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Effect of different N doses on maize yield and quality

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SUMMARY

The effect of N doses on the yield and nutritional values of the Sushi (FAO 340) maize hybrid were analysed in three years (2018, 2019, and 2020). The analyses were performed at the Látókép Experimental Station of the University of Debrecen on calcareous chernozem soil, in a striped, small-plot, non-irrigated long-term field experiment. In the experiment, in addition to the non-fertilized treatment (A_0), the N-fertilizer doses were applied as basic fertilizer and top dressing. The 60 and 120 kg N ha^{-1} dose (A_{60}, A_{120}) applied as spring basic fertilizer were followed by two phases of top-dressing in V6 ($V6_{90}$, $V6_{120}$) and V12 ($V12_{150}$, $V12_{180}$) phenophases; the amounts were +30 and +30 kg N ha^{-1}.

Maize yields were affected to varying degrees by crop year. The highest yields in 2018 and 2020 were recorded in the same $V6_{150}$ treatment, while in 2019 the highest yield was obtained in the A_{120} treatment.

Increasing the N doses resulted in an increase in the protein content of the maize kernel. Depending on the fertilizer treatments and the crop year effect, the protein content of maize kernels varied between 6.2–10.2 g x 100 g^{-1}. In all three years, the protein content was the lowest in the control treatment (A_0) and the highest in the $V6_{150}$ treatment.

The starch content ranged from 70.7 to 77.9 g x 100 g^{-1} in the average of the three years. In 2020, it was significantly higher in all nutrient treatments than in the other examined two years. The highest starch content – except for 2020 (A_{120}, 77.9 g x 100 g^{-1}) – was recorded in the A_0 treatment (74.2, 72.3 g x 100 g^{-1}).

The oil content of maize kernels varied between the values of 3.8 and 5.2 g x 100 g^{-1} in the average of three years. In terms of oil content, the results for 2018 and 2019 can be considered the same, while in 2020 it was significantly lower. Fertilizer treatments did not significantly affect the oil content of maize in any of the years.

The fertilizer dose applied in the V12 phenological phase was not effective in terms of yield and nutritional content (protein, starch and oil content).

Keywords: *maize; N fertilizer; quality*

INTRODUCTION

Maize is one of the most important and most widely produced crops in the world. In Hungary, the average yield of maize in 2019 was 8 million tons ha^{-1} (Central Statistical Office – CSO, 2019). It is a versatile raw material, thus it is important to strive for achieving the proper quality in terms of the utilization of the final product. The choice of the appropriate hybrid has a crucial role, which greatly influences the yield and quality (Izsáki, 2006; Győri, 2010; Pepó, 2017). Nutrient supply is required to achieve adequate yields. It has been confirmed that fertilizer plays a decisive role in the uptake of macro- and microelements (Berzsenyi and Lap, 2003; Nagy, 2017). Adequate nutrient supply is the basis of modern crop production, without which crop safety would not be satisfactory (Pepó, 2001).

Among the elements of cultivation technology, fertilization, including N fertilization largely determines yield and quality (Nagy, 2007; Győrffy et al., 1965; Láng, 1973).

It has been shown that nitrogen fertilization can increase not only yield but also the protein content of the grain (Loch and Nosticzius, 2004; Ling et al., 2020). The protein content of maize varies on average between 7–9%, mainly determined by the genotype of the variety, but its development is greatly influenced by cultivation technology and ecological factors. According to Izsáki (2006), crop year has a greater effect on protein content than N supply. It was also pointed out that excessive N-fertilization can reduce oil content (Izsáki, 2014). The starch content of maize is 65–70%, while its oil content is between 3–5% (Pepó and Sárvári, 2011).

MATERIALS AND METHODS

Production site description

The analyses were performed in Hungary at the Látókép Experimental Station of the University of Debrecen, on loess-based, calcareous chernozem soil. The experiment is a striped, small-plot long-term field experiment. Measurements were performed with natural precipitation in 2018, 2019 and 2020 using the Sushi (FAO 340) maize hybrid.

Soil

Based on the results of soil analyses in 2012, the following can be established about the properties of the soil: its pH KCl value is 6.6, weakly acidic, which is optimal for the nutrient uptake of plants. In the upper (20 cm) layer of the soil, Arany's plasticity index is 39, the total amount of water-soluble salts is 0.04%, which is considered a low level of salt content. The carbonated lime content in the upper 80 cm of the soil is around 0% while from 100 cm 12% lime content is present, which indicates that the soil is moderately calcareous. The organic matter content is 2.3% in the upper 20 cm layer

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of the soil, which does not exceed 1.0% at a depth of 120 cm. The potassium supply of the soil is good, its P supply is medium.

Experimental details

In the field experiment, in addition to the non-fertilized treatment (control, A_0), the N-fertilizer doses were applied as basic fertilizer and top-dressing. The spring basic fertilizer doses of 60 and 120 kg N ha^{-1} (A_{60}, A_{120}) were followed by two instances of top-dressing in the V6 and V12 phenophases; their amounts were +30 and +30 kg N ha^{-1} ($V6_{90}$, $V6_{120}$, $V12_{120}$ and $V12_{150}$). The green crop was maize. Maize was sown on 23/04/2018, 10/04/2019 and 17/04/2020. The harvest took place on 27/09/2018, 09/10/2019 and 23/10/2020. Harvested grain yield was corrected for moisture content of 14%. Following the harvest, nutritional values were determined by means of a Foss-Infratec Grain Analyzer.

Climatic characterization of crop years

Weather was evaluated based on data measured by an automatic weather station located in the experimental area. The values were compared to the averages of the period 1981–2010 (I1.).

The winter semester preceding the 2018 growing season had extreme precipitation, with rainfalls of 341 mm, nearly 130 mm above the multi-year average. The average temperature of 16.0 °C in April was almost 5 °C above average and less there was less precipitation than usual. In May, there was a record high average temperature (19.7 °C) again. The monthly precipitation was close to the average, most of which fell in the middle decade of the month. June showed a positive temperature anomaly of 0.9 °C while July only 0.4 °C. July was characterized by a balanced, near-average temperature weather free of extremes. Precipitation also fell in relatively even amounts, but its volume was slightly below the multi-year average. Significant precipitation did not fall until the end of August. In the first two decades of September, the mean temperature was 2–3 °C higher than the average (Nagy et al., 2020).

April 2019 was milder and drier than the average. May was characterized by a rainy, chilly weather. The above-average (76 mm) precipitation fell in an even distribution. June was drier than average, there was only 32 mm precipitation and the mean temperature (22.8 °C) was also exceptionally high. The mean temperature in July was very low (21.1 °C). The monthly precipitation was significantly above the multi-year average, with a value of 99 mm representing a positive anomaly of 33 mm. In August, there was very few precipitation (15 mm) and the temperature was initially around average, but the end of the month was marked by a significant positive anomaly. In September, temperature (17.1 °C) was slightly above average and precipitation (35 mm) was slightly below average (Nagy et al., 2020).

In April 2020, the monthly rainfall of 16.5 mm was significantly below the multi-year average of 52.8 mm. The rainfall-free period lasted until the end of May. Temperature conditions were also favourable, with April being slightly cooler than average (monthly average temperature anomaly of -0.4 °C) and the average monthly temperature in May being 2.6 °C lower than the multi-year average monthly temperature. In June, a total of 118.5 mm of rain fell on 15 rainy days, nearly double of the multiannual monthly precipitation of 66.5 mm. The daily maximum temperatures did not exceed 25 °C, and in the middle of the month the maximum value was only around 20 °C several times. The average monthly temperature of 21.0 °C in July was 0.3 °C lower than the multi-year average, with a monthly precipitation of 148.5 mm being outstanding. In August, the 70 mm precipitation exceeded the multi-year average of 49 mm. In terms of temperature, this was the warmest period of the 2020 growing season. The monthly average temperature of 22.3 °C was nearly 2 °C higher than the multi-year monthly average of 20.8 °C. In September, the average temperature was 2 °C above the multi-year average. Most of the month was characterized by a rainless, dry period (Nagy and Nagy, 2020).

Statistical evaluation

The evaluation was performed with the SPSS for Windows 21.0 statistical software package.

RESULTS AND CONCLUSIONS

Effect of N-fertilization on yield

In the dry year of 2018, the yield of treatment without fertilization was 7.14 t ha^{-1}. Compared to the control treatment (A_0), the 44.8% yield-increasing effect ($P<0.05$) of the 60 kg N ha^{-1} basic treatment (A_{60}) could be detected (*Figure 1*). The 0.96 t ha^{-1} increase between A_{60} and A_{120} treatments was not statistically significant. Increasing the 60 kg N ha^{-1} applied as a base treatment in the V6 phenophase by an additional 30 kg N ha^{-1} ($V6_{90}$) did not result in a statistically significant yield surplus. The $V6_{150}$ treatment proved to be the most effective, the application of additional top-dressing resulted in a non-significant yield reduction.

In 2019, which can be considered as an average crop year, the yield measured when applying the basic fertilizer treatment (A_{60}) showed a 25.2% increase compared to the non-fertilized treatment ($P<0.05$). Yield increase was significant between 60 and 120 kg N ha^{-1} basic treatments ($P<0.05$). Maize did not respond to the +30 kg N ha^{-1} dose ($V6_{90}$) applied to the 60 kg N ha^{-1} base fertilizer dose in the V6 growth stage with a significant yield increase. The highest yield was obtained by the 120 kg N ha^{-1} treatment applied as a basic treatment (A_{120}), which was also statistically confirmed ($P<0.05$).

In the year 2020, which was rich in precipitation, the lowest yield was in the control treatment, similarly to the other years. The highest yield was provided by the $V6_{150}$ treatment ($P<0.05$).

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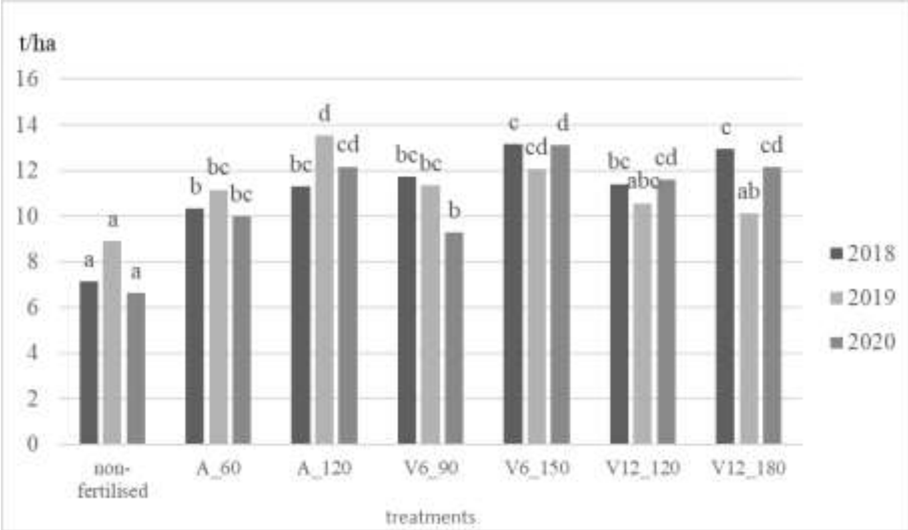
Figure 1. **Effect of N doses on the development of yield (Látókép 2018–2020)**

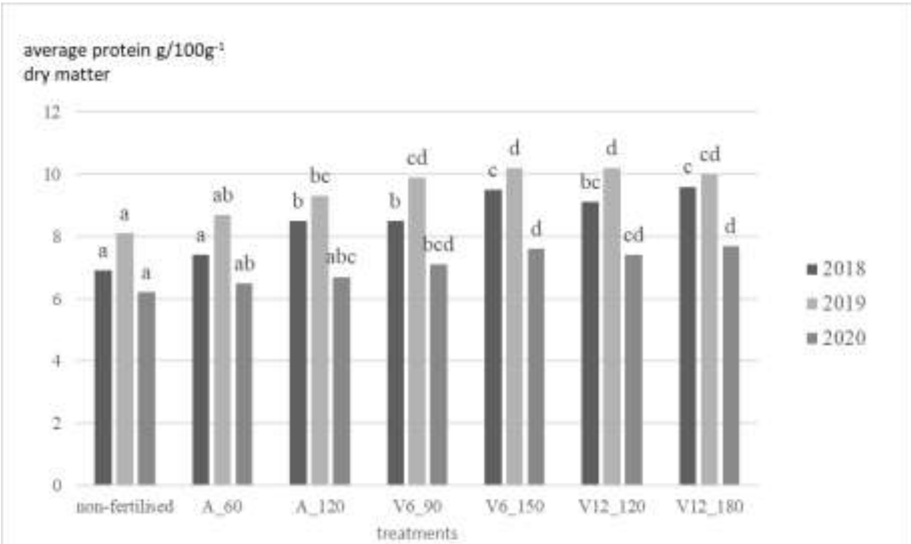


Note: Yields marked with different letters differ significantly from each other at probability levels P≤0.05 based on the Duncan test

Effect of N fertilization on the nutritional values of maize

Depending on the fertilizer treatments and the crop year effect, protein content of the Sushi hybrid varied from 6.2 to 10.2 g x 100 g^{-1}. In all three years, the control treatment had the lowest protein content (*Figure 2*). As N doses increased, the protein content of maize increased as well. In 2018 and 2020, the highest protein content (9.6 and 7.7 g x 100 g^{-1}) was provided by the $V12_{180}$ treatment. However, a statistically significant difference was already detected in the $V6_{150}$ treatment. In 2019, the $V6_{150}$ treatment also proved effective in terms of protein content.

Figure 2. **Effect of N doses on the development of protein content (Látókép 2018–2020)**



Average starch content ranged from 70.7 to 77.9 g x 100 g^{-1} over the average of three years (*Figure 3*). In 2018 and 2019, the highest starch content (74.2 and 72.3 g x 100 g^{-1}) was obtained with the A_0 treatment, which showed a decreasing trend with higher N dose. The starch content of the A_0 treatment in 2018 differed from the $V6_{150}$ and $V12_{180}$ treatments ($P<0.05$), while in 2019 there was no reliable difference between the treatments. In 2020, a much higher starch content was obtained than in previous years. The highest starch content (77.9 g x 100 g^{-1}) and at the same time the statistically significant largest significant difference was recorded in the A_{120} treatment.

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The oil content of maize kernels ranged from an average of 3.8 to 5.2 g x 100 g^{-1} over three years (*Figure 4*). 2020 had the lowest value of the analysed years. The basic and top-dressing treatments did not significantly affect the oil content in any of the studied years.

Figure 3. **Effect of N doses on the development of starch content (Látókép 2018–2020)**

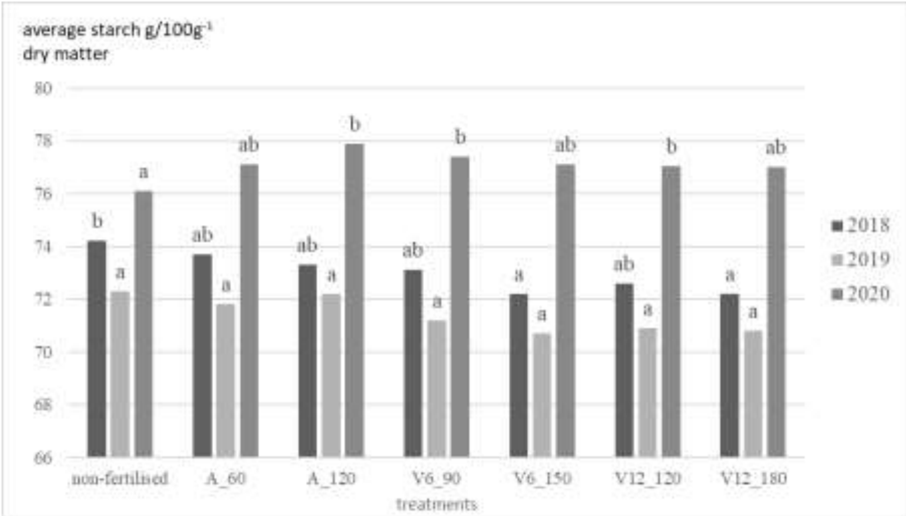
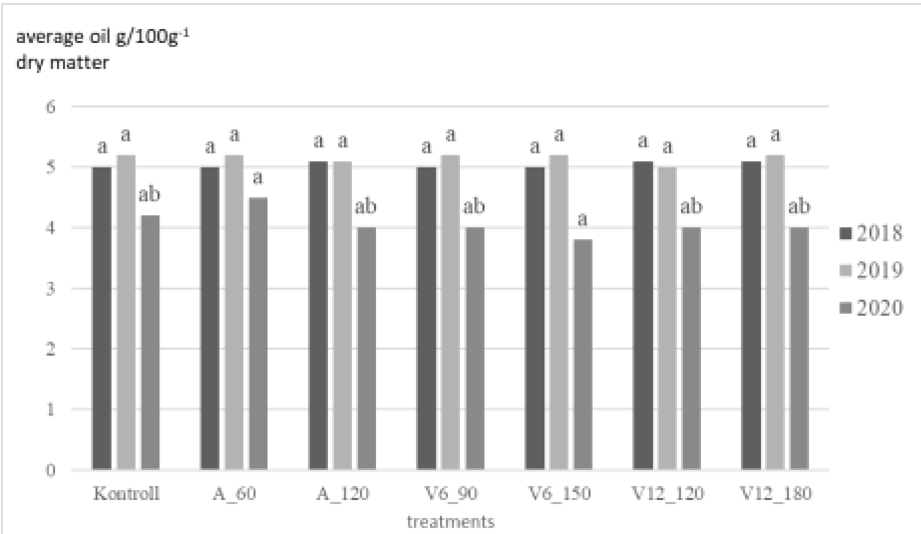


Figure 4. **Effect of N doses on the development of oil content (Látókép 2018–2020)**



Overall, similarly to the results of Loch and Nosticzius (2004), it was found that increasing N doses resulted in an increase in protein content of maize grains. In all three years, protein content was the lowest in the control treatment (A_0) and the highest in the $V6_{150}$ treatment. Starch content in 2020 was significantly higher in all nutrient treatments than in the other two years studied. The highest starch content – with the exception of 2020 (A_{120}) – was recorded in the A_0 treatment. In terms of oil content, the results for 2018 and 2019 can be considered the same, while in 2020 it was significantly lower. Fertilizer treatments did not significantly affect the oil content of maize in any of the years.

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