Review on Agriculture and Rural Development 2014. vol. 3 (1) ISSN 2063-4803

THE VARIATION OF SOME VEGETATION INDICES OF MAIZE UNDER THE INFLUENCE OF MINERAL FERTILIZATION

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ABSTRACT
The present research studied the variation of foliar area and chlorophyll in maize under the influence of mineral fertilization.
The fertilizers applied were nitrogen, in doses that varied from 0 to 200 kg a.s. ha^{-1}, and the PK complex in doses between 0 and 150 kg a.s. ha^{-1}. The vegetation indices were studied in the leaf opposite the ear, and the determinations were made during the silking stage. The foliar area varied between 513.88±16.47 cm^2 in the control variant and 724.32±13.61 cm^2 in the variant with $P_{150}K_{150}N_{200}$. Chlorophyll values ranged from 30.74±0.89 to 55.93±0.73 SPAD units in the same variants. The experimental results present high degree of statistical certainty ($p< 0.01$; F >> F crit, for Alfa = 0.001). The interdependence identified between the vegetation indices and the fertilizer doses was revealed by statistical-mathematical analysis (correlations and regressions) as well as by graphical representation.

Keywords: maize, foliar area, chlorophyll, mineral fertilizers

INTRODUCTION

Maize is one of the most important crop plants, being widely cultivated due to its multiple uses as food for humans and as fodder (TAGNE ET AL. 2008, OECD-FAO, 2013).
A large number of studies have focusses on the influence of climate changes on the population, on the vegetal cover, on agricultural crops and food safety, (HARTKAMP ET AL. 2001, IPCC 2001, JONES and THORNTON 2003, LOBELL ET AL., 2008). The relation between maize and vegetation and technological factors, with fertilizers in particular, has also widely been studied, for the purpose of ensuring qualitative and quantitative stability of the yield, (SCHRÖDER ET AL., 1996, DOUGLAS ET AL., 1998, SCHRÖDER ET AL. 2000, ANDRASKI and BUNDY, 2003, VETSCH and RANDALL, 2004, TAJUL ET AL., 2013).
The way in which plants make use of the vegetation conditions and especially of nutriments provided through fertilization is reflected in certain vegetation indices, such as foliar area and chlorophyll content, (LING and SILBERBUSH 2002). Both indices are directly involved in photosynthesis and therefore they are determining factors for the yield. Their assessment in the vegetation period helps in establishing the nutrition status and in estimating the yield.
Our research was aimed at evaluating maize vegetation status based on foliar area and chlorophyll content, as well as at finding the interdependence degree between fertilization and the values of vegetation indices under analysis.

MATERIAL AND METHOD

The present research evaluated the variation of foliar area and of chlorophyll content in maize, in the leaf opposite the ear, under the influence of mineral fertilization.

The fertilizers involved in our study included complex mineral fertilizers of the type NPK (S) + Zn and ammonium nitrate (35:0:0) in various combinations, making up the following variants: $P_0K_0N_0$, $P_0K_0N_{100}$, $P_0K_0N_{200}$, $P_{50}K_{50}N_{50}$, $P_{50}K_{50}N_{100}$, $P_{50}K_{50}N_{200}$, $P_{100}K_{100}N_{100}$, $P_{100}K_{100}N_{150}$, $P_{100}K_{100}N_{200}$, $P_{150}K_{150}N_{150}$ and $P_{150}K_{150}N_{200}$.

The soil in the location of the experiment was slightly gleyed cambic chernozem with medium fertility: *p*H = 6.85, poor phosphorus supply (P = 25.2 ppm) and good potassium supply (K = 184.26 ppm), the humus content being 2.86%:

The climate conditions in the crop years period 2011 – 2013 were generally characterized by rainfall deficit as compared with the multiannual average, and by uneven distribution of rainfall throughout the year, with droughts and high temperatures especially in July and August. These climatic particularities of the crop years influenced the evolution of the maize crop especially during flowering and pollination, formation and development of kernels on the cob.

The tested maize hybrid was DKC5143, with good productivity, stability and yield quality. The experimental variants were set in randomized blocks, in three replicates. The area of a variant was 30 m^2. Complex fertilizers were applied in autumn, and nitrogen fertilizers were applied in spring. Both fertilizations were made manually, for better uniformity. The crop technology ensured uniform conditions for plant growth and development.

The vegetation indices under study – foliar area and chlorophyll content - were studied in the leaf opposite the ear, and the determinations were made during the silking stage.

The experimental data were processed statistically through variance analysis, correlations, regressions, multivariate analysis using the statistic module from EXCEL 2007 and the programme PAST.

RESULTS AND DISCUSSIONS

Fertilization generated different conditions for growth and development of the maize plants. Therefore, the two variation indices studied, i.e. foliar area and chlorophyll, displayed specific variations. *Table 1* presents the results.

Table 1. Values of productivity elements of, hybrid DKC 5143, depending on fertilization

Variant / Parameter: Fertilizer dose	Variant number	Foliar area (cm^2)	Chlorophyll (SPAD units)
$P_0K_0N_0$	V_1 (Mt)	513.88±16.47	30.74±0.89
$P_0K_0N_{100}$	V_2	687.05±11.29	51.72±0.45
$P_0K_0N_{200}$	V_3	707.26±9.46	54,73±0.64
$P_{50}K_{50}N_{50}$	V_4	662.97±4.98	48.12±1.31
$P_{50}K_{50}N_{100}$	V_5	683.46±8.91	52.44±1.22
$P_{50}K_{50}N_{200}$	V_6	727.26±8.42	55.76±0.65
$P_{100}K_{100}N_{100}$	V_7	671.36±8.71	51.63±1.04
$P_{100}K_{100}N_{150}$	V_8	689.59±10.80	53.68±0.71
$P_{100}K_{100}N_{200}$	V_9	729.26±12.93	55.14±1.19
$P_{150}K_{150}N_{150}$	V_{10}	698.60±9.38	53.15±0.99
$P_{150}K_{150}N_{200}$	V_{11}	724.32±13.61	55.93±0.73

The values of foliar area ranged from 662.97±4.98 cm^2 in variant $P_{50}K_{50}N_{50}$ to

724.32±13.61 cm^2 in variant $P_{150}K_{150}N_{200}$, while in the control variant $P_0K_0N_0$ foliar area was 513.88±16.47 cm^2. The foliar area increase caused by mineral fertilization, in the leaf opposite the ear, varied between 149.09 and 230.44 cm^2.

The values of chlorophyll ranged from 48.12±1.31 SPAD units in variant $P_{50}K_{50}N_{50}$ to 55.93±0.73 SPAD units in variant $P_{150}K_{150}N_{200}$. Under the same experimental conditions, the chlorophyll content in the control variant was 30.74±0.89 SPAD units. The foliar area increase caused by mineral fertilization ranged from 17.38 to 25.19 SPAD units.

ANOVA statistical analysis proves that the experimental results have statistical assurance with high confidence degree ($p < 0.001$; F >> F crit, for Alfa = 0.001), *Table 2*.

Table 2. ANOVA: Single Factor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2794634	3	931544.5	177.2477	3.92E-23	6.59454
Within Groups	210224.3	40	5255.608			
Total	3004858	43				

Alfa = 0.001

Relations of interdependence were identified between the vegetation indices studied and the doses of fertilizer applied; the correlation degree of the two vegetation indices was higher with nitrogen than with the PK complex.

Table 3. Correlation matrices

	N	PK	FS	Chl
N	1.000			
PK	0.423	1.000		
FS	0.**874**	0.486	1.000	
Chl	0.**842**	0.458	0.**985**	1.000

FS – foliar surface; Chl – Chlorophyll content

The relation between foliar area and fertilization can be described by relation (1), with high degree of confidence and high statistical assurance ($R^2 = 0.778$; $p<0.01$).

$$FS = 575.715 + 0.7344N + 0.0783PK \tag{1}$$

The relation of chlorophyll with fertilization is described by relation (2), also with high degree of confidence and statistical assurance ($R^2 = 0.723$; $p<0.01$). The values of the coefficients corresponding to the two categories of fertilizers N and PK in equations (1) and (2) also define the participation degree of the two types of fertilizers for the realization of each index taken separately, whence the justification of different correlation degrees. The differentiated participation of nitrogen and the PK complex in the values of foliar area and chlorophyll is emphasized also by tridimensional graphic representation, *Figures 1 and 2*.

$$Chl = 39.1705 + 0.0831N + 0.0079PK \tag{2}$$

Positive correlation was identified between the two vegetation parameters, with high degree of significance, ($R^2 = 0.989$), *Figure 3*.

Multivariate analysis of experimental data grouped the variants into three distinct clusters: one includes the control variant, with the smallest values of the indices under analysis. The other two clusters include 5 variants each, depending on the results generated, their grouping being obviously influenced by the doses of fertilizer applied, *Figure 4*. The cophenetic coefficient is 0.774, which indicates high certainty in grouping the variants.

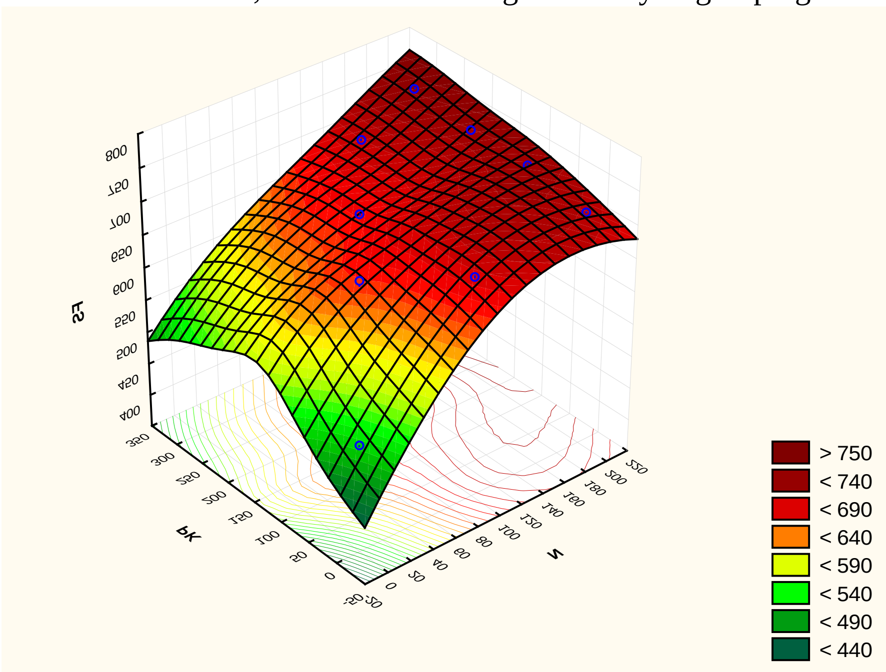

Figure 1. Tridimensional graphic representation of the foliar area distribution of maize, the leaf opposite the ear, under the influence of the two types of fertilizers (N and PK)

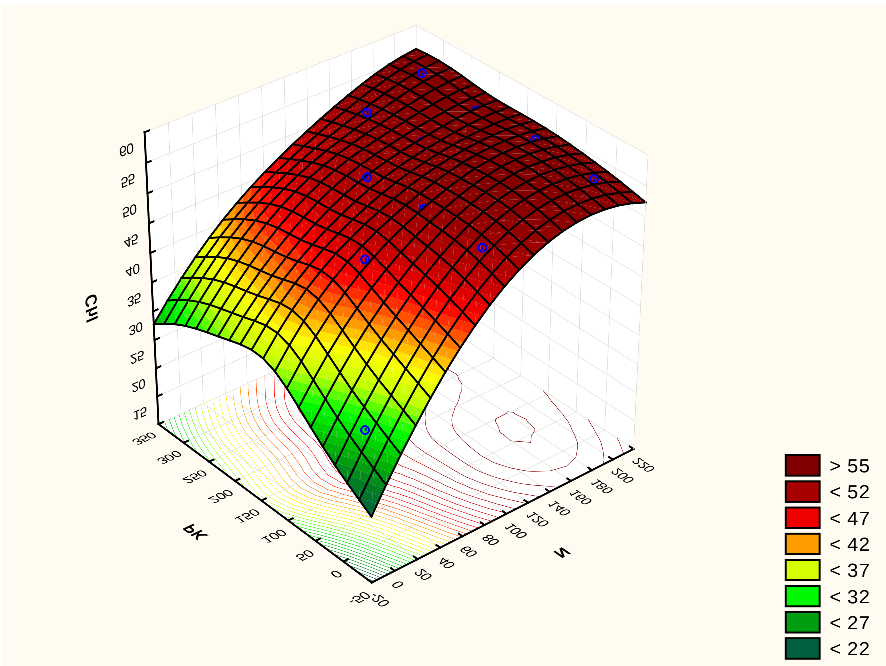

Figure 2. Tridimensional graphic representation of chlorophyll distribution in maize, the leaf opposite the ear, under the influence of the two types of fertilizers (N and PK)

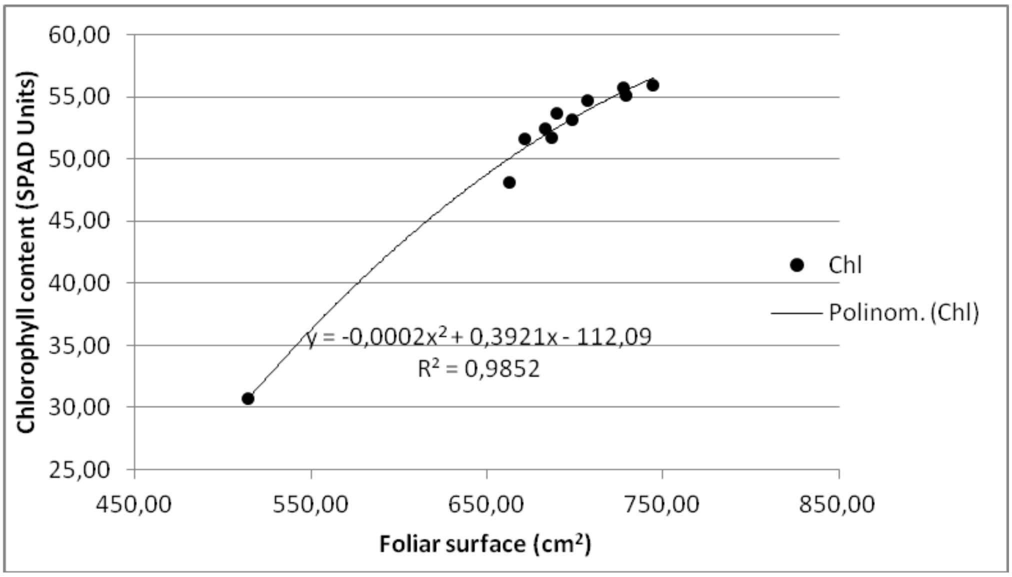

Figure 3. Graphic representation of the correlation between foliar area and chlorophyll content in maize, in the leaf opposite the ear, hybrid DKC5143

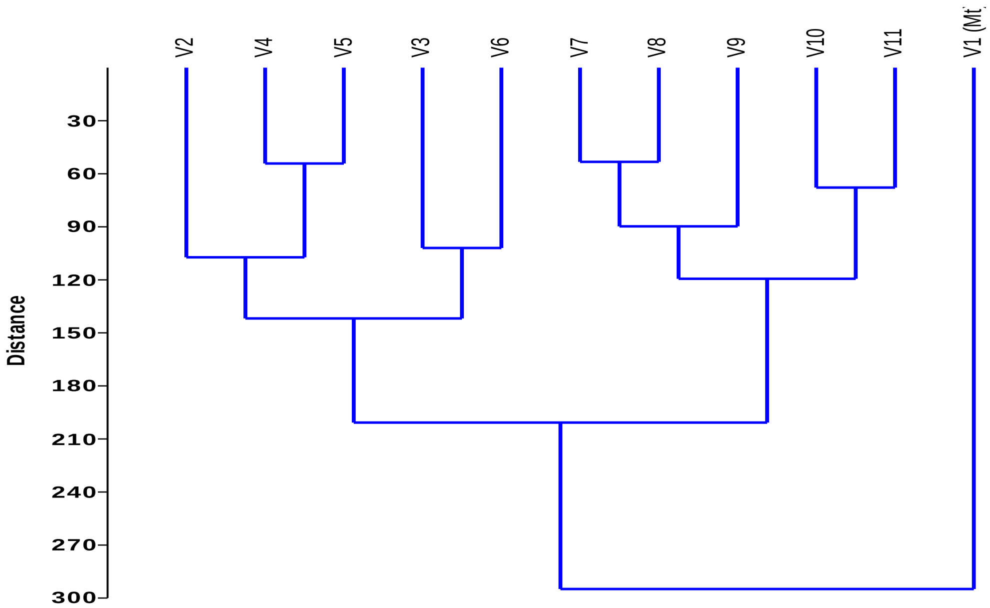

Figure 4. Cluster grouping of the variants based on the results generated

CONCLUSIONS

NPK mineral fertilization of maize determines different variation of the foliar area and chlorophyll in the leaf opposite the ear, in relation to the dose and combination of fertilizers. The contribution of nutrients in the fertilizers is different to the variation of the foliar area and chlorophyll as vegetation indices. Nitrogen has a greater contribution to the variation of the two indices (r = 0.874 for foliar surface; r = 0.842 for chlorophyll) than the PK complex, as revealed by statistical and mathematical methods (correlations and regressions) and by graphical methods, as well. Multivariate analysis allowed the grouping of variants based on similarity with high statistical assurance; cophenetic coefficient has the value 0.774.

ACKNOWLEDGEMENTS

The authors express their thanks to the staff of the Didactic and Experimental Station of the Banat University of Agricultural Sciences and Veterinary Medicine "Regele Mihai I al României" of Timișoara, Romania for facilitating the set-up of the experimental field for this research.

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