PHOTOSYNTHESIS OF MAIZE (ZEA MAYS L.) REGARDING TO NUTRIENT SUPPLY

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Abstract

The photosynthesis of maize is influenced by different ecological and agrotechnical factors. We measured the photosynthesis parameters of maize hybrids in 1999-2008 in small parcel field experiments on nutrient supply. The soil of the experimental area is calciferous chernozem soil with favourable water regime.

In the examined ten years the water supply fluctuated from the favourable conditions (1999, 2004, 2008) to the extreme dry (2002, 2003). After data processing we found that there were significant differences on P=0.1% level in the net photosynthesis, between the nutrient levels in every year.

The photosynthetic gas exchange parameters of maize are remarkably improved by nutrient supply in well watered conditions when maximum photosynthetic activity was detected at $N_{120}P_{75}K_{90}$ kg ha^{-1} and $N_{200}P_{125}K_{150}$ kg ha^{-1} doses. The water stress through decreased stomatal conductance has significant negative effect on the assimilation parameters. In dry years the maximum photosynthetic activity we measured at $N_{40}P_{25}K_{30}$ kg ha^{-1} and $N_{120}P_{75}K_{90}$ kg ha^{-1}. The highest photosynthetic intensity was detected on second and third date, at pollination and grain filling. It decreased in the vegetation period and at the last measurement gradually by every maize hybrid. There were significant differences between fertilizer level and net photosynthetic activity in the vegetation period at 0.1 % error level. We found significant differences between T_{leaf}-T_{air} and net photosynthesis. The anabolic condition of maize is can be highly standed upon the difference of leaves and air temperature.

Key words: maize, nutrient supply, photosynthesis.

INTRODUCTION

Researchers studied the influencing factors of the photosynthesis system of the crops from different aspects. The aim of our work is to add some information about the assimilation of maize. We examined the photosynthesis of maize in field trial at different nutrient supply in ten years.

Bindraban (1999) found that the photosynthesis of wheat depends mainly on the light intensity and the effect of nitrogen supply is low. Vidal et al. (1996) estimated, that in consequence of the tripling the light intensity, the photosynthesis intensity was doubled. Csajbók et al. (2007) comparing the photosynthesis of maize, winter wheat, potato and their weeds proved that C_4 plants' CO_2 fixation is long sight better at raised light intensity.

Shangguan et al. (2000), Futó (2003) and Kutasy-Csajbók (2009) agreed that the nitrogen and water supply have great effect on the photosynthetic gas exchange. The higher nitrogen supply lowered the water use efficiency of the plants and the net photosynthetic rate decreased. Under

N stress decreased the size of the green assimilation area (Vári, 2013) and the photosynthesis was reduced by a decreased light absorption and by the decreased utilization of assimilates (de Groot et al., 2003) too. Schmitt-Edwards (1981) data indicate that C_4 species maize had greater nitrogen use efficiency than either the two C_3 species examined.

The effect of nitrogen nutrition on photosynthetic characteristics was not identical under different water status (Csajbók-Kutasy, 2012). The incidence of droughty years is increasing, so it is essential to examine the production of plants under water deficit. Fernandez et al. (1996) monitoring physiological parameters (leaf water potential, leaf conductance and net photosynthesis rate) showed that water relationships of maize were not affected by the reduced N fertilization. Water deficit caused decreased water uptake and inhibited photosynthesis at winter wheat and barley (Johnson et al., 1974). Boyer-Westgate (2004) found that in maize the water deficits inhibit photosynthesis. Hirasawa and Hsiao (1999) measured the leaf photosynthetic rate of maize grown in arid summer environment. On days of high atmospheric vapour pressure deficit, leaf photosynthesis reached a maximum in the late morning and then decreased gradually as the day progressed, though the soil was well irrigated. Kang et al. (2000) established, that stomatal resistance and leaf photosynthesis of water-stressed maize rapidly recovered to the control level three days after rewatering if regulated water deficit was applied at the seedling stage.

Edwards et al. (2012) and Shangguan et al. (2000) defined, that the water use efficiency of plants increased in drought, primarily because stomatal conductance, and thus water loss declined more than carbon fixation. Ben-Asher et al. (2008) found that the high temperature reduced net photosynthesis and increased the transpiration and as a result, decayed the water use efficiency.

MATERIAL AND METHOD

The trials were carried out in Látókép at the research site of the University of Debrecen in 1999-2008 in small plot experiments on nutrient supply in the field. The soil of the experimental area is calciferous chernozem. The pH of the soil is neutral, nitrogen, phosphorus and potassium content are medium and the water regime of the soil is favourable. The water table is at 8-10 meters depth, and the soil can store high quantities of water (808 mm/0-200 cm) originated from precipitation. The unavailable water content is 295 mm in the 0-200 cm layer. The amount of disponible water in saturated state is 513 mm in the 0-200 cm layer of which 342 mm is readily available.

We detected the photosynthesis parameters of different maize hybrids.

Fertilizer levels were: $N_0P_0K_0$, $N_{40}P_{25}K_{30}$, $N_{120}P_{75}K_{90}$, $N_{200}P_{125}K_{150}$.

Assimilation parameters were measured in the field by the LICOR LI-6400 portable photosynthesis system. It has two infrared gas analyzers to measure CO_2 and H_2O mole fraction in air. We measured net photosynthesis rate, stomatal conductance, intercellular CO_2 level, transpiration and air and leaf temperature at leaves adjusted to light, six times per leaf, in four repetitions.

Light changes will cause immediate photosynthetic rate changes therefore the light was controlled (2000 µmol m^{-2} s^{-1} PAR), with 90 % red (630 nm) and 10 % blue (470 nm) light. in the sample chamber. There is a contact thermometer in the leaf chamber to measure leaf temperature.

We measured the first leaf above the cob on two plants per block, six times per leaf, in four repetitions at four hybrids from different maturity groups. The photosynthesis was measured four times in the growing season of the maize, from the middle of June to the end of August.

Data were processed with SPSS 13.0 statistical software, we used Multivariate General Linear Model (GLM) and LSD test.

RESULTS AND DISCUSSION

In the examined ten years the maize had significantly different water supply. The water supply fluctuated from the favourable conditions (1999, 2004, 2008) to the extreme dry (2002, 2003).

After data processing we found that there were significant differences on P=0.1% level in the net photosynthesis, between the nutrient levels in every year. Figure 1 shows the effect of nutrient supply in average of maize hybrids. The data measured in the $N_0P_0K_0$ blocks are significantly lower than those in the other levels in most of the years, except the extremely dry 2003 year. In the first measurement the increasing nutrient doses caused higher photosynthetic activity. Later in the growing season results of the $N_{40}P_{25}K_{30}$ treatment are the best, better than $N_{120}P_{75}K_{90}$ and $N_{200}P_{125}K_{150}$ levels. In the average of ten years it is detectable, that the net photosynthesis was higher at $N_{120}P_{75}K_{90}$ nutrient supply, but the $N_{40}P_{25}K_{30}$ level was favourable too (Fig. 2). Without fertilizer, the measured photosynthesis was lower.

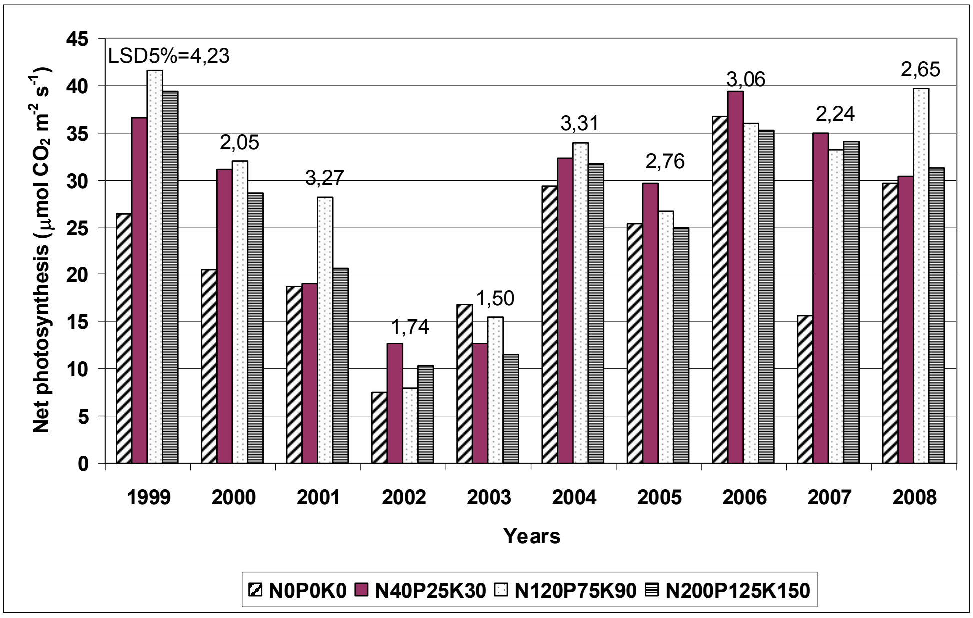

Fig. 1. Net photosynthesis of maize hybrids at pollination on different nutrient levels (1999-2008)

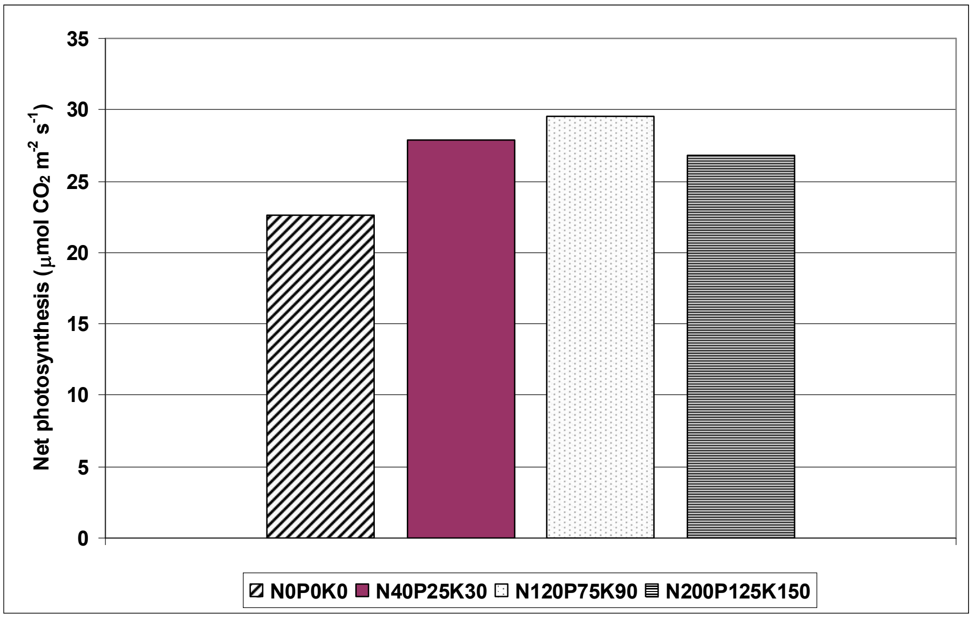

Fig. 2. Net photosynthesis of maize at average of ten years

Based on the results of the Pearson correlation analysis we found significant and close negative correlation between the difference of leaf and air temperature and the net photosynthesis (Table 1). The value of correlation coefficient varied from -0.434 to -0.895.

Table 1

The Pearson correlations (2 tailed) between the difference of the leaf and air temperature and the assimilation parameters (1999-2008)

		Tleaf – Tair (°C)									
	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Net photosynhesis (μmol m^{-2} s^{-1})	Correlation coefficient	-0.434	-0.833	-0.819	-0.835	-0.782	-0.794	-0.858	-0.800	-0.895	-0.864
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	672	996	1344	1440	1920	972	960	960	720	668
Stomatal conductance (mol m^{-2} s^{-1})	Correlation coefficient	-0.514	-0.813	-0.817	-0.855	-0.831	-0.342	-0.933	-0.926	-0.953	-0.941
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	672	996	1344	1440	1920	972	960	960	720	668
Intercellular CO_2 level (μmol mol^{-1})	Correlation coefficient	-0.167	-0.472	-0.501	-0.191	-0.754	-0.702	-0.042	0.007	-0.106	-0.671
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.348	0.868	0.102	0.000
	N	672	996	1344	1440	1920	972	960	960	720	668
Transpiration (mmol m^{-2} s^{-1})	Correlation coefficient	-0.802	-0.936	-0.957	-0.853	-0.880	-0.742	-0.938	-0.932	-0.960	-0.951
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	672	996	1344	1440	1920	972	960	960	720	668

The higher is the leaf temperature to the air temperature, the smaller is the intensity of photosynthesis. Figure 3 shows the connection between net photosynthesis and T_{leaf}-T_{air} in a favourable year (1999), while figure 4 represents an extremely dry year (2003). The difference between the air and leaf temperature pretends well the plant is able to cool its leaves by transpiration, or not. The cooling effect of transpiration was weak in 2003 (Fig. 4) the temperature of the leaves were higher than that of air in average. These data show severe water stress condition in that year. In the favourable 1999 year the cooling effect of transpiration was expressed and the net photosynthesis rate was much higher than in the drier years.

As the calculation is based upon numerous data (N=668-1920), the correlation is very reliable. The close correlation (r=-0.742 - -0.960) between the transpiration and the difference of leaf and air temperature is caused by the cooling effect of transpiration (Table 1).

The connection in the case of intercellular CO_2-level is not as obvious, because it highly depends on many factors (stomatal conductance, the quantity of CO_2 applied or rather produced by respiration).

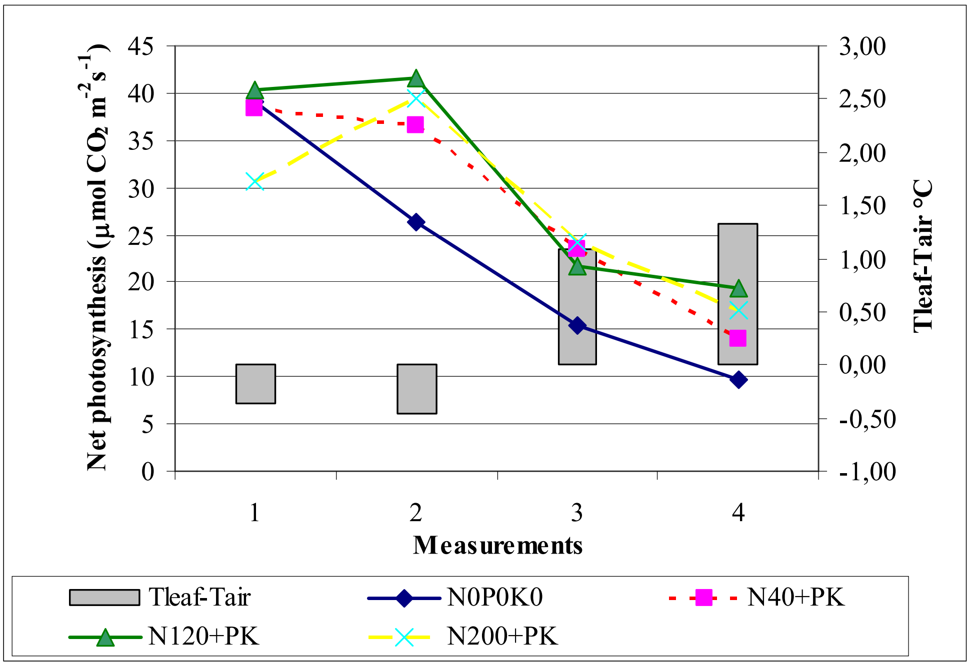

Fig. 3. Net photosynthesis and T_{leaf}-T_{air} of maize in the vegetation period at different nutrient supply in 1999

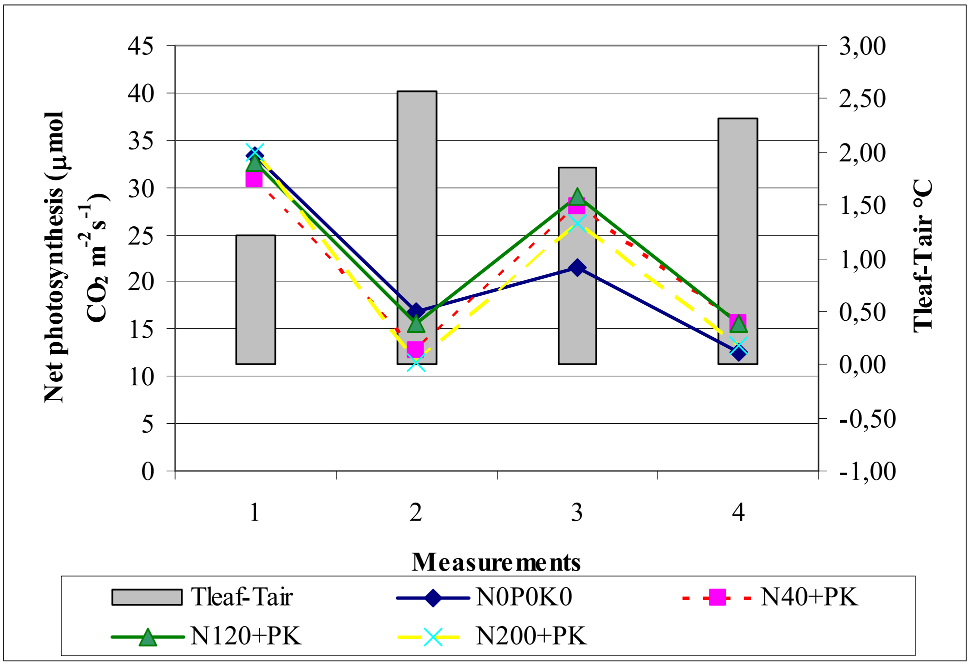

Fig. 4. Net photosynthesis and T_{leaf}-T_{air} of maize in the vegetation period at different nutrient supply in 2003

CONCLUSIONS

Summerizing the results it can be stated, that the maximum photosynthetic activity was detected at $N_{120}P_{75}K_{90}$ kg ha^{-1} and $N_{200}P_{125}K_{150}$ kg ha^{-1} nutrient doses in favourable years, while in unfavourable years the maximum was at $N_{40}P_{25}K_{30}$ kg ha^{-1} and $N_{120}P_{75}K_{90}$ kg ha^{-1}.

The photosynthetic gas exchange parameters of maize are remarkably improved by nutrient supply in well watered conditions. The water stress through decreased stomatal conductance has significant negative effect on the assimilation parameters.

The highest photosynthetic intensity we measured on second and third date, at pollination and grain filling. It decreased in the vegetation period and at the last measurement (physiological ripening) gradually by every maize hybrid. There were significant differences between fertilizer levels in net photosynthetic activity in the vegetation period at 0.1 % error level.

The anabolic condition of maize is can be highly standed upon the difference of leaves and air temperature.

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