2134/agronj1970.00021962006200020023x

Lashkari M., Madani H., Ardakani R. M., Golzardi F., Zargari K. (2011): Effect of plant density on yield and yield components of different corn (Zea mays L.) hybrids. American-Eurasian Journal of Agricultural & Environmental Science. 10. (3.) 450-457.

Lutz A. J., Camper M. H., Jones D. G. (1971): Row spacing and population effects on corn yields. 63. (1.) 12-14. DOI: http://dx.doi.org/10.2134/agronj1971.00021962006300010005x

Mohseni M., Sadarov M., Haddadi H. M. (2013): Study of tillage, plant pattern and plant densities on kernel yield and its component of maize in Iran. International Journal of Agriculture and Crop Sciences. 5. (15.) 1682 -1686.

Nagy M. (1983): A tenyészterület alak, sűríthetőség, levélterület-index és a terméseredmények alakulása különböző kukorica hibrideknél. Debreceni Agrártudományi Egyetem Tudományos Közleményei. 23. 259-274.

Pepó P., Sárvári M. (2013): Agrotechnikai változások. Magyar Mezőgazdaság. 24-31.

Roekel, R. J., Coulter, A. J. (2011): Agronomic responses of corn to planting date and plant density. Agronomy Journal. 103. (5.) 1414-1422. DOI: http://dx.doi.org/10.2134/agronj2011.0071

Sárvári M., Futó Z., Zsoldos M. (2002): A vetésidő és a tőszám hatása a kukorica termésére. 51. (3.) 291-307.

Shapiro A. Ch., Wortmann S. Ch. (2006): Corn response to nitrogen rate, row spacing, and plant density in Eastern Nebraska. Agronomy Journal. 98. (3.) 529-535. DOI: http://dx.doi.org/10.2134/agronj2005.0137

Sváb J. (1981): Biometriai módszerek a kutatásban. Mezőgazdasági Kiadó. 171-179. DOI: http://dx.doi.org/10.1002/bimj.19700120410

Widdicombe D. W., Thelen D. K. (2002): Row width and plant density effects on corn grain production in the Northern Corn Belt. 94. (5.) 1020-1023. DOI: http://dx.doi.org/10.2134/agronj2002.1020