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Correlation analysis of relative chlorophyll content and yield of maize hybrids of different genotypes

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SUMMARY

In 2021, correlation between relative chlorophyll content and yield in three maize hybrids of different genotypes was examined. The data were collected at the Látókép Experimental Station of the University of Debrecen located on the Hajdúság loess ridge in Hungary. The soil of the small plot field strip plot trial, which was set up in 2011, was calcareous chernozem. Apart from the control treatment (without fertilisation), N fertiliser is applied in the form of base and top dressing. The base fertiliser containing 60 and 120 kg ha^{-1} N of nutrient applied in spring was followed by top dressing containing +30–30 kg ha^{-1} N in V6 and V12 phenophases. SPAD values measured at different phenological stages of the growing season increased by an average of about 28% up to 10 leaf stage for all three hybrids. In the pre-silking period (Vn), the relative chlorophyll content decreased by 8% on average. After an average increase of 14% in the tasselling and silking period, SPAD decreased by an average of about 29% at full maturity (R6).

For the different fertiliser treatments, higher N doses resulted in higher yields. In the basal fertiliser treatment, the A_{60} N dose resulted in an average 34% increase in yield, and the A_{120} N dose resulted in an average 94% increase in yield compared to the control. The 60 kg ha^{-1} N basal fertiliser (A_{60}) increased in the V6 phenophase with an additional 30 kg ha^{-1} N resulted in an average yield increase of 26%. When 120 kg ha^{-1} N of basal fertiliser (A_{120}) was increased by an additional 30 kg ha^{-1} N in the V6 phenophase, only the Merida hybrid showed a significant yield increase (7%). No further yield increase was observed when $V6_{90}$ and $V6_{150}$ treatments were increased by an additional 30 kg ha^{-1} N in the V12 phenophase. The yield of the Armagnac hybrid decreased by almost 20%, the yield of Fornad by 3% and the yield of Merida by 1%.

Keywords: *chlorophyll content, maize, SPAD value, yield*

INTRODUCTION

Maize is one of the world's most important crops. Its production is growing rapidly and it plays a prominent role in human food and animal feed (Nagy, 2008). Between 1999 and 2019, its area increased from 137 million hectares to 197 million hectares and its production from 607 million tonnes to 1148 million tonnes (FAOSTAT, 2021). It is likely to maintain its leading position and role in the future (Sárvári et al., 2008)

In terms of maize production, Hungary is one of the leading countries in the European Union. Next to wheat, maize is the most widely cultivated crop in Hungary, with 1–1.2 million hectares per year (Nagy, 2018). As in the rest of the world, maize is one of the most prominent crops in Hungary, with 981,000 hectares, 24% of arable land in 2020. Most of the 8.4 million tonnes of maize produced in 2020 was used for feed, industrial use and export. Its economic importance is illustrated by the fact that, compared to an average of 3 million tonnes exported between 2016 and 2019, 4.2 million tonnes, 50% of the total production, were exported in 2020 (KSH, 2021).

Maize has a very high nutrient requirement; therefore, fertilisation is essential to ensure adequate yields. The optimum rate of fertiliser for maize depends on the nutrient requirements of the maize, the nutrient supply capacity of the soil, the amount of active ingredients applied in previous years and the nutrient utilisation capacity of the particular hybrid (Nagy, 2021). Among nutrients, nitrogen has the most significant yield enhancing effect (Ványiné Széles et al., 2012; Sárvári and Pepó, 2014). Application of different doses of nitrogen has different effects on maize yields, and in addition to yield, it also has a significant impact on the yield quantity and quality (Széles et al., 2019; Horváth et al., 2021; Széles et al., 2018). Precision nutrient supplementation can increase the nitrogen use efficiency of maize by up to 50%, resulting in higher yields with lower environmental stress (Muschietti-Piena et al., 2018).

The green colour of photosynthetic plants is provided by chlorophyll molecules (Pethő, 2002). The application of different fertiliser doses significantly affects chlorophyll content (SPAD values) at different phenological stages. SPAD values increase with increasing nitrogen application rates as the growing season progresses (Ványiné Széles et al., 2012; Horváth et al., 2019), Ványiné Széles and Nagy (2012) found a strong correlation between chlorophyll content and yield.

MATERIALS AND METHODS

Production site description

The studies were carried out at the Látókép Experimental Station of the University of Debrecen (N 47°33' E 21°27'), on a deep humus layer, medium-bedded, lowland calcareous chernozem soil. The one and a half hectare, split-split-plot, two replicate trial was set up in 2011. The trials were carried out with three maize hybrids of different genotypes (Armagnac-FAO490, Fornad-FAO420, Merida-FAO380) grown under non-irrigated conditions.

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Soil properties/condition

The soil analysis of the experimental area indicates that in terms of soil physics the area is classified as loam (K_A=43–45). The humus content is average (Hu%=2.7–2.8), the humus layer is around 80 cm thick. The pH of the upper part of the soil is close to neutral (pH_{KCl}), which helps the uptake of nutrients by plants. The phosphorus supply is medium and the potassium supply is in the medium to good range (Nagy, 2019).

The design of field experiment

In the field trial, apart from the no fertiliser (control) treatment, N fertiliser rates were applied as a base and top dressing. The spring application of 60 and 120 kg ha^{-1} N as base fertiliser was followed by two top dressings in the V6 and V12 phenophases at +30 and +30 kg ha^{-1} N. Maize was sown on 08.04.2021 and harvested on 24.09.2021. The yield was corrected to 14% moisture. The relative chlorophyll content of maize was measured in nine different phenophases (V6, V8, V10, V12, Vn, VT, R1, R3, R6) using a Konica Minolta SPAD-502.

Statistical analysis

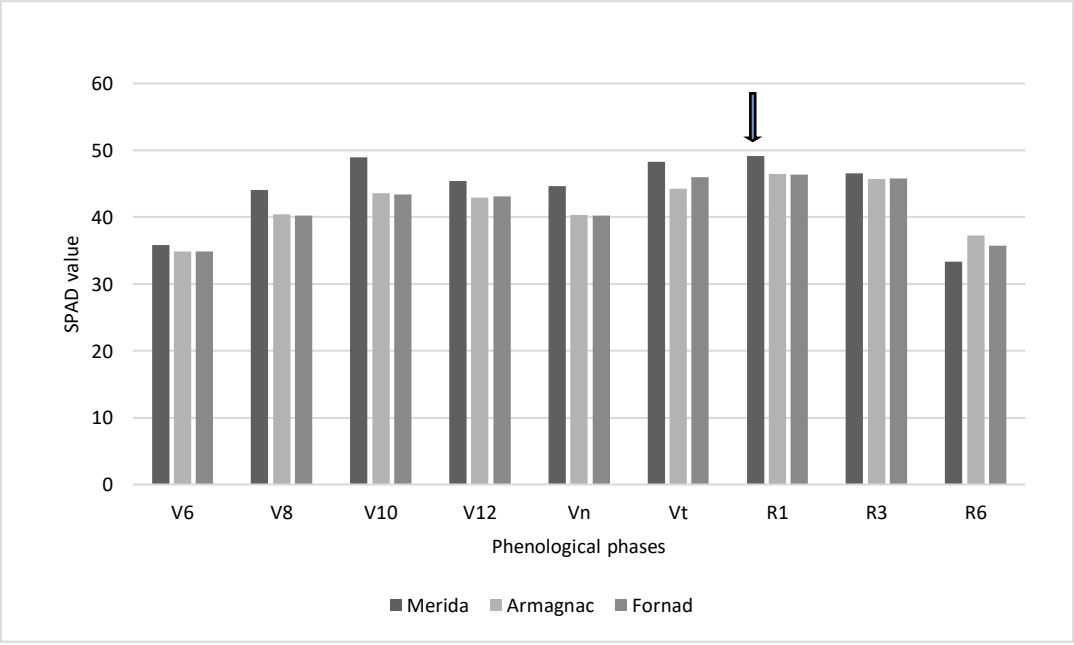
For statistical evaluation, the statistical software package SPSS for Windows 21.0 was used.

RESULTS AND DISCUSSION

Evolution of SPAD values and yield for maize hybrids with different genotypes

Based on the analyses, the Merida hybrid had the highest SPAD value (49.11), which was 5% higher than the maximum of the other two hybrids with nearly the same SPAD value (*Figure 1*). In terms of the development of SPAD values measured at different phenological stages of the growing season (*Figure 1*), it was observed that all three hybrids increased their values by an average of about 28% up to the 10 leaf stage. Relative chlorophyll content increased the most (36%) between phenophases V6 and V10 for the Merida hybrid. In the pre-flowering period (Vn), the relative chlorophyll content was on average 8% lower. Following an average increase of 14% in the tasselling and silking periods, SPAD values decreased by an average of about 29% at full maturity (R6).

Figure 1: **Development of SPAD values for hybrids with different genotypes (Látókép, 2021)**



In the study of the effects of different fertiliser treatments on yield (*Figure 2*), the results were in agreement with the findings of Ványiné Széles et al. (2012), Ványiné Széles and Nagy (2012), Sárvári and Pepó (2014) and Horváth et al. (2019), who found that higher yields were obtained by increasing the N dose. In basal fertilisation, the A_{60} N dose resulted in an average yield increase of 34% compared to the control. The highest yield increase was in the Merida hybrid (42%). The A_{120} N dose resulted in an average yield increase of 94% compared to the control. The highest yield increase was more than doubled in the Armagnac hybrid, which also showed the highest significant difference. On average, the A_{120} N dose resulted in 45% higher yields compared to the A_{60} N dose, with the highest yield increase (56%) in the Armagnac hybrid. Increasing the 60 kg ha^{-1} N basal fertilisation (A_{60}) in the V6 phenophase by an additional 30 kg ha^{-1} N resulted in an average yield increase of 26%, with the highest increase in the yield of the hybrid Armagnac (38%) and the lowest increase in the yield of the hybrid Merida (11%). Increasing the A_{120} kg ha^{-1} N basic

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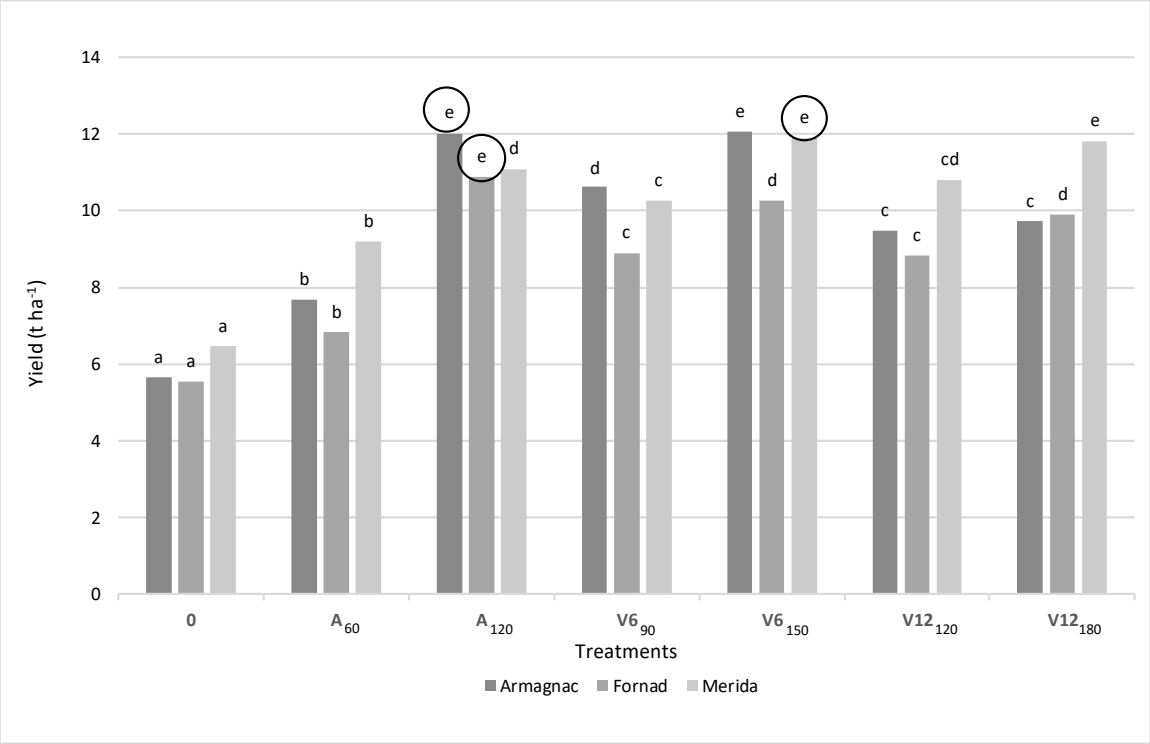
fertilisation (A_{120}) by 30 kg ha^{-1} N in the V6 phenophase only resulted in a significant yield increase (7%) for the Merida hybrid. No further yield increase was observed when $V6_{90}$ and $V6_{150}$ treatments were increased by an additional 30 kg ha^{-1} N in the V12 phenophase. The yield of the Armagnac hybrid decreased by almost 20%, that of the Fornad hybrid by 3% and the yield of Merida by 1%.

The statistically verifiable differences are confirmed in different treatments by hybrid (*Figure 2*). For the Armagnac hybrid, the highest yield (12.06 t ha^{-1}) was obtained in the $V6_{150}$ treatment, but the highest difference was already observed in the A_{120} treatment. This treatment also gave the highest significance for the hybrid Fornad. For the Merida hybrid, the highest yield ($p<0.05$) was obtained when the $V6_{150}$ kg ha^{-1} N treatment was applied.

Figure 2: **Yield as a function of maize hybrids with different genotypes and fertiliser application (Látókép, 2021)**



Note: Values indicates by different letters differ significantly from each other at probability levels $p<0.05$ based on the Duncan test

Investigating the relationship between relative chlorophyll content and yield

A correlation analysis was performed between SPAD values and yield (*Table 1*). It can be concluded that in the 6 leaf phenophase, no significant correlation between the two factors can be demonstrated for any of the hybrids. As the phenological stages progressed, a correlation of varying closeness per hybrid could be observed.

In the case of the Armagnac hybrid, the closest correlations were observed at 8 leaf stage or at the time of the milk stage. SPAD values measured during these periods had a significant effect on yield development (r=0.80).

In the case of the Merida hybrid, the closest correlation (r=0.92) between the two factors was observed at the time of the milk stage. Only in the case of the Merida hybrid a significant correlation was found at full maturity (r=0.72). For the hybrid Fornad, a weaker correlation was observed at each phenophase. The strongest correlation is at 12 leaf stage (r=0.79).

Table 1: **Correlation analysis of relative chlorophyll content and yield (Látókép, 2021)**

	V6	V8	V10	V12	Vn	See	R1	R3	R6
Armagnac	NS	**r=0.80**	r=0.74	r=0.65	r=0.57	r=0.71	r=0.75	**r=0.80**	NS
Merida	NS	r=0.76	r=0.80	r=0.71	r=0.72	r=0.65	r=0.80	**r=0.92**	**r=0.72**
Fornad	NS	r=0.72	r=0.70	**r=0.79**	r=0.44	r=0.42	r=0.68	r=0.65	NS

Note: NS-non significant

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