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EVALUATION OF THE YIELD PRODUCTION OF C_3 (*TRITICUM AESTIVUM* L.) AND C_4 (*ZEA MAYS* L.) CEREALS WITH A NEW PLANT PHYSIOLOGICAL PARAMETER

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ABSTRACT

In a polifactorial long-term experiment, the effects of the year and the agrotechnical factors on the yields and plant physiological parameters (LAI, SPAD) of winter wheat and maize were studied on chernozem soil in the period of 2011-2013. Results of our long-term experiments proved that the yield of winter wheat was influenced both by the fertilization and the crop rotation. The productivity of the C_4-type maize was higher than that of the C_3-type winter wheat. Our results proved that the plant physiological parameters (LAI, SPAD) of winter wheat (C_3) and maize (C_4) were not different, however, there were great differences in productivity between the two crops. A new parameter (Ph.C.) was developed for the characterization of the photosynthetic capacity in winter wheat and maize. The Ph.C. values of winter wheat (C_3) and maize (C_4) were significantly different (300-400 Ph.C. and 800-1200 Ph.C.). The Ph.C. values can also be well used for the characterization of the agrotechnical elements (fertilization, crop rotation, irrigation). A close correlation was found between the yields of maize and winter wheat and the Ph.C. values ($r = 0.671\text{-}0.938^{**}$, $r = 0.792\text{-}0.934^{**}$).

Key words: C_3 (wheat), C_4 (maize), photosynthetic capacity (Ph.C.), yield

Abbreviations: photosynthetic capacity-Ph.C.

INTRODUCTION

Cereals have a determining role in crop production both in Hungary and worldwide. Cereal crops account for about 50% of the world's arable land, while the same ratio in Hungary is extremely high (~68%). The effects of global climatic changes decreased the yields of cereals and increased the yield fluctuation (Olesen and Bindi, 2002). Similar situations can be found in Hungarian wheat and maize production. The frequency of extreme agrometeorological phenomenous has gone up because of global climatic change (Lobell *et al.*, 2012; Semenov and Shewry, 2011) and the responses of different field crops are quite different for climatic change depending on genotypes, agrotechniques, soil types and their CO_2-tolerance (Fry, 2008). There are great differences between wheat and maize in their ecological and agrotechnical requirements and also in their productivity. The two crops belong to different photosynthetical groups, wheat is a C_3-, while maize is a C_4-type plant. Photosynthetic capacity and efficiency are bottlenecks to raising productivity and there is strong evidence that increasing photosynthesis will increase crop yields provided that other constraints do not become limiting (Parry *et al*., 2011).

The phytomass and the amount of the useful yield are influenced by numerous physiological parameters of the cereal stands. From among these, the leaf area index (LAI) and the chlorophyll content of the leaves are particularly important. The leaf area of wheat is determined partly by ecological and partly by agrotechnical factors. Nutrient supply, primarily nitrogen fertilization, significantly increased the LAI values (Uribelarrea *et al.*, 2009) and the dry matter accumulation also (Duan *et al.*, 2014). From among the environmental factors, weather during the vegetation period is of special importance. In order to determine the yield formation of wheat, it is important to know the spatial and temporal changes in leaf area (Yang *et al.*, 2007). There is a close correlation between the leaf area and the yield of wheat until reaching the optimal LAI value level (Petr *et al.*, 1980).

Results of Bavec and Bavec (2002) showed that values of the LAI varied significantly during different phenological stages. The maximum leaf area was affected by many agrotechnical factors. The leaf area of maize is influenced strongly by the fertilization, especially by nitrogen fertilization. According to the studies of Anderson *et al.* (1985) and Singh and Stoskopf (1971), proper nitrogen fertilization promotes the rapid early development of maize leaf area and increases its size. The dynamics and maximum value of the LAI were significantly determined by fertilization and the crop rotation had also a strong effect, though it varied with the year (Pepó and Vári, 2014). Weather factors (Borrás *et al.*, 2003) and the biological bases (hybrid) also influence the rate of leaf area development and its final value. Duncan *et al.* (1965) proved that the amount of yield is dependent upon the assimilative production of the plant which was supported by the close positive correlation between the yield and the leaf area. According to Idikut and Kara (2011), the agrotechnical factors are also impact the yield of maize, particularly previous crop and N fertilization.

The chlorophyll content of the leaves provides extremely important agronomical information on the physiological condition of the plants (Carter, 1994). Hu *et al.* (2010) found a close positive correlation between the SPAD values, the nitrogen content of leaves and the chlorophyll content of leaves in wheat. In addition to fertilization (Ji *et al.*, 2007; Hao *et al.*, 2011), the SPAD values of wheat are influenced also by the forecrop (Smagacz, 2004).

Evans (1989), Niinemets and Tenhunen (1997), Yoder and Pettigrew-Crosby (1995) and Lemaire *et al.* (2008) found a close positive correlation between the chlorophyll and nitrogen contents of maize leaves and the SPAD values. The SPAD values of maize were influenced by the nitrogen fertilization (Nagy, 2010), the irrigation (Széles, 2007) and the hybrid (Berzsenyi *et al.*, 2006). Rostami *et al.* (2008), Huan *et al.* (2010) found a close positive correlation between the SPAD values of maize leaves and the amount of yield.

MATERIALS AND METHODS

The polifactorial long-term experiment was set up in 1983 at the Látókép 33 (N 47º33' E 21º27') Experimental Farm of the University of Debrecen FAFES Institute of Crop Sciences. The experimental site is located 15 km from Debrecen. The experimental soil was calcareous chernozem loam (humus 2.6-2.8%; pH_{KCl} = 6.5; AL-soluble P_2O_5 and K_2O = 130 mg kg^{-1} and 240 mg kg^{-1}, respectively; heaviness index according to Arany: A_K = 42-44). The soil has favourable water management characteristics (the water holding capacity of the 0-200 cm soil layer is 680 mm out of which 50% is available water.

In the long-term experiment, several agrotechnical factors were studied as follows:

Winter wheat (variety GK Csillag)

crop rotation: biculture (maize-winter wheat) and triculture (maize-pea-winter wheat)

fertilization (kg ha^{-1}):

a) Control
b) 50 N + 35 P_2O_5 + 40 K_2O
c) 100 N + 70 P_2O_5 + 80 K_2O
d) 150 N + 105 P_2O_5 + 120 K_2O
e) 200 N + 140 P_2O_5 + 160 K_2O

irrigation: non-irrigated and irrigated treatment
crop protection: extensive, average, intensive

All other agrotechnical elements were adjusted to meet the agronomical requirements of winter wheat. The examinations were carried out in two crop rotations under non-irrigated conditions with average crop protection in the control and the N_{150}+PK fertilizer treatments.

Maize (the hybrid Reseda: PR37M81; FAO 360)
crop rotation: monoculture (maize since 1983), biculture (maize-wheat) and triculture (maize-pea-winter wheat)
fertilization (kg ha^{-1}):

a) Control
b) 60 N + 45 P_2O_5 + 45 K_2O
c) 120 N + 90 P_2O_5 + 90 K_2O
d) 180 N + 135 P_2O_5 + 135 K_2O
e) 240 N + 180 P_2O_5 + 180 K_2O

irrigation: non-irrigated and irrigated treatment plant density: 40 000 ha^{-1}, 60 000 ha^{-1}, 80 000 ha^{-1}

The other agrotechnical elements satisfied the requirements of modern maize production. The examinations were performed in three crop rotations at the plant density of 60 000 ha^{-1} under irrigated and non-irrigated conditions in the control, the N_{120}+PK and the N_{180}+PK treatments.

The irrigation dosages applied in the maize experiment were as follows: in non irrigated treatment = 0 mm in 2011; 2012 and 2013 years, respectively and in irrigated treatment the irrigated waters were 50 mm in 27-28th June 2011, 50 mm in 10-11th July 2012 and 50 mm in 26-28th June, 50 mm in 13-20th July, 50 mm 27-29th July 2013 years (150 mm in 2013), respectively.

The experimental plots were set up in a randomized block design in four repetitions. The gross area of the plots was 46 m^2 for both crops. The main blocks of the long-term experiment were the crop rotation variates, the sub-blocks were the irrigation treatments and the crop protection models for winter wheat and the plant density treatments in the case of maize. The fertilizer treatments were set up within these.

In the long-term experiment, diverse phenological, agronomical, plant health and plant physiological measurements are carried out and the yields are also recorded.

The leaf area index (LAI) and the chlorophyll content were recorded on 5-6 times during the vegetation periods of winter wheat and maize. For our study, the LAI_{max} and the $SPAD_{max}$ values were used. The leaf area index (LAI) was determined using a SunScan Canopy Analysis System (SSI) portable leaf area measuring instrument in four repetitions with eight measurements per repetition.

For the measurement of the SPAD values in winter wheat and maize, a portable Soil Plant Analysis Development (SPAD-502 Plus, Konica Minolta) instrument was used. The instrument measures the light absorption of leaves in the blue and red (R = 600-700 nm) spectrum range, which corresponds to the maximum light absorption of chlorophyll. The SPAD values can be regarded equal to the leaf chlorophyll content, as there is a very close correlation between the SPAD value and the chlorophyll content in the different crops (Wood *et al.*, 1993; Cartelat *et al.*, 2005; Hu *et al.*, 2010).

The monthly precipitation values and the monthly mean temperatures of the experimental years are presented in Tables 1. In this table, the 30-year averages were also included for comparison. The weather factors had an impact on the vegetative and generative development and the yield formation processes of winter wheat and maize.

The statistical evaluation of the experimental data was performed using the programmes Microsoft Excel 2013 and SPSS for Windows 13.0. For the evaluation of the results, analysis of variance and Pearson's correlation analysis were used.

RESULTS

The agrotechnical treatments of the polifactorial long-term experiment (crop rotation and fertilization in winter wheat and crop rotation, fertilization and irrigation in maize) provided an opportunity for the evaluation of the interactions between the agrotechnical factors and the year (agrotechnique x environment) in maize and in winter wheat in addition to the effects and interactions between these factors. The weather factors had a great effect both on the yields and on the agrotechnical elements' impact on the yield.

The yields of winter wheat are presented in Figure 1. The yields of winter wheat varied between 2046-10 050 kg ha^{-1}, 2429-8203 kg ha^{-1} and 1558-8660 kg ha^{-1} in 2011, 2012, 2013 depending upon the crop rotation and the fertilizer treatment. Biculture (maize forecrop) had an unfavourable effect in the control and the small-medium treatments (N_{50-100} + PK) as compared to triculture (pea forecrop). In biculture, the maximum yields were obtained in the N_{200} +PK fertilizer treatment in all three years (8423 kg ha^{-1}, 8179 kg ha^{-1} and 8317 kg ha^{-1}). In the more favourable triculture, considerably lower optimum fertilizer treatments ($N_{100-150}$ + PK) were enough for the realization of the higher maximum yields (10 050 kg ha^{-1}, 8203 kg ha^{-1} and 8660 kg ha^{-1}).

The yields of maize are presented in Figures 2, 3 and 4. In the long-term maize experiment, close interactions could be found between the agrotechnical factors and the agrotechnical elements and the year. The yields of maize varied between 6226-14 117 kg ha^{-1}, 6715-13 170 kg ha^{-1}, 4862-14 689 kg ha^{-1} in 2011, 2012 and 2013 depending upon the crop rotation, the fertilization treatment and the water supply. The excellent nutrient-providing capacity of the chernozem soil was proved by the very favourable yields obtained in the control treatments of biculture and triculture. The yield-increasing impact of irrigation varied with the year and the crop rotation. The largest yield increment in maize due to irrigation was obtained in the dry year of 2013 (3000-4000 kg ha^{-1}), while in the years of 2011 and 2012 with better water supply, the increase was lower (1000-2000 kg ha^{-1} and 1000-1500 kg ha^{-1}). The maximum yield was obtained in different fertilization treatments depending upon the crop rotation and the water supply. Maize gave the maximum yield in the $N_{180-240}$ +PK, $N_{120-180}$ +PK, N_{60-120} +PK treatments in monoculture, biculture and triculture, respectively. A deeply interesting interaction was found between the water and nutrient supply in maize. In the case of nutrient deficiency (control treatment), the yield increment due to irrigation was extremely low (300-500 kg ha^{-1}in 2011, 300-800 kg ha^{-1} in 2012, 900-2000 kg ha^{-1} in 2013 depending upon the crop rotation).

In certain treatments of the long-term experiment, the changes in the leaf area index (LAI) and the chlorophyll content (SPAD) were determined several times (5-6 occasions per year) during the vegetation periods of winter wheat and maize. From the results, the maximum leaf area index (LAI_{max}) and the maximum chlorophyll content ($SPAD_{max}$) values were used for developing a new plant physiological parameter.

The LAI_{max} and the $SPAD_{max}$ values and the yield of winter wheat and maize are included in Tables 2 and 3, respectively. The evaluation of the LAI and SPAD results lead to an interesting conclusion in the cases of winter wheat (C_3) and maize (C_4). In spite of the fact that the yields of maize were considerably higher (11 000-15 000 kg ha^{-1} yield maximum depending upon the year) than those of winter wheat (8000-10 000 kg ha^{-1} maximum yield depending upon the year), the differences in the plant physiological parameters were moderate. The LAI_{max} values of winter wheat in the optimum fertilizer treatment varied between 3-4 m^2m^{-2} and the LAI_{max} values of maize were also in the same range. A similar statement could be made about the $SPAD_{max}$ values. In the optimum fertilizer treatment, the SPAD values of winter wheat and maize ranged between 53-59 and 57-61, respectively, depending upon the year, the crop rotation and the water supply. These data indicated that the two crops have different photosynthetic capacities. Under photosynthetic capacity (Ph.C.) we mean the combined value of leaf area and chlorophyll content as correlated to the yield, which can be described by the special parameter developed by us:

$$\text{Ph.C.} = \left(\frac{\text{Yield max}}{\text{LAI max}} * \frac{\text{Yield max}}{\text{SPAD max}}\right) /1000$$

By the introduction of this new parameter, the C_3 (winter wheat) and C_4 (maize) crops could be well differentiated and the effects of the agrotechnical factors could also be characterized. In the optimal agrotechnical treatments, the Ph.C. values of maize and wheat varied between 243-446 and 584-1658, respectively, depending upon the year. The Ph.C. values proved that the C_3 (winter wheat) cereal species has a much lower photosynthetic capacity (~300-400 Ph.C.) than the C_4 (maize) cereal (~800-1200 Ph.C.). This difference in the photosynthetic capacity could be the reason for the much higher productivity of maize as compared to that of winter wheat. The results included in Tables 2 and 3 also proved that the Ph.C. values can be well used for characterizing the impacts of agrotechnical elements. In the case of winter wheat, fertilization increased the Ph.C. values in both crop rotations. In triculture, the Ph.C. values were more favourable in winter wheat than in biculture. The effect of fertilization on the photosynthetic capacity was undoubtedly positive in the case of maize also (higher Ph.C. values) in all three crop rotations. Irrigation considerably increased the Ph.C. values as compared to the non-irrigated treatment. The smallest Ph.C. values were obtained in monoculture in maize, while the values were much more favourable in biculture and triculture.

The relationship between the yield and the photosynthetic capacity in winter wheat and in maize was analyzed using Pearson's correlation analysis (Table 4). The results showed a close, significant correlation between the yield and the Ph.C. values. The values of the correlation coefficient (r) at the significance level of LSD$_{1\%}$ ranged between 0.671-0.938 and 0.792-0.934 in winter wheat and in maize, respectively, depending upon the year.

Table 1. Monthly rainfall (mm) and mean air temperature in different crop years (Debrecen, Hungary)

Year	Debrecen Weather Bureau, Hungary: LTA = the long-term average (30-years)												
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Febr.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	
	Rainfall (mm)												**Total**
2010/2011	22.8	52.9	104.2	19.2	16.8	35.1	15.6	52.3	22.0	175.0	42.7	6.2	564.8
2011/2012	18.1	0	71.1	28.0	17.8	1.4	20.7	71.9	91.7	65.3	4.1	3.5	393.6
2012/2013	22.4	16.6	65.8	38.7	52.9	136.3	48.0	68.7	30.8	15.6	32.2	47.6	575.6
LTA	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	65.7	60.7	38.0	565.3
	Mean air-temperature (^oC)												Mean
2010/2011	6.9	7.7	-1.7	-1.2	-2.5	5.0	12.2	16.4	20.5	20.4	21.4	18.0	10.26
2011/2012	8.6	0.6	1.5	-0.6	-5.7	6.3	11.7	16.4	20.9	23.3	22.5	18.5	10.33
2012/2013	11.1	7.2	-1.2	-1.0	2.3	2.9	12.0	16.6	19.6	21.2	21.5	14.0	10.68
LTA	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.7	20.3	19.6	15.8	9.84

Table 2. Effect of agrotechnical elements on the photosyntetic capacity (P-index) of winter wheat (Debrecen, Hungary, 2011-2013).

Year	Fertilization	Biculture (non-irrigated)				Triculture (non-irrigated)			
		Yield (kg ha^{-1})	**LAI$_{max}$ (m^2 m^{-2})**	**SPAD$_{max}$**	**P-index**	**Yield (kg ha^{-1})**	**LAI$_{max}$ (m^2 m^{-2})**	**SPAD$_{max}$**	**P-index**
2011	Ø	2046	1.3	56	61	6570	2.2	43	469
	N$_{150}$+PK	7742	3.4	59	305	9830	4.1	54	446
2012	Ø	2429	2.0	38	82	5015	2.8	56	159
	N$_{150}$+PK	7283	3.6	59	240	8203	3.7	59	309
2013	Ø	1558	0.9	32	90	4811	2.2	45	243
	N$_{150}$+PK	6205	3.1	53	243	8660	4.2	54	372

Table 3. Effect of agrotechnical elements on the photosyntetic capacity (P-index) of maize (Debrecen, Hungary, 2011-2013).

Year	Monoculture									
	Non irrigated					Irrigated				
	Fertilization	**Yield (kg ha^{-1})**	**LAI$_{max}$ (m^2 m^{-2})**	**SPAD$_{max}$**	**P-index**	**Fertilization**	**Yield (kg ha^{-1})**	**LAI$_{max}$ (m^2 m^{-2})**	**SPAD$_{max}$**	**P-index**
2011	Ø	6226	2,4	50	325	Ø	6741	2,0	47	501
	N$_{180}$+PK	11362	2,8	56	815	N$_{180}$+PK	12903	3,1	58	926
2012	Ø	6715	2,7	52	325	Ø	7028	2,6	55	346
	N$_{180}$+PK	10641	3,3	59	584	N$_{180}$+PK	11669	3,5	59	656
2013	Ø	4862	1,4	48	341	Ø	5725	1,7	44	439
	N$_{180}$+PK	9386	2,6	57	607	N$_{180}$+PK	12821	2,5	57	1176

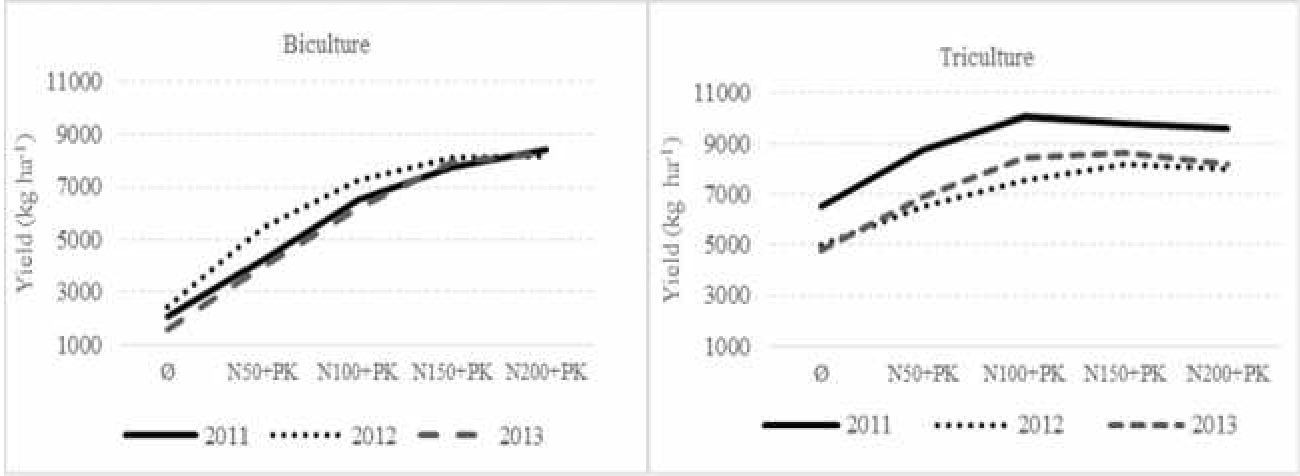
Year	Biculture									
	Non irrigated					Irrigated				
	Fertilization	Yield (kg ha^{-1})	LAI$_{max}$ (m^{2} m^{-2})	SPAD$_{max}$	P-index	Fertilization	Yield (kg ha^{-1})	LAI$_{max}$ (m^{2} m^{-2})	SPAD$_{max}$	P-index
2011	Ø	8769	2,9	54	484	Ø	9075	3,2	55	470
	N_{180}+PK	12670	3,5	58	788	N_{180}+PK	14117	3,8	60	888
2012	Ø	9389	2,8	61	508	Ø	10126	2,8	59	614
	N_{180}+PK	11886	3,2	61	729	N_{180}+PK	13083	3,0	61	931
2013	Ø	9208	2,0	53	808	Ø	11614	2,1	51	1266
	N_{180}+PK	11947	3,0	58	813	N_{180}+PK	14689	2,3	57	1631

Year	Triculture									
	Non irirgated					Irrigated				
	Fertilization	Yield (kg ha^{-1})	LAI$_{max}$ (m^{2} m^{-2})	SPAD$_{max}$	P-index	Fertilization	Yield (kg ha^{-1})	LAI$_{max}$ (m^{2} m^{-2})	SPAD$_{max}$	P-index
2011	Ø	9602	3,9	59	407	Ø	10652	3,5	57	570
	N_{180}+PK	12388	4,2	60	615	N_{180}+PK	13148	4,2	59	695
2012	Ø	9656	2,8	58	573	Ø	10140	2,6	58	671
	N_{180}+PK	11955	3,1	60	781	N_{180}+PK	13170	3,1	60	940
2013	Ø	9029	2,1	51	781	Ø	10971	1,9	53	1202
	N_{180}+PK	10812	2,6	57	800	N_{180}+PK	14676	2,4	55	1658

Table 4. Pearson-correlation between the photosyntetic capacity (P-index) and yields of winter wheat and maize (Debrecen, Hungary, 2011-2013).

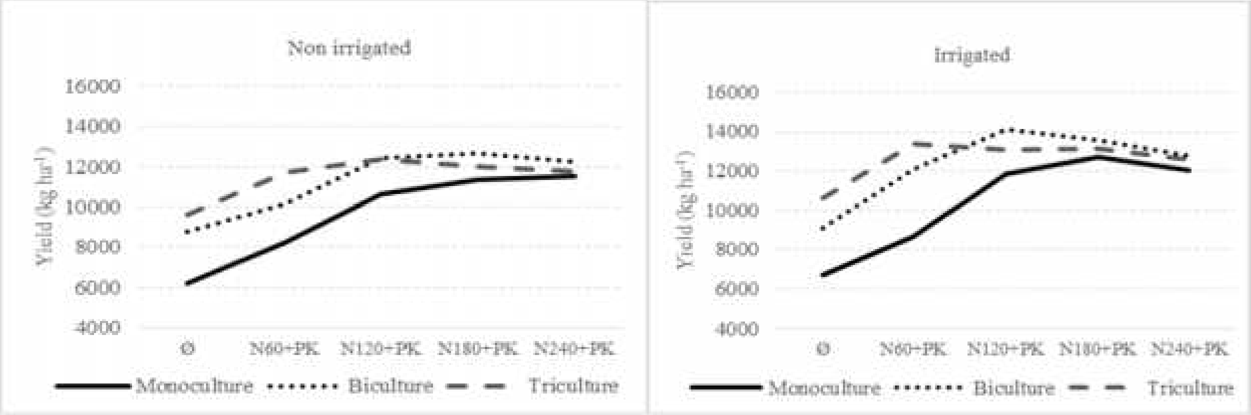
Years	**Winter wheat**	**Maize**
	Correlation coefficients	
2011	0.811(**)	0.792(**)
2012	0.938(**)	0.934(**)
2013	0.671(**)	0.888(**)

(**) Correlation on LSD$_{1\%}$



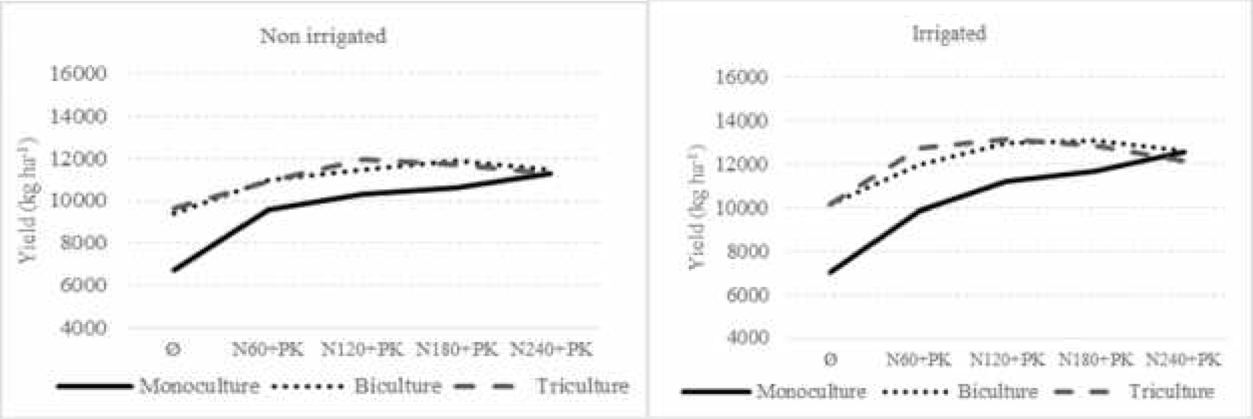
LSD$_{5\%}$=355 kg ha^{-1} (2011), 476 kg ha^{-1} (2012), 529 kg ha^{-1} (2013)

Figure 1. Effect of agrotechnical elements on the yields of winter wheat (Debrecen, Hungary, 2011-2013)



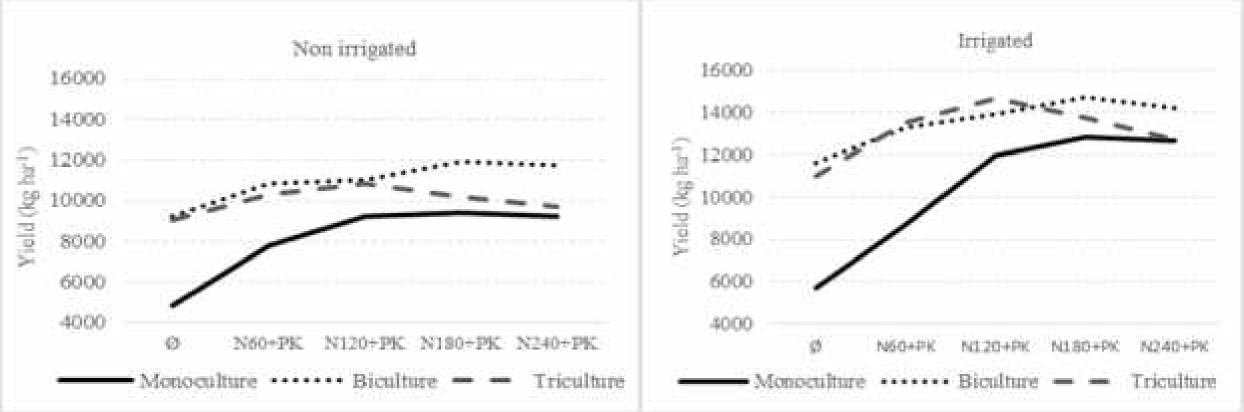
LSD$_{5\%}$=904 kg ha^{-1} (monoculture), 1206 kg ha^{-1} (biculture), 864 kg ha^{-1} (triculture)

Figure 2. Effect of agrotechnical elements on the yield of maize (Debrecen, Hungary, 2011)



LSD$_{5\%}$=781 kg ha^{-1} (monoculture), 1008 kg ha^{-1} (biculture), 1055 kg ha^{-1} (triculture)

Figure 3. Effect of agrotechnical elements on the yield of maize (Debrecen, Hungary, 2012)



LSD $_{5\%}$=841 kg ha^{-1}(monoculture), 1239 kg ha^{-1}(biculture), 927 kg ha^{-1}(triculture)

Figure 4. Effect of agrotechnical elements on the yield of maize (Debrecen, Hungary, 2013)

DISCUSSION

In a polifactorial long-term experiment, the effects of the year and the agrotechnical factors on the yields and plant physiological parameters (LAI, SPAD) of winter wheat and maize were studied on chernozem soil in the period of 2011-2013. The yields of winter wheat were slightly or more strongly influenced by the year. In the optimum agrotechnical treatment of wheat, the maximum yields were 10 050 kg ha^{-1} in 2011, 8203 kg ha^{-1} in 2012 and 8660 kg ha^{-1} in 2013. The yield of winter wheat was significantly influenced both by the fertilization and the crop rotation (Rieger *et al.*, 2008; Sieling *et al.*, 2005). In our long-term experiment, the yields of the C_4-type maize were considerably higher than those of the C_3-type winter wheat. The maximum yields of maize varied between 9400-12 700 kg ha^{-1} in the non-irrigated treatment and between 12 700-14 700 kg ha^{-1} in the irrigated treatment depending upon the year. The maize yield was mainly influenced by the fertilization (Vad and Dóka, 2009; Széles *et al.*, 2013) and the crop rotation (Qiang *et al.*, 2010) and slightly (depending upon the water supply of the year) by irrigation (Pepó *et al.*, 2008).

Our long-term wheat experimental results proved that the LAI_{max} values of wheat were mainly modified by fertilization (Petr *et al.*, 1980; Benett *et al.*, 1988; Uribelarrea *et al.*, 2009) and crop rotation, too. Fertilization (Ji *et al.*, 2007; Hu *et al.*, 2010; Hao *et al.*, 2011) and crop rotation (Smagacz, 2004) had positive effects on the SPAD values of wheat, but we did not find significant effects between these agrotechnical elements and SPAD (chlorophyll content) in wheat production.

The LAI_{max} values of maize have been reported to be influenced by fertilization (Anderson *et al.*, 1985; Sing and Storskopf 1971), environment (Borrás *et al.*, 2005). In the present study the LAI_{max} values were increased by fertilization (in control 1.4-3.5 m^2m^{-2} ; in N_{180}+PK treatment 2.3-4.2 m^2m^{-2} depending on crop year, crop rotation and water supply). In our long-term experiments of maize we found non-significant correlation between the SPAD values of maize and agrotechnical elements which were opposite statements comparing with the results of Evans (1989), Lemaire *et al.* (2008) (fertilization), Széles (2007) (irrigation), Pepó and Vári (2014) (crop rotation).

Results of our plant physiological examinations proved that there are relatively moderate differences in the LAI and SPAD values of the C_3- (winter wheat) and C_4- (maize) type cereal species. However, the maximum yield of maize (11 000-15 000 kg ha^{-1}) was significantly higher than that of winter wheat (8000-10 000 kg ha^{-1}). Our examinations proved that the difference is due to the different photosynthetic capacity of the two crops. For the description of this, a new parameter was developed by Pepó (P-index, Ph.C.). The research results showed that the P-index (Ph.C.) values of the C_3 winter wheat and the C_4 maize varied between 300-400 and 800-1200, respectively. The Ph.C. cannot only be used for the differentiation of C_3 and C_4 cereal species, but also for the characterization of the agrotechnical factors (Table 4). The Ph.C. values were influenced by the fertilization and the crop rotation in winter wheat and by the fertilization, the crop rotation and the irrigation in maize. Using Pearson's correlation analysis, a tight significant correlation was found between the yield of winter wheat and the P-index (Ph.C.) values ($r = 0.671\text{-}0.938^{**}$) and between the yield of maize and the P-index (Ph.C.) values ($r = 0.792\text{-}0.934^{**}$).

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