Review on Agriculture and Rural Development 2022 vol. 11 (1-2) ISSN 2677-0792
DOI: 10.14232/rard.2022.1-2.105-111

EVALUATION OF NDVI, SPAD VALUES AND YIELD OF TWO DIFFERENT MAIZE (*ZEA MAYS* L.) GENOTYPES UNDER FOLIAR FERTILISATION

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ABSTRACT
Ensuring global food security has become a matter of great concern with the constantly increasing population growth, resulting in rising food demands. Simultaneously, climate change and land degradation pose major risks to agricultural production. Maize is one of the most produced crops globally and maize yields must be increased to meet the population's needs. Fertilisation is considered indispensable for the crop growth and development. Foliar fertilisation, unlike root fertilisation, enables rapid access of nutrients to plants while sustaining the environment. Our research was carried out at Látókép in 2021, where, foliar sprays of Natur Plasma T biostimulant, Natur Active complex foliar fertiliser, Zinc and Sulphur Mono additives were applied at the 8-leaf stage on two maize hybrids, Mv 352 (FAO 350) and Mv Anissa (FAO 510). The main objectives were to examine the treatment's effect on crops at critical phenophases (12-leaf stage, silking, maturity), besides determining its impacts on the harvested yields. Based on our findings, foliar nutrients had positively influenced the NDVI and SPAD values of both crops. Furthermore, in comparison with the control plots, the yield of Mv Anissa was 9% higher, while that of Mv 352 was 5.4% higher. Consequently, Mv Anissa produced the highest yield of 21.345 t/ha, i.e. 2.8 tons higher than that obtained by Mv 352. Moreover, the treatment increased their thousand-grain weight.
Thereby, our study demonstrates the efficiency of the foliar fertilisation method in improving maize vegetative growth and development in addition to its productivity by enhancing its final yield.

Keywords: NDVI, SPAD, yield, maize genotypes, foliar fertiliser

INTRODUCTION

Ensuring global food security has become a matter of great concern owing to the limited availability of arable land due to the degradation phenomenon, as well as the world's growing population to an estimated 9 billion people by 2050 (GODFRAY ET AL., 2010), causing inflation in food demands by 70 % (RANDIVE ET AL., 2021). Additionally, climate change is putting further pressure on natural resources, contributing altogether to a decline in worldwide crop productivity.

Maize, one of the top three primary crops widely grown, serves as a staple food for most of the population, a source for livestock feed, raw material for industrial processing, and other alternative uses. Due to its important role in human livelihoods, maize yield must be increased to meet human needs. Improved irrigation and fertilisation management techniques have been widely implemented in order to raise agricultural outputs. According to NAGY (2003), the use of irrigation and fertilisation showed a strong correlation with crop yield. In addition, it was highlighted by NAGY (2006) that maize is sensitive to water and essential nutrient availability, especially at physiological stages, which are critical periods for healthy crop development. During these specific phases, and depending on the maize genotypes, a certain amount of heat unit is necessary to attain each phenological stage (HORVÁTH ET AL., 2021). Moreover, NAGY (2010) pointed out the importance of irrigation supply in reducing about 5 % of the adverse impacts of drought conditions. On the other hand, the foliar nutrient application is considered a sustainable method for crop production and gained major importance as it tends to avoid adverse impacts on the soil characteristics and the whole environment (EL-FOULY, 2001; KANNAN, 2010). Contrary to root fertilisation, it is sprayed directly to the leaves making the replenishment of nutrient deficiencies efficient at different specific crop growth stages. This technique has been in practice for a long time where several research studies have been applying different fertilisers to several crops for different purposes, including maize (ALI ET AL., 2016).

In order to determine the response of the crop under the treatment and evaluate the efficiency of the technique, the normalized difference vegetation index (NDVI) has frequently been used to examine the crop canopy structure and health. The leaf chlorophyll content index is another important indicator and has been used in numerous research studies all over the world for grain yield prediction and nitrogen management for various crops, using the chlorophyll meter (SPAD).

The main aims of our research were to evaluate the effects of foliar fertilizers on the crop NDVI and SPAD values at critical stages of crop development, as well as to determine their impacts on the harvested yield, of two maize genotypes.

MATERIALS AND METHODS

The examinations were performed at the Látókép Plant Production Experiment Site in 2021. The area of the experiment site is evenly distributed, classified as a calcareous chernozem type of the Hajdúság loess ridge. It is characterized by an Arany's plasticity index of 43-45, a medium humus content (2.7 %), a near-neutral pH (pH KCL=5.97), and excellent water retention.

The amount and distribution of rainfall and temperature trends play a decisive role in the initial development of maize. Compared with recent years, the cool weather in April and May 2021 did not favor the germination and initial development stages. April and May were 3.0°C and 2.1°C cooler than the long-term average. During the first two months of summer, the weather was significantly warmer than average, with relatively little precipitation. June temperatures were 2.8°C above the multi-year average. July recorded a positive anomaly of 2.6°C. The lack of rainfall led to a severe drought situation towards the end of the month. In June, a total of 10 mm of precipitation was recorded, 56 mm below the multi-year average. July also saw only a small amount of rain (30 mm). This was sufficient to allow only the top layer of soil to soak for a few days. The stress caused by the lack of water and the high temperatures affected the development of the maize plant, affecting the mass gain of the stands and the increase in height and leaf area. The drought continued, albeit to a lesser extent, in August (32 mm), with temperatures around average. The year 2021 was characterized by drought, as indicated by the 72 mm of rainfall in the three summer months at the Látókép Experiment Site. Even in September, only 19 mm of rain fell. During this month, temperatures did not deviate from the multi-year average, thus conditions were suitable for ripening and watering of the grains.

The two hybrids tested were Mv 352 (FAO 350) and Mv Anissa (FAO 510). The experiment area was 0.33 ha. For soil preparation, 135 kg N, 35 kg CaO and 25 kg MgO per hectare were applied on 7th March. Sowing was performed on the fourth of April 2021 with a number of 84 000 plants/ha. Germination occurred on 05/06 (Mv 352) and 05/09 (Mv Anissa). A drip irrigation system was installed in the stand, with which 8 mm of irrigation water was applied every two days during the growing season from 14 June to 29

August 2021, for a total of 38 applications during this period. The amount of water applied was 304 mm. Harvesting took place on 1st October. The applied foliar fertilizer was applied to the designated plots on 10.06.2021, when the stand was at the 7-8 leaf stage. Control and treated plots were separated by an untreated row.

The applied foliar fertilizers and their doses were: 2 l/ha Natur Plasma T biostimulant, 4 l/ha Natur Active complex foliar fertilizer, 1 l/ha Zinc mono additive (120 g/l), 1 l/ha Sulphur mono additive (91 g/l).

Natur Plasma T is a biostimulant containing concentrated live algae and their beneficial organic by-products, which in addition to providing nutrients for plants, have a regenerative effect. Thanks to its organic components, it is 100 % bioavailable. Its components are essential amino acids, non-essential amino acids, vitamins, and growth hormones. Nutrients include N, P, K, Ca, Mg, Fe, Cu, Zn, Co, Mo, B, S, Na, and C.

Complex foliar fertilizer (Natur Active):

Natur Active is a foliar fertilizer with a wide range of concentrated formulations, including macro, meso, and microelements necessary for plant life. 13 different nutrients are present in the solution in concentrated amounts: 150 g/l N, 1.25g/l P_2O_5, 37.5 g/l K_2O, 5 g/l MgO, 5 g/l S, 0.625 g/l CaO, 3.75 g/l Fe, 2.5 g/l Mn, 1.5 g/l Cu, 1.875 g/l Zn, 2.5 g/l B, 0.125 g/l Mo, 0.0625 g/l Co.

In this research, the relative chlorophyll content of leaves was measured with the SPAD-502 on the uppermost adult leaf before the appearance of the ear and subsequently on the leaf opposite the ear. Measurements were made at the 12-leaf stage, silking and physiological maturity in the control and treated plots. In parallel, at the same developmental stages, NDVI photosynthetic activity was measured using the GreenSeeker Handheld meter. After the harvesting period, the maize yield and thousand-grain weight were measured. For accurate determination of the crop quantitative productivity parameter, a Haldrup grain laboratory thresher was used. Moreover, we used Minitab software in order to perform the statistical analyses which include the analysis of variance (ANOVA) and the comparison of means using Fisher's least significant difference (LSD) method where the mean differences were considered significant at $P < 0.05$.

RESULTS

According to our findings, both genotypes had positively responded to the foliar nutrients at all examined plant growth stages. However, during the silking and maturity phases, the application of foliar fertilisers had a significant effect on the NDVI values for both maize genotypes. As a result of the treatment, the obtained NDVI values of the genotype Mv 352 were improved at the silking and physiological maturity stages by 8 % and 25 %, respectively, in comparison with the control plots. Similarly, in the case of the genotype Mv Anissa, the registered NDVI values increased and were 6 % higher than that of Mv 352 (14 %) at the silking stage while they were 21 % less than that of the hybrid Mv 352 at the physiological maturity stage. The increase of the recorded NDVI values indicates the positive response of maize genotypes to the foliar fertilisers which in turn reflects the prevailing crop health conditions. Since the normalized difference vegetative index consists of quantifying the state of the plant health based on how it reflects a certain range of the electromagnetic spectrum, it is one of the most valuable tools to understand and remotely assess vegetative changes in the plant.

The analysis of variance (*Table 1*) showed that at the maturity stage, the applied treatments presented significant differences and their interaction with the hybrids significantly affected the changes in the NDVI values in contrast to the difference between the hybrids, which was not significant. At the silking stage, it was statistically found that only the difference between the applied treatments was significant. However, this difference was not significant at the 12-leaf stage, instead, the hybrids presented significant differences in terms of performance. Thus, Mv 352 registered the highest NDVI value of 0.84 at the 12-leaf stage, as well as the lowest value of 0.61 at physiological maturity, both in control plots (*Figure 1. A*).

It has been shown through the analysis of variance that the SPAD values were significantly affected by the interconnection of the treatments and the hybrids rather than them being separate at the 12 leaf stage. Also, the SPAD values did not statistically show any significant difference at the silking and maturity stages. The obtained SPAD readings demonstrate the effectiveness of foliar nutrients, particularly for the Mv 352, where the trend of the SPAD values improved at the 12-leaf and silking phases by 12 % and 4 %, respectively, in comparison with the control plots. At the same time, the trend of the SPAD values obtained from the treated plots of the genotype Mv Anissa dropped at these two phenophases and only increased by 9 % (compared to the control plots) at the maturity phase. The lowest SPAD value was measured in the control plot of the Mv 352 genotype at the 12-leaf stage (43.3 SPAD), while the highest SPAD value was obtained from the control plot with the hybrid Mv Anissa at the silking stage (61.6 SPAD) (*Figure 1. B*).

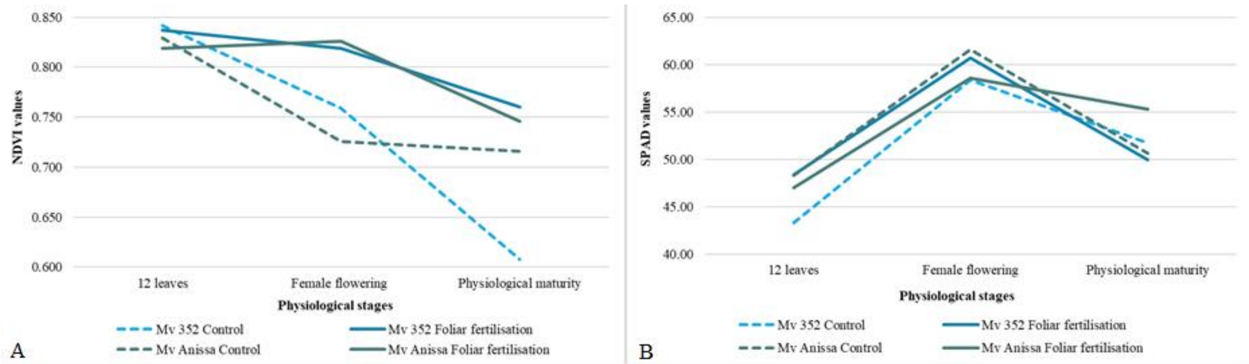

Figure 4. A. Effect of foliar fertiliser on the NDVI values of maize genotypes at different growth stages. **B**. Effect of foliar fertiliser on the SPAD values of maize genotypes at different growth stages

According to the results of analysis of variance (*Table 2*), there was a significant difference in yield among the two studied maize hybrids with the different applied treatments. Without applying foliar fertilisers, the yield of the genotype Mv 352 was 17.6 t/ha, i.e. 2 tons lower than that of Mv Anissa. Our results clearly showed that foliar feeding enhanced the yield for both studied maize genotypes. Thus, with the foliar fertiliser treatment, the yield of Mv 352 increased by 5.4 % (0.96 t/ha), whereas that of Mv Anissa was even greater and increased by almost 9 % (1.74 t/ha), compared to the control plots. The highest yield increase was obtained by Mv Anissa (21.35 t/ha), i.e. 2.8 tons higher than the yield obtained by Mv 352. Apart from the influence of foliar fertilisers, the difference in the yield growth could be related to the nature of the hybrid itself which is statistically shown, and its capacity to utilize nutrients as a reaction with fertiliser's application (*Figure 2. A*).

Based on the obtained results, the foliar fertilisation provided a higher thousand-grain weight for both maize genotypes, although its influence on the studied parameter was not significantly different from the control treatment. Hence, the thousand-grain weight of the genotype Mv 352 increased by 16 grains compared to the control. Moreover, the genotype Mv Anissa positively responded to the foliar nutrients as the thousand-grain weight in the treated plots was 20-grain weight higher than that of the control plots. Despite having a higher increase than Mv 352, this latter value was the highest thousand-grain weight (425.3 g) among both examined genotypes and for the different plots. This could be explained by the fact that there was a significant difference between the hybrids by which each hybrid reacted to the applied treatment and utilized the added nutrients differently, therefore, significantly affecting the thousand-grain weight (*Figure 2. B*).

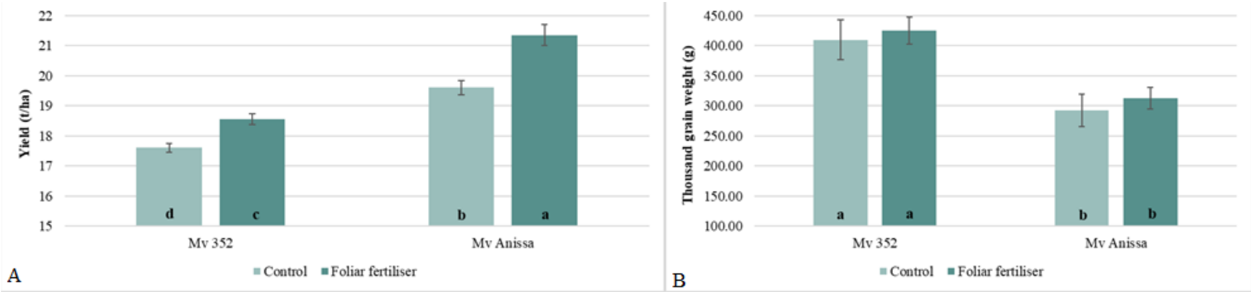

Figure 2. A. Yield of maize genotypes under control and foliar fertiliser treatment. B. Thousand-grain weight of maize genotypes under control and foliar fertilizer treatment

Table 2. Analysis of variance of the studied hybrids at the 12-leaf, silking, and maturity stages

Parameter	S.O.V	df	F-value			P-value		
			V12	Flowering	Maturity	V12	Flowering	Maturity
NDVI	Treatment	1	1.47	45.84	16.11	0.233^{ns}	0.000***	0.001***
	Hybrid	1	6.29	1.21	4.30	0.017*	0.279^{ns}	0.055^{ns}
	Treatment*Hybrid	1	0.16	2.87	7.24	0.688^{ns}	0.099^{ns}	0.016*
SPAD	Treatment	1	1.58	0.05	0.89	0.217^{ns}	0.826^{ns}	0.359^{ns}
	Hybrid	1	1.48	0.18	1.82	0.232^{ns}	0.678^{ns}	0.196^{ns}
	Treatment*Hybrid	1	4.73	4.10	4.20	0.036*	0.050^{ns}	0.057^{ns}

Significance levels: * P < 0.05, ** P < 0.01, *** P < 0.001, ns: not significant at P > 0.05

Table 3. Analysis of variance of the studied hybrids

Parameter	S.O.V	df	F-value	P-value
Yield	Treatment	1	126.25	0.000***
	Hybrid	1	398.89	0.000***
	Treatment*Hybrid	1	10.67	0.007*
Thousand-grain weight	Treatment	1	2.44	0.138^{ns}
	Hybrid	1	100.87	0.000***
	Treatment*Hybrid	1	0.03	0.867^{ns}

Significance levels: * P < 0.05, ** P < 0.01, *** P < 0.001, ns: not significant at P > 0.05

DISCUSSION

SZELES VANYINE ET AL. (2012) found that the increased application of nitrogen fertilisers (which is present in the fertiliser products used in our study), has led to a significant increase in the chlorophyll content of the maize hybrids. They reported in their study the importance of using SPAD measurements to determine the nitrogen demand of maize as well as to detect its deficiency. A three-year-long experimental study was performed by VIG ET AL. (2012) aiming to evaluate the effectiveness of using natural foliar fertilisers on the fertility of maize yield. Based on their results, foliar fertilisers had significantly

affected the SPAD values of the examined maize hybrid. Consequently, their study proves our findings. Concerning the harvested yield, the latter researchers (VIG ET AL., 2012), confirmed our results, as their research work had proved the efficiency of using foliar nutrients to increase crop yields. Additionally, BAREL and BLACK (1979) studied the growth response of corn to foliar application in field experiments. Their research work had clear support for our results, as they found a significant yield increase of the examined corn in the sprayed plots. ALI ET AL., (2016) have found that the plot sprayed with 3 and 2 % of potassium concentrations produced the highest grain yield. They have also pointed out that the 3% concentration was more efficient for increasing maize growth and yield as compared to soil application and fertilisation of potassium fertiliser.
The application of foliar fertilisers has been practiced not only on maize but also on wheat as documented by KOSTADINOVA ET AL., (2015). These researchers reported that the use of foliar fertilisers with the Amalgerol+Cereal mix, Foliar extra and KTS products, led to the highest yield increases of wheat in comparison to that in the untreated plots by 39.3, 38.1 and 36.2 %, respectively. Moreover, they pointed out the efficiency of foliar fertilisation with HiPhos in improving wheat yield under drought conditions.
We can conclude that the application of foliar fertilisers has influenced the behavior of both studied maize genotypes during each growth stage. Overall, foliar nutrients led to producing higher yields compared to the control and resulted in a surplus of 1.74 t/ha for the Mv Anissa genotype. Thus, through our research work, the foliar fertilisation method has been proved to be efficient in improving maize vegetative growth and development in addition to its productivity by enhancing its final yield under drought conditions.

ACKNOWLEDGMENTS

“Project no. TKP2021-NKTA-32 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the TKP2021-NKTA funding scheme.”

REFERENCES

Ali, A., Hussain, M., Habib, H. S., Taj Kiani, T., Anees, M. A., Abdul Rahman M. (2016): Foliar Spray Surpasses Soil Application Of Potassium For Maize Production Under Rainfed Conditions. Turkish Journal Of Field Crops 21: 36-43. https://doi.org/10.17557/tjfc.66054

Barel, D., Black, C. A. (1979): Foliar Application of P. II. Yield Responses of Corn and Soybeans Sprayed with Various Condensed Phosphates and P-N Compounds in Greenhouse and Field Experiments. Agronomy Journal 71: 21-24. https://doi.org/10.2134/agronj1979.00021962007100010005x

El-Fouly, M.M. (2001): Quality of Foliar Fertilizers. International Symposium On Foliar Nutrition Of Perennial Fruit Plants 594: 277-281. https://doi:10.17660/ActaHortic.2002.594.32

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C. (2010): Food Security: The Challenge Of Feeding 9 Billion People. Science 327: 812-818. https//doi:10.1126/science.1185383

Horváth, É., Gombos, B., Széles, A. (2021): Evaluation phenology, yield and quality of maize genotypes in drought stress and non-stress environments. Agronomy Research 19 (2): 408-422. https://doi.org/10.15159/AR.21.073

Kannan, S. (2010): Foliar Fertilization for Sustainable Crop Production. [In: Lichtfouse, E. (ed) Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming. Sustainable Agriculture Reviews 4. https://doi:10.1007/978-90-481-8741-6] (Chapter 3): 371- 402. https://doi:10.1007/978-90-481-8741-6_13

Kostadinova, S., Kalinova, St., Hristoskov, A., Samodova A. (2015): Efficiency of Some Foliar Fertilizers in Winter Wheat. Bulgarian Journal of Agricultural Science. Agricultural Academy 21: 742-746.

Nagy, J. (2003): Effect Of Irrigation On Maize Yield (*Zea Mays* L.). Acta Agraria Debreceniensis 11: 30-35. https://doi.org/10.34101/actaagrar/11/3441

Nagy, J. (2006): Maize Production. Akademiai Kiado. Budapest.

Nagy, J. (2010): Impact Of Fertilization And Irrigation On The Correlation Between The Soil Plant Analysis Development Value And Yield Of Maize. Communications In Soil Science And Plant Analysis 41: 1293-1305. https://doi.org/10.1080/00103621003759304

Randive, K., Raut, T., Jawadand, S. (2021): An Overview Of The Global Fertilizer Trends And India's Position In 2020. Mineral Economics 34: 371-384. https://doi.org/10.1007/s13563-020-00246-z

Szeles-Vanyine, A., Toth, B., Nagy, J. (2012): Effect Of Nitrogen Doses On The Chlorophyll Concentration, Yield And Protein Content Of Different Genotype Maize Hybrids In Hungary. African Journal Of Agricultural Research 7: 2546-2552. https://doi.org/10.5897/AJAR11.979

Vig, R., Dobos, A., Molnar, K., Nagy, J. (2012): The Efficiency Of Natural Foliar Fertilizers. Quarterly Journal of the Hungarian Meteorological Service 116: 53-64.