The study of changes in the assimilation surface, relative chlorophyll content and maize yield with different agrotechnical factors

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Abstract

This research focused on the effects of previous crop, fertilization and irrigation on the Leaf Area Index (LAI) and relative chlorophyll content (SPAD) of maize and the amount of yield in three different crop years. We were also looking for the relations between these parameters. As an average of the three years, the year, the crop rotation, the irrigation and the fertilization had a 3.5%, 29.8%, 21.5% and 45.2% share in the yield, respectively. The maximum SPAD-values were measured at tasseling and silking periods depending upon the year. In all three crop rotation models, significant differences were found between the control and the fertilization levels of N120-180+PK. As a result of irrigation, an increasing trend can be observed in the SPAD. The maximum LAI were measured at the 12-leaf or tassel depending on the period of the year. The dynamics and maximum value of the LAI were significantly determined by fertilization. Crop rotation had a strong effect, though it varied with the year. There were no significant differences in leaf area between the irrigated and the non-irrigated treatments. The fertilization had the strongest impact ($r = 0.533–0.723$) on yield among the agrotechnical elements. The correlation between the crop rotation and the yield was significant but weak ($r = 0.336–0.423$), while irrigation had a loose, non-significant correlation with yield in 2011 and 2012. In 2013, irrigation had a greater influence on the yield than in 2011 and 2012 ($r = 0.497$).

Keywords: agrotechnical factors, relative chlorophyll content, Leaf Area Index, yield of maize.

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1 Introduction

The productivity of field crops is determined primarily by the biological, genetic factors, secondly, by the ecological conditions and thirdly, by the agrotechnical factors. In the production technology of cereals, these factors should be harmonized.

Some of the biggest challenges in maize production are environmental changes caused by the lack of available water and the decrease of ground water [1]. Fresh water is becoming scarce not only in arid and drought prone areas but also in regions where rainfall is abundant. Effective management of water for agricultural production in water scarcity regions therefore requires the use of innovative and sustainable approaches [2]. Global climate change – temperature rising and inadequate distribution of precipitation over time – responsible for drought is expected to result in yield loss in maize production [3]. According to [4], besides the total amount of rainfall in a crop year it is its distribution over time that significantly affects yield. Adverse weather conditions show up as abiotic stress factors in the generative and the vegetative stages of corn development thus yield decreases [5]. Combined analysis of variance by [6] show that it is the crop year (especially the amount of rainfall) that affects yield the most. Smaller yields are not always linked to drought years but higher yields usually occur in wet years [7]. According to [8], crop year and agrotechnical factors jointly determine the amount and stability of corn yield. The most important agrotechnical factors determining yield are crop rotation, fertilization, plant density and irrigation. Higher yields can be reached in bicultures (soyabean – maize) than in monocultures [9]. According to [10] maize tolerates partial monocultures but grown in a monoculture it produced 1.3 t ha^{-1} less yield in an average of years and 3 to 4 t ha^{-1} less in a drought year compared to the yield achieved in crop rotation. Maize requires harmonic NPK supply but nitrogen has the most important role among macro nutrients [11, 12]. Experiments by [13] between 2008 and 2010 proved that there was a significant relationship between fertilization and harvested productions of maize. Based on the studies by [14] the highest yields were achieved by using up 96 kg ha^{-1} N in 2003, then 153 kg ha^{-1} in 2004 and 159 kg ha^{-1} in 2005, which meant that optimum fertilizer doses varied significantly depending on the crop year (water supply). Nitrogen is one of the main elements of the chlorophyll which means that the nitrogen supply of plants is strongly connected to the size of the leaf area [15] and relative chlorophyll content. Chlorophyll content of the leaves provides information on the physiological condition of the plant [16] and there is a strong relationship between SPAD values, nitrogen and chlorophyll content of the leaves [17–19]. Lönhardné and Németh [20] experienced a strong relationship between the maximum size of the leaf area and yield realized during the time of tasseling. Duncan *et al.* [21] proved that, basically, the amount of yield depended on the assimilation performance of the plant and described the strong relationship between the yield and the leaf area. Therefore, one of the basic elements of the yield formation process is the development of the assimilation system – especially the leaf blade – of the plant.

2 Objectives

The effects of agrotechnical treatments can be measured in significant differences in yield, however, less is known about the ecological and physiological factors behind the yield differences and the interactions between them. For these reasons, special emphasis was laid on the ecophysiological examinations, especially on the exploration of new correlations between the yield, relative chlorophyll content and leaf area of the maize. We aim to determine the relationship between these parameters and the yield of the studied crop. Our target is to determine how the environmental conditions (weather) determine the SPAD-values, the assimilation surface and the yield of maize.

3 Materials and methods

The study was carried out in the period between 2011 and 2013 at the experimental site of the University of Debrecen at Látókép in the polyfactorial long-term experiment set up by Prof. Dr. László Ruzsányi in 1983 and supervised by Prof. Dr. Péter Pepó.

The experimental site is located in Eastern-Hungary, 15 km far from Debrecen, on the area of the aeolain loess of the Hajdúság (N: 47º33', E: 21º27'). The site is plain, even and the type of soil is chernozem with lime patches. Experimental data of the baseline show that the area can be classified as loamy and nearly neutral. Phosphorus supply of the soil is medium, its potassium supply is rather medium or good as shown in Table 1. The experimental plots were set up in a randomized block design in four repetitions, the plot size was 9.2 m x 5 m (46 m^2). The maize hybrid used in the experiment was Reseda (PR37M81; FAO 360).

Table 1: Experimental soil data.

Soil layes (cm)	pH value	Soil physical structure	Humus content %	Total N %	NO_3+ NO_2 ppm	P_2O_5 AL soluble mg/l	K_2O AL soluble mg/l
0-25	6.46	43.0	2.76	0.150	6.20	133.4	239.8
25-50	6.36	44.6	2.16	0.120	1.74	48.0	173.6
50-75	6.58	47.6	1.52	0.086	0.60	40.4	123.0
75-100	7.27	46.6	0.90	0.083	1.92	39.8	93.6
100-130	7.36	45.4	0.59	0.078	1.78	31.6	78.0

The first tested production technology element was the crop rotation where triculture (pea-wheat-maize), biculture (wheat-maize) and monoculture (maize) treatments were set up. The second agrotechnical element was the fertilization (control, $N_{120}P_{90}K_{90}$, $N_{180}P_{135}K_{135}$). The third factor was the irrigation where the treatments applied were non-irrigated (I1), and irrigated to the optimum water supply (I3). The applied research methods in maize were: chlorophyll measurement and leaf area measurement. The assessments were adjusted to the different phenophases of maize (Figure 1.).

We could examined the amount of yield at five fertilization levels (control, $N_{60}P_{45}K_{45}$, $N_{120}P_{90}K_{90}$, $N_{180}P_{135}K_{135}$, $N_{240}P_{180}K_{180}$) three crop rotation systems (triculture-pea-wheat-maize, biculture-wheat-maize and monoculture) and three irrigation models (non-irrigated-I1, irrigated to 50% of the optimum water supply-I2 and irrigated to the optimum water supply-I3).

The meteorological data are presented in Figure 2.

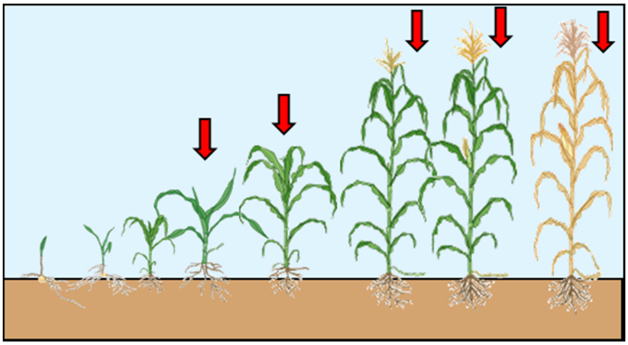

Figure 1: The measurement were performed to the different phenophases of maize.

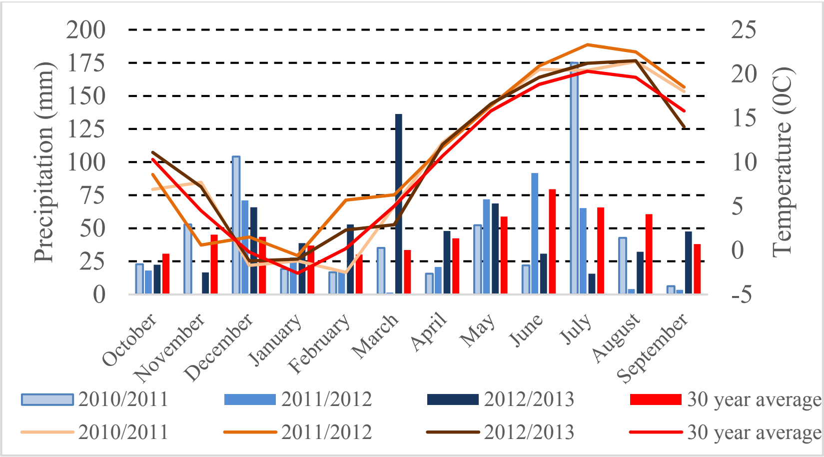

Figure 2: Evaluation of meteorological parameters (precipitation, mean monthly temperature) between October 2010 and September 2013.

A mobile Soil Plant Analysis Development chlorophyll indicator (SPAD-502 Plus, Konica Minolta) was used to determine nitrogen supply of maize.

During each crop year, measurements were applied five times and this meant 15 measurements by repetition. In every case, the leaf area was determined by the SunScan Canopy Analysis Systems (SS1) portable leaf area meter, measurements were applied five times in each years. Eight measurements were applied by repetition.

The statistical evaluation of the data was performed using the programs Microsoft Excel 2013 and SPSS for Windows 13.0. The results were evaluated by using one-way analysis of variance. For determining the relationships between the studied factors, Pearson's correlations were calculated. The quantification of the agrotechnical elements' effects on the yield was done by variance component decomposition.

4 Results

4.1 The effect of ecological and agrotechnical factors on the yields of maize

The yield of maize was significantly influenced by the fertilization and the crop rotation. As an average of the three years, the year, the crop rotation, the irrigation and the fertilization had a 3.5%, 29.8%, 21.5% and 45.2% share in the yield, respectively (Figure 3).

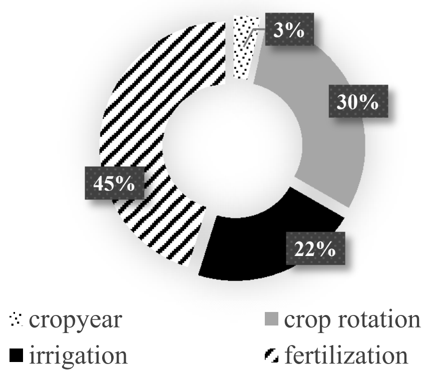

Figure 3: The roles of fertilization, crop rotation, irrigation and the year in the yield of maize (Debrecen, 2011–2013).

Maize grown in monoculture gave 2003–2090 kg ha^{-1} lower yields as an average of three years than maize grown in crop rotation. According to our studies, the optimum N+PK amount is influenced by several factors, on the one hand, by the year, on the other hand, by the applied agrotechnique (crop rotation, irrigation).

Based on the three-year results, the highest yields were obtained at the fertilization levels of $N_{180-240}$+PK in monoculture, $N_{120-180}$+PK in biculture and N_{60-120}+PK in triculture. The yield increment due to irrigation was determined by the nature of the year. In all three experimental years, maize was irrigated several times, (in 2011 there was irrigated by 25 mm in I1 and 50 mm in I2, in 2012 the irrigated water was in I1 and 50 mm in I2, and in 2013 year 75 and 150 mm, respectively) therefore, we could quantify the impact of irrigation, which resulted in a yield increment of 434–994 kg ha^{-1} in 2011, 994–653 kg ha^{-1} in 2012 and 1874–2664 kg ha^{-1} in 2013. In the intensive model, the yield of maize was between 12.5–14.5 t ha^{-1}. In the extensive crop production model, the yield of maize varied between 4.5 and 7.0 t ha^{-1} (in monoculture), 9.0 and 11.5 t ha^{-1} (in biculture) and 9.0 and 11.0 t ha^{-1} (in triculture), it was considerably lower than that in the intensive technology.

Table 2: The effect of irrigation, fertilization and crop rotation on the yield of maize between 2011–2013 (kg ha^{-1}).

Irri-gation	Fertili-zation	Monoculture			Biculture			Triculture		
		2011	2012	2013	2011	2012	2013	2011	2012	2013
I1	control	6226	6715	4862	8769	9389	9208	9602	9656	9029
	N_{60}+PK	8237	9571	7751	10143	10970	10812	11692	10932	10276
	N_{120}+PK	10619	10297	9216	12428	11481	11046	**12388**	**11955**	**10812**
	N_{180}+PK	11362	10641	**9386**	**12670**	**11886**	**11947**	12020	11710	10203
	N_{240}+PK	**11515**	**11289**	9217	12271	11470	11719	11751	11303	9675
I2	control	6370	6881	5488	8805	9820	10963	9961	9827	10219
	N_{60}+PK	8324	9742	8070	10842	11182	12527	11712	11427	12336
	N_{120}+PK	11050	11043	10545	**13304**	11674	13469	**12990**	12504	**13387**
	N_{180}+PK	11927	11284	**11825**	12990	**12406**	**13942**	12782	**11670**	13005
	N_{240}+PK	**12351**	**11910**	11283	12180	11669	13176	12617	11347	13029
I3	control	6741	7028	5725	9075	10126	11614	10652	10140	10971
	N_{60}+PK	8659	9852	8667	12093	11980	13292	**13420**	12736	13492
	N_{120}+PK	11887	11235	11974	**14117**	12996	13906	13086	**13170**	**14676**
	N_{180}+PK	**12704**	11669	**12821**	13586	**13083**	**14689**	13148	12848	13750
	N_{240}+PK	12035	**12569**	12648	12775	12610	14174	12621	12132	12719
$LSD_{5\%}$ crop rot.		***678***			***531***			***738***		
$LSD_{5\%}$ irrigation		***737***			***565***			***790***		
$LSD_{5\%}$ fert.		***636***			***522***			***956***		

4.2 The effect of ecological and agrotechnical factors on the development of leaf area of maize

A strong increasing period was observed in the leaf area index until the 12-leaf or tasseling stages. The maximum leaf area was obtained at that time, then a slow or steep reduction was found. The leaf area was significantly modified by the year and the agrotechnical factors. The dynamics and maximum value of the leaf area index were significantly determined by fertilization. In bi- and triculture crop rotation systems, fertilization had a significant effect on the dynamics and the maximum value of the leaf area index up to the N_{180}+PK treatment. A similar trend could be observed in monoculture and significant differences were measured between the three fertilization treatments in all three years. When comparing the three crop rotation systems, we found that a strong effect, though it varied with the year. The lowest leaf area was measured in monoculture in 2011 and 2013. In biculture and triculture, even the dying of leaves was slower than in monoculture. However, monoculture proved to be significantly better in 2012 than biculture or triculture (Tables 3–5). There were no significant differences in leaf area between the irrigated and the non-irrigated plots.

Table 3: Impact of the agrotechnical factors on the development of leaf area of maize in 2011.

Crop rotation	Irrigation	Fertilization	6–8 leaf stages	12 leaf stages	tasseling	grain filling
Monoculture	I1	control	1.0	2.4	1.7	0.5
		N_{120}+PK	1.4	2.8	2.1	0.6
		N_{180}+PK	1.7	2.8	2.2	0.9
	I3	control	0.9	1.9	1.9	0.5
		N_{120}+PK	1.3	2.3	3.0	0.8
		N_{180}+PK	1.3	2.7	3.1	1.0
Biculture	I1	control	1.1	2.6	2.9	1.4
		N_{120}+PK	1.1	2.7	3.6	1.7
		N_{180}+PK	1.2	3.2	3.5	2.2
	I3	control	1.0	2.4	3.2	0.8
		N_{120}+PK	1.1	2.7	3.8	1.0
		N_{180}+PK	1.3	2.7	3.8	1.4
Triculture	I1	control	1.2	2.8	3.9	1.7
		N_{120}+PK	1.3	3.0	4.2	2.4
		N_{180}+PK	1.6	3.1	4.4	2.3
	I3	control	1.0	2.6	3.5	0.8
		N_{120}+PK	1.1	3.0	4.0	1.0
		N_{180}+PK	1.1	3.1	4.2	1.2
LSD $_{5\%}$ crop rotation			***0.1***	***0.3***	***0.3***	***0.3***
LSD $_{5\%}$ irrigation			***0.1***	***0.2***	***0.4***	***0.3***
LSD $_{5\%}$ fertilization			***0.1***	***0.2***	***0.5***	***0.4***

Table 4: Impact of the agrotechnical factors on the development of leaf area of maize in 2012.

Crop rotation	Irrigation	Fertilization	6–8 leaf stages	12 leaf stages	tasseling	silking period	grain filling
Monoculture	I1	control	0.4	2.0	2.7	1.9	1.7
		N_{120}+PK	0.4	2.6	3.2	2.3	2.0
		N_{180}+PK	0.6	3.1	3.3	2.5	2.0
	I3	control	0.4	2.3	2.6	2.1	1.7
		N_{120}+PK	0.3	3.0	3.6	2.5	1.9
		N_{180}+PK	0.4	3.0	3.5	2.8	2.2
Biculture	I1	control	0.3	1.8	2.8	2.4	1.4
		N_{120}+PK	0.4	2.2	2.6	2.8	1.8
		N_{180}+PK	0.3	2.1	3.2	2.7	1.8
	I3	control	0.4	2.0	2.8	2.5	1.9
		N_{120}+PK	0.4	2.3	3.2	2.6	2.1
		N_{180}+PK	0.4	2.2	3.0	2.6	2.4
Triculture	I1	control	0.2	2.0	2.8	2.3	1.7
		N_{120}+PK	0.3	2.8	3.1	2.7	1.8
		N_{180}+PK	0.3	2.9	3.2	2.9	1.8
	I3	control	0.3	2.1	2.6	2.3	1.6
		N_{120}+PK	0.3	2.8	3.1	2.6	1.7
		N_{180}+PK	0.4	3.0	3.2	2.7	2.0
LSD $_{5\%}$ crop rotation			***0.1***	***0.3***	***0.2***	***0.2***	***0.2***
LSD $_{5\%}$ irrigation			***0.1***	***0.3***	***0.2***	***0.1***	***0.2***
LSD $_{5\%}$ fertilization			***0.1***	***0.3***	***0.2***	***0.1***	***0.2***

Table 5: Impact of the agrotechnical factors on the development of leaf area of maize in 2013.

Crop rotation	Irrigation	Fertilization	6-8 leaf stages	12 leaf stages	tasseling	silking period	grain filling
Monoculture	I1	control	0.1	1.0	1.2	0.9	1.4
		N_{120}+PK	0.2	1.6	2.3	2.0	1.9
		N_{180}+PK	0.1	1.9	2.6	2.4	1.8
	I3	control	0.1	1.6	0.9	0.9	1.7
		N_{120}+PK	0.2	2.1	2.1	2.2	2.1
		N_{180}+PK	0.2	2.3	2.5	2.4	2.2
Biculture	I1	control	0.2	1.0	2.0	1.9	1.9
		N_{120}+PK	0.2	1.5	2.4	2.7	2.1
		N_{180}+PK	0.2	1.4	2.6	3.0	2.2
	I3	control	0.2	1.3	1.8	1.4	2.1
		N_{120}+PK	0.2	1.6	2.3	2.4	2.1
		N_{180}+PK	0.2	1.6	2.3	2.7	2.2
Triculture	I1	control	0.2	1.3	2.1	1.5	1.7
		N_{120}+PK	0.2	1.9	2.6	2.2	1.8
		N_{180}+PK	0.2	2.0	2.3	2.4	2.0
	I3	control	0.2	1.7	1.9	1.5	2.1
		N_{120}+PK	0.2	2.0	2.2	2.3	2.4
		N_{180}+PK	0.2	2.0	2.2	2.6	2.4
LSD $_{5\%}$ crop rotation			***0.02***	***0.2***	***0.3***	***0.4***	***0.2***
LSD $_{5\%}$ irrigation			***0.02***	***0.2***	***0.2***	***0.3***	***0.1***
LSD $_{5\%}$ fertilization			***0.02***	***0.2***	***0.2***	***0.2***	***0.2***

4.3 The effect of ecological and agrotechnical factors on the SPAD values of maize

The relative chlorophyll content of maize can be described by a bell-shaped curve, the maximum SPAD values were measured in tasseling and silking periods depending upon the year. In all three crop rotation models, significant differences were found between the control and the fertilization levels of N120-180+PK. From among the three crop rotation systems, the lowest relative chlorophyll content was obtained in monoculture and depending upon the applied agrotechnique, considerably lower values were measured in the period of grain filling. As a result of irrigation, an increasing trend can be observed in the relative chlorophyll content, however, this could not be proven statistically (Tables 6–8).

4.4 Study of the correlations between the yield-influencing factors in maize

Using correlation analysis, the strength of the correlations between the studied parameters and the applied agrotechnical treatments was determined ($r < 0.5$ = small, $0.5 < r < 0.7$ = medium, $r > 0.7$ = strong correlation). We aimed to determine the correlations between the crop rotation, the fertilization, the irrigation and the yield of maize. We found that the leaf area index (LAI), the relative chlorophyll content (SPAD) have primary roles in the yield forecast in the early season.

Table 6: Effect of the agrotechnical factors on the relative chlorophyll content of maize in 2011.

Crop rotation	Irri-gation	Fertili-zation	6-8 leaf stages	12 leaf stages	tasseling	grain filling
Monoculture	I1	control	50.1	44.9	46.9	32.5
		N_{120}+PK	52.1	51.0	51.4	44.0
		N_{180}+PK	50.1	53.7	55.7	49.4
	I3	control	47.5	42.3	42.3	31.1
		N_{120}+PK	50.5	51.7	55.5	36.7
		N_{180}+PK	51.9	53.7	58.0	43.3
Biculture	I1	control	51.6	54.2	53.6	33.9
		N_{120}+PK	51.1	54.2	56.9	41.8
		N_{180}+PK	47.5	53.4	57.9	43.9
	I3	control	52.2	51.0	54.6	40.6
		N_{120}+PK	53.8	54.0	59.9	45.6
		N_{180}+PK	53.2	53.9	59.3	45.4
Triculture	I1	control	49.0	53.8	58.5	48.2
		N_{120}+PK	51.0	53.6	60.0	44.5
		N_{180}+PK	51.8	56.0	60.3	50.8
	I3	control	51.2	53.5	56.6	40.9
		N_{120}+PK	53.8	54.2	58.9	42.7
		N_{180}+PK	52.4	54.8	59.2	47.7
LSD $_{5\%}$ ***crop rotation***			***1.5***	***1.5***	***1.5***	***1.5***
LSD $_{5\%}$ ***irrigation***			***2.2***	***2.2***	***2.2***	***2.2***
LSD $_{5\%}$ ***fertilization***			***2.7***	***2.7***	***2.7***	***2.7***

Table 7: Effect of the agrotechnical factors on the relative chlorophyll content of maize in 2012.

Crop rotation	Irrigation	Fertilization	6-8 leaf stages	12 leaf stages	tasseling	silking period	grain filling
Monoculture	I1	control	36.8	51.7	51.5	45.5	8.7
		N_{120}+PK	36.8	51.6	58.7	57.2	26.8
		N_{180}+PK	34.6	53.1	57.4	59.2	32.3
	I3	control	34.5	51.9	54.8	46.5	16.5
		N_{120}+PK	36.3	51.4	58.6	56.7	18.2
		N_{180}+PK	35.1	50.6	59.1	57.7	43.8
Biculture	I1	control	35.7	50.9	59.6	61.3	27.0
		N_{120}+PK	35.8	53.8	60.6	59.4	52.4
		N_{180}+PK	33.0	51.8	60.9	60.7	53.4
	I3	control	32.7	49.9	58.9	57.7	40.0
		N_{120}+PK	33.7	51.5	59.2	60.6	50.5
		N_{180}+PK	31.7	52.4	61.4	61.0	52.2
Triculture	I1	control	35.3	51.6	57.3	57.8	27.1
		N_{120}+PK	33.8	50.8	60.0	59.2	50.9
		N_{180}+PK	32.6	53.6	59.3	61.6	52.4
	I3	control	33.4	51.7	58.0	53.5	25.1
		N_{120}+PK	33.8	51.7	60.1	60.5	47.6
		N_{180}+PK	32.1	50.4	60.2	60.3	42.8
LSD $_{5\%}$ crop rotation			***1.3***	***1.3***	***1.3***	***1.3***	***1.3***
LSD $_{5\%}$ irrigation			***1.5***	***1.5***	***1.5***	***1.5***	***1.5***
LSD $_{5\%}$ fertilization			***1.5***	***1.5***	***1.5***	***1.5***	***1.5***

Table 8: Effect of the agrotechnical factors on the relative chlorophyll content of maize in 2013.

Crop rotation	Irrigation	Fertilzation	6-8 leaf stages	12 leaf stages	tasseling	silking period	grain filling
Monoculture	I1	control	31.9	48.0	44.8	39.7	27.8
		N_{120}+PK	37.3	52.7	52.4	54.7	37.5
		N_{180}+PK	35.5	52.6	55.2	56.8	35.2
	I3	control	31.9	44.5	44.3	39.6	29.4
		N_{120}+PK	33.7	53.4	51.6	54.8	38.9
		N_{180}+PK	37.6	56.8	54.9	56.4	46.4
Biculture	I1	control	31.3	48.9	51.8	53.0	46.3
		N_{120}+PK	30.6	50.7	53.2	56.4	47.5
		N_{180}+PK	29.9	54.4	56.5	58.2	49.2
	I3	control	29.1	50.9	48.7	48.5	35.3
		N_{120}+PK	33.2	52.9	57.2	58.7	41.1
		N_{180}+PK	29.8	53.0	56.8	56.7	36.2
Triculture	I1	control	33.4	50.7	48.2	49.6	26.8
		N_{120}+PK	33.7	53.7	55.3	57.0	26.5
		N_{180}+PK	35.2	55.1	57.8	56.8	25.7
	I3	control	33.0	49.2	53.2	48.2	45.4
		N_{120}+PK	34.7	53.5	57.2	59.0	45.7
		N_{180}+PK	36.6	55.0	58.2	55.1	47.6
LSD $_{5\%}$ crop rotation			***1.3***	***1.3***	***1.3***	***1.3***	***1.3***
LSD $_{5\%}$ irrigation			***1.5***	***1.5***	***1.5***	***1.5***	***1.5***
LSD $_{5\%}$ fertilization			***1.5***	***1.5***	***1.5***	***1.5***	***1.5***

The fertilization had the strongest impact (r = 0.533–0.723) on the amount of yield from among the agrotechnical elements. The correlation between the crop rotation and the amount of yield was significant but weak (r = 0.336–0.423), while irrigation had a loose, non-significant correlation with yield in 2011 and 2012. In 2013, irrigation had a greater influence on the yield than in 2011 and 2012 (r = 0.497).

5 Conclusion

Summarizing our scientific results we can state that different levels of fertilizer doses and crop rotation had a considerable impact on the dynamics and maximum values of the leaf area, SPAD values and yields as well.

We must know the changes in leaf canopy and the chlorophyll content of the leaves to understand the growth and yield of maize that can assist to the future development and optimization of maize production researches.

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