COMPLEX EVALUATION OF YIELD LEAF AREA INDEX AND RELATIVE CHLOROPHYLL CONTENT DEVELOPMENT OF MAIZE HYBRIDS OF DIFFERENT GENOTYPES

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Abstract

The small-plot field experiment was set up at the Látókép Field Research Centre of the University of Debrecen, Centre for Agricultural Sciences on a calcareous chernozem soil type. In this experiment the development of yield, leaf area index and relative chlorophyll content of three maize hybrids of different genotypes, namely Sarolta (FAO 290), NK Lucius (FAO 330) and SY Afinity (FAO 470) were studied. Two row spacings (45 and 76 cm) and three plant densities (50, 70 and 90 thousand plants per hectare) were set.

*Assimilation area of maize hybrids has determining role in yield production; positive correlation can be determined between them. As a result of the application of different row spacings and plant densities yield amount depended on the given crop year. Parallel to the increasing plant density leaf area index increased as well, while relative chlorophyll content decreased. In order to evaluate the studied factors in a complex way, Péter Pepó has introduced the Ph.C. or P-index value that determines the photosynthetic capacity. Strong correlation was found between yield and Ph. C. value in all studied crop years (0.781-0.881**). Photosynthetic capacity values varied between 649 and 1198 in 2013, between 401 and 920 in 2014 while between 206 and 362 in 2015.*

Key words: maize, row spacing, plant density, LAI, SPAD-value, Ph.C.

INTRODUCTION

Differences in the production area of hybrids result in changing microenvironment of plants and increasing competition for ecological factors (light, water and nutrients) Berzsenyi and Lap (2005). Plant density is a production factor that has the most expressed effect on leaf area index and thus on light reception of maize populations Berzsenyi and Lap (2006). Maize photosynthetic capacity is determined by the size of leaf area on the one hand and on the other hand by the chlorophyll content of leaves. Maximal LAI values can be measured in the flowering phase. In case of a plant density of 80,000 plants ha^{-1} – which could be considered as close to the optimal – LAI_{max} values varied between 4.40 and 5.34 m^2 m^{-2}. Plant density has a significant effect on vegetative Tetio-Kagho and Gardner (1988 a) and reproductive Tetio-Kagho and Gardner (1988 b) development of maize. Maize grain yield shows correlation with leaf area genetically Johnson (1973). According to Menyhért et al. (1980) agrotechnical parameters, that limit the size of the assimilation area, just as its efficiency and thus the yield amount of the given hybrid basically, shall be determined for each variety. Several research studies have confirmed that the chlorophyll content of maize husk is decreased if plant density is increased (Jiang et al. 2010, Su et al. 2012). Cai et al. (2010) have revealed significant correlation between SPAD values and yield amount, while they did not find any difference in the SPAD values of the studied hybrids.

MATERIAL AND METHOD

The small-plot field experiment was set up at the Látókép Field Research Centre of the University of Debrecen, Centre for Agricultural Sciences in split-split-plot design with four replications. The experimental soil type is calcareous chernozem. Three maize hybrids with different genotypes were involved in the experiment, namely Sarolta (FAO 290), NK Lucius (FAO 330) and SY Afinity (FAO 470). In the present research work the effect on row spacing (45 and 76 cm) and plant density (50, 70 and 90 thousand plants ha^{-1}) were studied on the development of yield amount, leaf area index and relative chlorophyll content. Grain moisture content and harvested grain yield amount were measured at harvest and grain yield amount with moisture content of 14% was calculated using these data. Leaf area index (LAI) and relative chlorophyll content (SPAD value) were continuously monitored during the vegetation period. LAI (m^2 m^{-2}) was measured with a portable Sun Scan Canopy Analysis Systems (SS1) leaf area measurement device. SPAD values were determined with a SPAD-502 Plus, Konica Minolta chlorophyll measurement instrument. Relative chlorophyll content is defined by this device as a number without dimension ranging from 0 to 100.

The studied crop years showed different weather conditions. Amount of precipitation and average temperature data before and during the vegetation periods are shown in Table 1. The amount of precipitation during the period before the vegetation of the crop year of 2012-2013 was significantly higher than the long-term average. This is resulted by the high amount of precipitation in March (136.3 mm) that filled the water stock of the chernozem soil. Regarding the vegetation, an amount of precipitation less than the long-term average fell in June and July. Regarding the crop year of 2013-2014 the amount of precipitation before vegetation was low (167.1 mm) while in June – which can be considered as a critical month from the aspect of maize development – fell only 7.9 mm precipitation (that was 71.6 mm less than the long-term average value). Regarding the whole vegetation period it can be stated that the distribution of precipitation was unfavourable. In the crop year of 2014-2015 the lack of precipitation and its unfavourable distribution were associated with high temperature values. Registered temperature values were higher than the long-term average values in every crop year. Temperature values of the vegetation period of 2015 showed extreme deviances from the 30-years average values.

Table 1.

Amount of precipitation (mm) and monthly average temperature (°C) data before and during maize vegetation

Year	2012-2013.	2013-2014.	2014-2015.	30-years average (1961-1990)
Precipitation (mm)				
Before maize vegetation (October-March)	332.7	167.1	215.6	220.2
During maize vegetation (April-September)	242.9	385.4	303.8	345.1
Total	**575.6**	**552.5**	**519.4**	**565.3**
Monthly average temperature (^{O}C)				
Before maize vegetation (October-March)	3.6	6.4	4.8	2.9
During maize vegetation (April-September)	17.5	17.4	18.3	16.8
Average	**10.5**	**11.9**	**11.5**	**9.8**

Statistical evaluation of result data was executed by three-way ANOVA and Pearson correlation analysis using the software SPSS 13.0 for Windows. The analysed three factors were row spacing (A), plant density (B) and hybrid (C). According to Sváb (1981) the strength of relationships was defined as follows: if r-value was <0.4 weak, if it was between 0.4 and 0.7 medium and in case of an r-value of >0.9 strong correlations were determined.

RESULTS AND DISSCUSIONS

The development of yield, leaf area index and relative chlorophyll content of three maize hybrids with different genotypes were studied in a small-plot field experiment when applying different row spacings and plant densities.

In the crop year of 2013 yield amount showed increasing tendency parallel to the increasing plant density; the highest yield amount was measured in case of the highest plant density (90,000 plants ha^{-1}) regarding the average of the hybrids. Depending on the hybrid and plant density yield amount varied between 10.8 and 16.9 t ha^{-1} in case of a row spacing of 45 cm, and between 11.8 and 15.9 t ha^{-1} in case of a row spacing of 76 cm. The average of the two row spacings was the same. Yield was significantly determined by plant density, just as by the given hybrid.

In contrast to the previous crop year yield amount showed decreasing tendency parallel to the increasing plant density when applying a row spacing of 45 cm in 2014. The highest yield was measured in case of the population with a density of 50,000 plants ha^{-1} (11.2 t ha^{-1}). In case of the row spacing of 76 cm the highest yield amount (13.8 t ha^{-1}) was measured by a density of 90,000 plants ha^{-1}, just like in the previous year. All studied factors resulted in a significant difference in the yield amount.

Hybrids produced lower yield in the crop year of 2015 than in the previous years. Heat days were more frequent during the vegetation and low amount of precipitation fell with unfavourable distribution. Yield amounts varied between 6.9 and 10.5 t ha^{-1} in case of the application of a row spacing of 45 cm, while in case of that of 76 cm between 7.3 and 10.8 t ha^{-1}. The highest yield amount was produced in case of both row spacings by the application of a plant density of 70,000 plants ha^{-1}.

Parallel to the increasing plant density leaf area index showed increasing, while relative chlorophyll content showed decreasing tendency. LAI and SPAD values of the studied hybrids showed maximal values during the phenological phases of male and female flowering, just as during grain filling (between the 1st and 25th July). Leaf area index was affected by all studied factors. Relative chlorophyll content was influenced by plant density in 2013, while by none of the studied factors in 2014 and significant differences were resulted by plant density and hybrid in 2015. Depending on the hybrid, row spacing, plant density and the given crop year maximum value of leaf area index varied between 2.4 and 5.3 m^2 m^{-2} and that of relative chlorophyll content between 55.9 and 66.5.

For the expression of the differences between experimental treatments and crop years the photosynthetic capacity index (Ph. C. = P-index) elaborated by Dr Péter Pepó was used. The index can be calculated according to the following formula:

$$\text{Ph. C.} = \frac{\text{Yield}}{\text{LAI}_{max}} \times \frac{\text{Yield}}{\text{SPAD}_{max}} / 1000$$

Development of Ph. C. values depending on row spacing, plant density and crop year is shown of Figures 1, 2 and 3. The combined effect of yield amount, leaf area index and relative chlorophyll content values can be revealed in Ph. C. values. Due to the different weather conditions of the different crop years yield results showed different trends. Ph. C. showed the highest values in all studied crop years and in case of all studied hybrids by the application of a row spacing of 76 cm: in the crop year of 2013 it ranged between 649 and 1198, in 2014 between 401 and 920, while in the crop year of 2015 between 206 and 362. In case of the row spacing of 45 cm and regarding the average of the hybrids the highest photosynthetic capacity value was measured in the treatment with a plant density of 70,000 plants ha^{-1}, while in case of the row spacing of 76 cm in the crop years of 2013 and 2015 the highest value was found by the plant density of 50,000 plants ha^{-1} and in 2014 by that of 70,000 plants ha^{-1}. Considering the LAI and SPAD values beside the yield amount maximal photosynthetic capacity values were found in different treatments than maximal yield amounts.

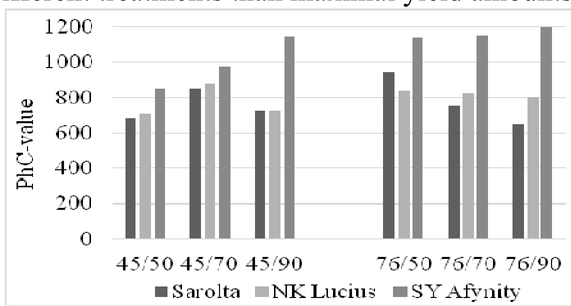
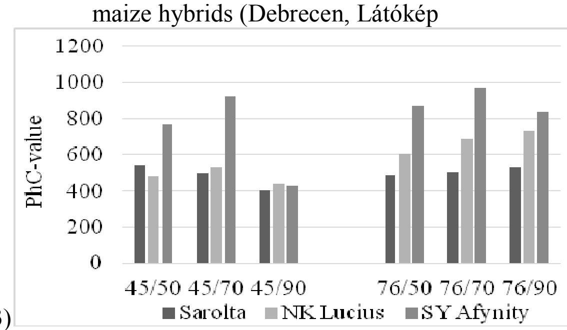
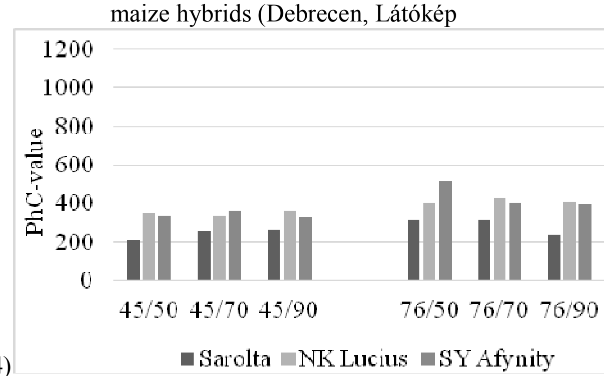


Fig. 1. The effect of row spacing and plant density on the photosynthetic capacity of maize hybrids (Debrecen, Látókép



2013)

Fig. 2. The effect of row spacing and plant density on the photosynthetic capacity of maize hybrids (Debrecen, Látókép



2014)

Fig. 3. The effect of row spacing and plant density on the photosynthetic capacity of maize hybrids (Debrecen, Látókép 2015)

Table 2 shows the results of the Pearson correlation analysis. Strong correlation was found between yield amount and Ph. C. value in each crop year (0.781-0.881**). Weak, or medium positive correlation was found between yield and leaf area index (0.307-0.437**).

Table 2.

Correlation analysis between leaf area index, relative chlorophyll content and yield of maize hybrids (Debrecen, Látókép 2013, 2014, 2015)

	Yield 2013	Yield 2014	Yield 2015
LAI_{max}	0,437 (**)	0,319 (**)	0,307 (**)
$SPAD_{max}$	-0,164	0,067	0,180
PhC	0,781 (**)	0,881 (**)	0,854 (**)

CONCLUSIONS

In the present research work the development of yield amount, leaf area index and relative chlorophyll content was studied using a combined index. The effect of crop year and the studied experimental factors can be revealed and analysed using the Ph. C. value. Maximal LAI and SPAD values of hybrids were measured at the flowering stage. Photosynthetic capacity values varied between 649 and 1198 in 2013, between 401 and 920 in 2014 while between 206 and 362 in 2015. Strong correlation was found between yield and Ph. C. value in all studied crop years (0.781-0.881**). Weak, medium positive correlation was found between yield and leaf area index (0.307-0.437**).

REFERENCES

1. Berzsenyi Z. – Lap, D. Q.: 2005. Kukorica (Zea mays L.) hibridek vetésidő- N-műtrágya és növényszám reakciója eltérő évjáratokban. [In: Nagy J. (szerk.) Kukorica hibridek adaptációs képessége és termésbiztonsága] 74-90.
2. Berzsenyi Z. – Lap, D. Q.: 2006. A növényszám hatásának vizsgálata különböző tenyészidejű kukorica (Zea mays L.) hibridek vegetatív és reproduktív szerveinek növekedésére Richards-függvénnyel. Növénytermelés. 55. 3-4: 255-275.
3. Cai, H. G. – Mi, G. H. – Chen, F. J. – Zhang, X. Z. – Gao, Q.: 2010. Genotypic variation of leaf SPAD value, nitrogen and nitrate content in maize. Acta Metallurgica Sinica. 16. 4: 866-873.
4. Jiang, L. L. – Han, X. R. – Yang, J. F. – Liu, X. H. – Gao, X. N. – Ma, B.: 2010. Effects of fertilization on photosynthetic physiological characteristic in maize of high yield variety with different planting density. Journal of Shenyang Agricultural University. 41. 3: 265-269.
5. Johnson, G. R.: 1974. Analysis of the genetic relationships between several yield components maize and leaf area at specific leaf positions. Crop Science. 14. 4: 559-561.
6. Menyhért Z. – Ángyán J. – Radics L.: 1980. A levélfelület-index (LAI), a fényviszonyok és a termés kapcsolata eltérő vetésidejű és tenyészterületű kukorica állományokban. Növénytermelés. 29. 4: 357-367.
7. Su, Y J. – Qin, Y. T. – Zhang, S. L. – Qin, G. W. – Xu, G. J. – Lu, R. Q. – Mei, Z. J.: 2012. Effects of planting density on growth and yield of summer maize Xundan 28. Acta Agriculture Jiangxi. 24. 6: 49-53.
8. Sváb J. (1981) Biometriai módszerek a kutatásban. Mezőgazdasági Kiadó. 171-179.
9. Tetio-Kagho, F. – Gardner, F. P.: 1988. (a) Responses of maize to plant population density. I. Canopy development, light relationships, and vegetative growth. Agronomy Journal. 80. 6: 930-935.
10. Tetio-Kagho, F. – Gardner, F. P.: 1988. (b) Responses of maize to plant population density. II. Reproductive development, yield, and yield adjustments. Agronomy Journal. 80. 6: 935-940.