Growth and clorophyll content dynamics of Winter Wheat (*Triticum aestivum* L.) in different cropyear

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SUMMARY

The experiments were carried out at the Látókép experimental station of the University of Debrecen on chernozem soil in a long term winter wheat experiment in the season of 2011 and 2012 in triculture (pea-wheat-maize) and biculture (wheat-maize) at three fertilisation levels (control, N_{50}+$P_{35}K_{40}$, N_{150}+$P_{105}K_{120}$). Two different cropyears were compared (2011 and 2012).

The research focused on the effects of forecrop and fertilisation on the Leaf Area Index, SPAD values and the amount of yield in two different cropyears. We wanted to find out how the examined parameters were affected by the cropyear and what the relationship was between these two parameters and the changes of the amount of yield.

Examining the effects of growing doses of fertilizers applied, results showed that yields increased significantly in both rotations until the N_{150}+PK level in 2011 and 2012. By comparing the two years, results show that in 2011 there was a greater difference in yields between the rotations (7742 kg ha^{-1} at N_{150}+PK in the biculture and 9830 kg ha^{-1} at N_{150}+PK in the triculture). Though wheat yields following peas were greater in 2012, results equalized later on at N_{150}+PK levels (8109–8203 kg ha^{-1}).

Due to the favorable agrotechnical factors, the leaf and the effects of the treatments grown to a great extent in 2011, while in 2012 the differences between treatments were moderate. Until the N_{150}+PK level, nitrogen fertilisation had a notable effect on the maximum amount of SPAD values (59.1 in the case of the biculture and 54.0 in the triculture).

The highest SPAD values were measured at the end of May (during the time of flowering and grain filling) in the biculture. In the triculture, showed high SPAD values from the beginning. The same tendency could be observed in the 2012 cropyear, although increasing doses of fertilizers resulted in higher SPAD values until N_{150}+PK level only from the second measurement. Maximum SPAD values were reached at the end of May in both crop rotation system

Keywords: *winter wheat, crop year, growth dynamics, yield*

ÖSSZEFOGLALÁS

A vizsgálatokat a Debreceni Egyetem AGTC Látóképi Kísérleti Telepén beállított tartamkísérletben végeztük, trikultúra (borsó-búza-kukorica) és bikultúra (búza-kukorica) vetésváltásban, 3 tápanyagszinten (kontroll, N_{50}+$P_{35}K_{40}$, N_{150}+$P_{105}K_{120}$) őszi búzánál mészlepedékes csernozjom talajon. Két eltérő évjáratot hasonlítottunk össze (2011, 2012).

A kísérletben az elővetemények és a műtrágyaadagok hatását vizsgáltuk az őszi búza levélfelületi indexére, SPAD értékeire, valamint a termés mennyiségére két eltérő évjárat esetén. Arra kerestük a választ, hogy a vizsgált paraméterek alakulását hogyan befolyásolja az évjárat, valamint, hogy e két mutató milyen összefüggésben van a termés mennyiségének változásával.

A műtrágyázás hatását vizsgálva 2011-ben és 2012-ben, mindkét vetésváltásnál megállapítható, hogy a növekvő trágyaszintek hatására szignifikánsan növekedtek a termés mennyiségek az N_{150}+PK tápanyagkezelésig. A két évet összehasonlítva megállapítható, hogy 2011-ben nagyobb különbségeket kaptunk az eltérő vetésváltás során a terméseredményekben (bikultúra az N_{150}+PK-nál 7742 kg/ha, trikultúra az N_{150}+PK-nál: 9830 kg/ha). 2012-ben ugyan több volt a termés mennyisége a borsó után vetett búza állományoknak, de az N_{150}+PK tápanyagszintnél már kiegyenlítődtek a termésmennyiségek (8109–8203 kg/ha).

Amíg 2011-ben a kedvező agrotechnikai tényezők hatására sokkal nagyobb levélfelület alakult ki (virágzás és a termékenyülés idején 1,3–4,2 m^2/m^2), és sokkal erőteljesebben jelentkeztek a kezelések hatásai, addig 2012-ben a kezelések közötti különbségek elhalványultak (virágzás és a termékenyülés idején 2–3,7 m^2/m^2).

Mindkét elővetemény után a N-műtrágyázásnak az N_{150}+PK kezelésig jelentős hatása volt a SPAD-értékek maximumára (bikultúránál: 59,1; trikultúránál: 54,0). A május végi mérés esetén (a virágzás és termékenyülés időszakában) kaptuk a legnagyobb SPAD-értékeket bikultúrában. Trikultúrában azonban már az első mérés során magas SPAD-értékeket mértünk. A 2012-es tenyészévben is hasonló tendencia volt megfigyelhető. A második méréstől tapasztaltuk, hogy a növekvő tápanyagszintek hatására szignifikánsan nagyobb SPAD-értékeket kapunk, N_{150}+PK kezelésig. A virágzás és termékenyülés időszakában kaptuk a legnagyobb SPAD-értékeket tri- (35,5–58,5) és bikultúrában (56,4–59,2) egyaránt.

Kulcsszavak: *őszi búza, évjárat, növekedési dinamika, termés*

REVIEW OF SCIENTIFIC LITERATURE

Some of the biggest challenges in crop production are environmental changes caused by lack of available water and the decrease of ground water (Efeoğlu et al., 2009). Global climate change – temperature rising and inadequate distribution of precipitation over time – responsible for drought is expected to result in yield loss in crop production (Campos et al., 2004). According to Pepó (2002) the biggest risk factors of wheat production are today's extreme weather conditions.

SPAD chlorophyll indicator is a widely known tool amongst several other existing used to forecast yield (Le Bail et al., 2005). Chlorophyll content of the leaves provides information on the physiological condition of the plant (Carter, 1994) and there is a strong relationship between SPAD values, nitrogen and chlorophyll content of the leaves (Wood et al., 1993; Cartelat et al., 2005; Hu et al., 2010;).

Another important indicator is the leaf area index (LAI) determining the amount of yield. According to Ragasits (1998), one half of the dry material incorporated into the grain comes from the assimilation during the ripening process and the other half is translocated from various parts of the plant. Sugár and Berzsenyi (2009) found differences in LAI values caused by nitrogen supply in 2007 and 2008 as well. The lowest LAI values were measured in the N_0 treatment which significantly increased at level N_{80} and reached the maximum – in line with seasonal dynamics – at N_{160} and N_{240} levels. Knowledge of the changes of leaf coverage over time and space is needed to understand the growth, development and yield formation of wheat (Yang et al., 2007).

MATERIALS AND METHODS

The experiments were carried out at the Látókép experimental station of the University of Debrecen on chernozem soil in a long term winter wheat experiment in the season of 2011 and 2012 in triculture (pea-wheat-maize) and biculture (wheat-maize) at three fertilisation levels (control, N_{50}+$P_{35}K_{40}$, N_{150}+$P_{105}K_{120}$). The wheat variety used in the long-term trial was GK Csillag. The soil of the research site is plain and homogen, its genetic soil type is calciferous chernozem. The soil-physical category of the soil is loam, its pH value is almost neutral, phosphorus supply is medium, and potassium supply is medium–good. Humus content is medium, the thickness of humus layer is about 80 cm. Estimated depth to groundwater is 3–5 m.

Two different cropyears were compared. A mobile Soil Plant Analysis Development chlorophyll indicator (SPAD-502 Plus, Konica Minolta) was used to determine nitrogen supply of wheat. During the cropyear, measurements were applied four times in 2011 (30 March, 26 April, 24 May, 21 June) and in 2012 (23 March, 19 April, 22 May, 25 June) and this meant thirty measurements by repetition. In every case, the leaf area was determined by the SunScan Canopy Analysis Systems (SS1) mobile indicator, measurements were applied four times in 2011 (30 March, 26 April, 24 May, 21 June) and six times in 2012 (23 March, 19 April, 9 May, 22 May, 14 June, 25 June) Eight measurements were applied by repetition.

A contrast could be observed in the weather of the 2010/2011 cropyear; a wet period from October till December and a dry season between January and June. Regarding the temperature, October, December and February were cooler than the average, while the rest of the year was warmer compared with the average of the prior 30 years, which had a positive impact on the development of winter wheat.

In the case of the 2011/2012 growing year, the amount of precipitation was higher only in December, May and June compared with the average over a period of time. Meteorological conditions regarding the temperature were optimal considering the development of wheat, although October and November were cooler compared with the average over a period of time *(table 1)*.

Table 1.

Meteorological parameters in the vegetation period of winter wheat (precipitation, mean monthly temperature) (Debrecen, 2011–2012)

Month	Precipitation (mm)				
	2010/2011	2011/2012	30-year average	Difference 2011	Difference 2012
October	22.8	18.1	30.8	-8.0	-12.7
November	52.9	0.0	45.2	7.7	-45.2
December	104.2	71.1	43.5	60.7	27.6
January	19.2	28.0	37.0	-17.8	-9.0
February	16.8	17.8	30.2	-13.4	-12.4
March	35.1	1.4	33.5	1.6	-32.1
April	15.6	20.7	42.4	-26.8	-21.7
May	52.3	71.9	58.8	-6.5	13.1
June	22.0	91.7	79.5	-57.5	12.2
Total precipitation (October–June) (mm)	340.9	320.7	400.9	-60.0	-80.2
	Temperature (°C)				
October	6.9	8.6	10.3	-3.4	-1.7
November	7.7	0.6	4.5	3.2	-3.9
December	-1.7	1.5	-0.2	-1.5	1.7
January	-1.2	-0.6	-2.6	1.4	2.0
February	-2.5	5.7	0.2	-2.7	5.5
March	5.0	6.3	5.0	0.0	1.3
April	12.2	11.7	10.7	1.5	1.0
May	16.4	16.4	15.8	0.6	0.6
June	20.5	20.9	18.8	1.7	2.1
Mean temperature (October–June) °C	7.0	7.9	6.9	0.1	1.0

RESULTS AND DISCUSSION

The research focused on the effects of forecrop and fertilisation on the Leaf Area Index, SPAD values and the amount of yield in two different cropyears.

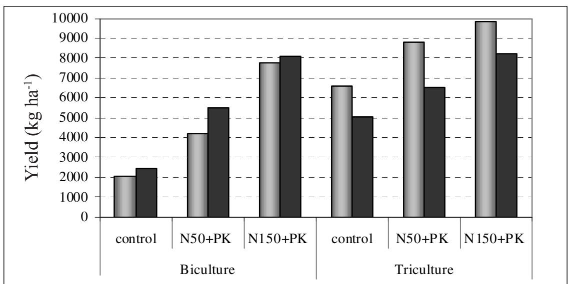
We wanted to find out how the examined parameters were affected by the cropyear and what the relationship was between these two parameters and the changes of the amount of yield.

The yield of winter wheat

Comparing maximum yields of wheat following corn and peas in 2011, it can be stated that the yields of wheat in triculture rotations were 2088–4615 kg ha^{-1} higher than the ones in the biculture at the same nutrition levels. Examining the effects of growing doses of fertilizers applied, results showed that yields increased significantly in both rotations until the N_{150}+PK level *(figure 1)*.

The tendency was the same in 2012 and, besides, statistically-proven positive impacts of fertilisation and crop rotation were also shown this year. By comparing the two years, results show that in 2011 there was a greater difference in yields between the rotations (7742 kg ha^{-1} at N_{150}+PK in the biculture and 9830 kg ha^{-1} at N_{150}+PK in the triculture). Though wheat yields following peas were greater in 2012, results equalized later on at N_{150}+PK levels (8109–8203 kg ha^{-1}).

Figure 1: **Effect of fertilisation on the yield of the winter wheat in biculture and triculture (Debrecen, 2011–2012)**

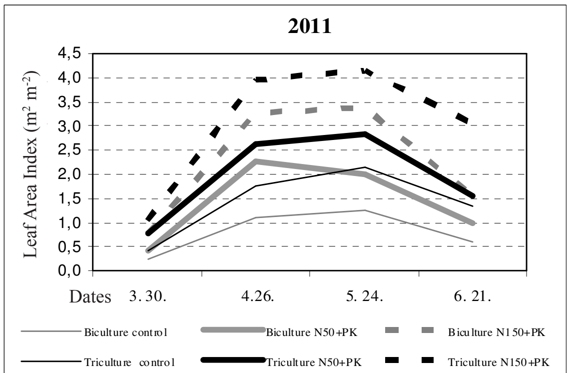


	2011	2012
LSD 5% crop rotation system	731	457
LSD 5% fertilisation	232	283
LSD 5% interaction	328	401

The development of leaf area of wheat

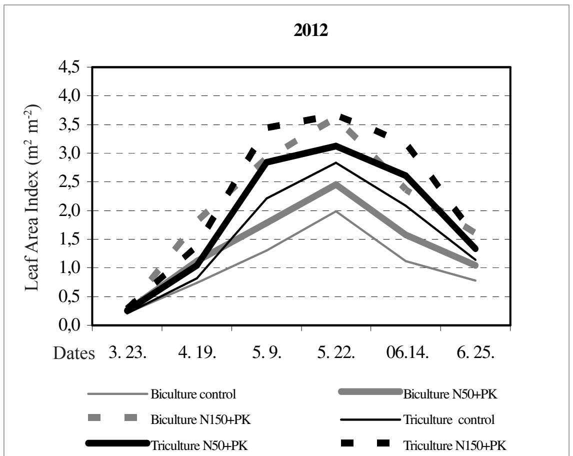
Grain yield and the volume of phytomass produced are altered by both the leaf area and its dynamics so we measured the leaf area per 1 m^2 and illustrated its dynamics. At the time of the first measurement in 2011, the Leaf Area Index showed significant differences between the control and the others doses of nitrogen, in both rotation system however (0.3–1.1 m^2 m^{-2}), in 2012 at the first measurement (at the end of March) irrespectively of plant nutrition and forecrop, the differences between LAI were rather small (0.2– 0.3 m^2 m^{-2}) *(figure 2– 3)*.

Figure 2: **Effect of crop year, fertilisation and forecrops on Leaf Area Index (LAI) of winter wheat (Debrecen, 2011)**



Dates	30.3.	26.4.	24.5.	21.6
LSD 5% crop rotation	0,3	0,9	0,6	0,9
LSD 5% fertilisation	0,2	0,4	0,4	0,2
LSD 5% interaction	0,2	0,6	0,5	0,2

Figure 3: **Effect of crop year, fertilisation and precrops on Leaf Area Index (LAI) of winter wheat (Debrecen, 2012)**



Dates	23.3.	19.4.	9.5.	22.5.	14.6.	25.6.
LSD 5% crop rotation	0,1	0,6	0,8	0,5	0,7	0,3
LSD 5% fertilisation	0,0	0,1	0,3	0,3	0,4	0,2
LSD 5% interaction	0,0	0,2	0,4	0,5	0,5	0,2

At the time of the following measurements, treatments resulted in significant differences in both crop years, however, positive effects of previous cropping and increased doses of fertilizers were stronger due to favorable weather conditions for wheat in 2011.

Regarding the changes of LAI over time, a significant increase could be experienced from the time of flowering and grain filling (the end of May) irrespectively of plant nutrition and previous crop. This was the point where the maximum level of leaf canopy was reached but showed a decreasing tendency afterwards. The difference is in the shape of the curves. Due to the favorable agrotechnical factors, the leaf area (1.3 and 4.2 m^2 m^{-2} at the time of flowering and grain filling) and the effects of the treatments grown to a great extent in 2011, while in 2012 the differences between treatments were moderate (2 and 3.7 m^2 m^{-2} at the time of flowering and grain filling).

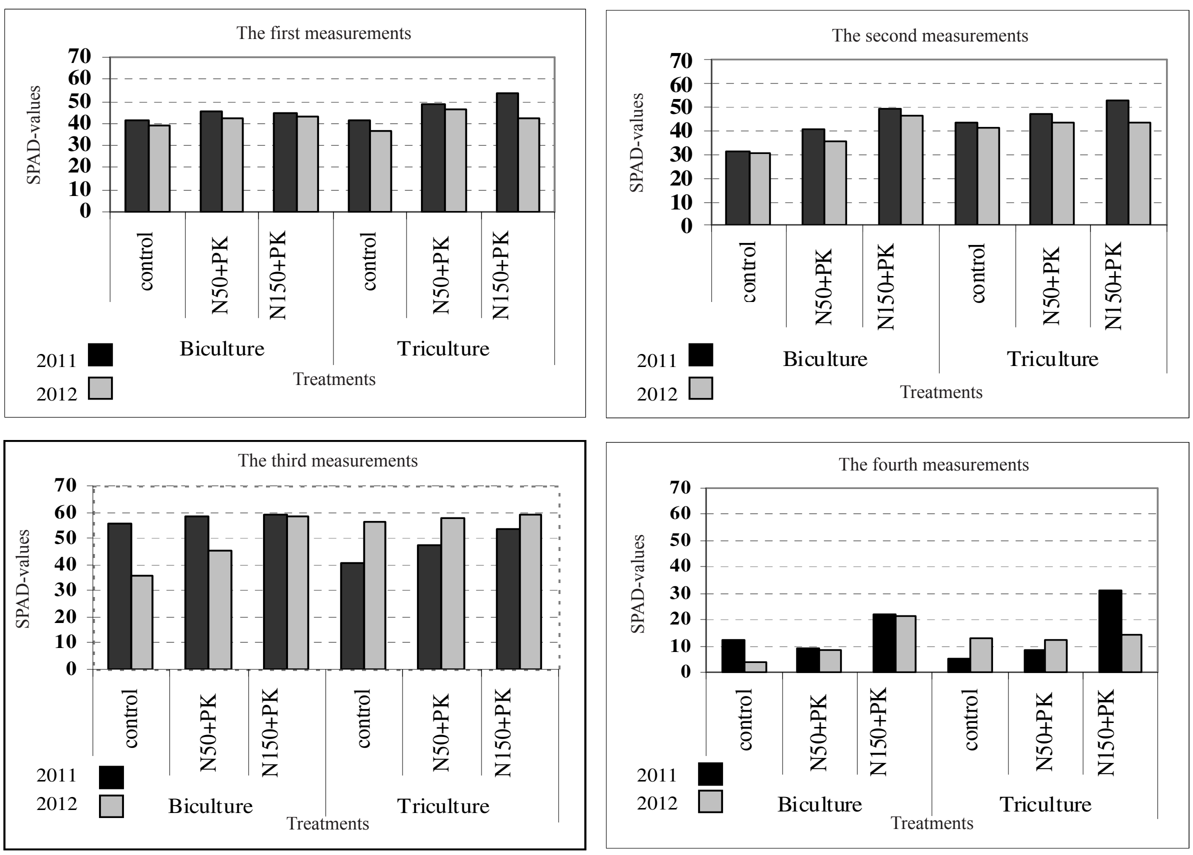
Increasing doses of fertilizers significantly enlarged the leaf area of winter wheat until the level of N_{150}+PK. By comparing the rotation systems, the leaf area of wheat was larger after peas, but this difference was not significant at any time of the measurement which fact can be proved by statistics. When setting the cropyears together, it can be concluded that wheat stands in 2011 kept their leaf areas much longer and values were between 0.6 and 3.1 m^2 m^{-2} even at the time of the last measurement. Accordingly, vegetative development of winter wheat was considerably determined by weather conditions.

The development of SPAD values of wheat

At the time of the first measurement in 2011, irrespectively of plant nutrition and previous crop, the differences between SPAD values were rather small (41.3 and 54.0), however, the second measurement showed significant differences between the control, the N_{50}+PK and the N_{150}+PK levels in both rotation systems. Until the N_{150}+PK level, nitrogen fertilisation had a notable effect on the maximum amount of SPAD values (59.1 in the case of the biculture and 54.0 in the triculture). It was a difference. The highest SPAD values were measured at the end of May (during the time of flowering and grain filling) in the biculture. In the triculture, on the other hand, showed great SPAD values from the beginning. However, SPAD values in winter wheat stands following peas were significantly lower than the ones following corn (55.8–59.1).

The same tendency could be observed in the 2012 cropyear, although increasing doses of fertilizers resulted in greater SPAD values until N_{150}+PK level only from the second measurement. Beneficial effects of crop rotation were shown this year since SPAD results increased notably in triculture in the cases of each treatment. Maximum SPAD values were reached at the end of May in both crop rotation system *(figure 4.)*.

Figure 4: **Effect of crop year, fertilisation and forecrops on dynamics of SPAD-values of winter wheat (Debrecen, 2011–2012)**



CONCLUSIONS

To sum it up, it is safe to say 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. These results have confirmed that the leaf area and the SPAD-values have altogether resulted in the production of maximum grain yields. These analysis makes it possible to predict the yield of winter wheat.

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