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The Impact of Crop Rotation and N Fertilization on the Leaf Area Index, Leaf Disease and Yield of Winter Wheat

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Abstract**—**The research focused on the effects of previous cropping and fertilizers on the LAI, rhythm of the dry matter, leaf disease intensity and amount of yield. Long term field experiments' results proved that the previous crop fundamentally determines size, rate and dynamics of the dry matter formation in the spring time vegetation period. The LAI index and crop results of winter wheat can be influenced mainly by raising the fertilizer amount. N fertilization has an outstanding role in the changes in leaf area index (LAI), weight of dry matter and yield of winter wheat. According to our results, the interaction effect of leaf area index, weight of dry matter and fertilization resulted in the maximum yield in biculture and triculture.

Keywords**—**Crop rotation, Leaf Area Index, leaf disease of winter wheat**.**

I. Introduction

MANY aspects of agricultural production can be adversely affected by weather [1]. The importance of climate factors is decisive for wheat yield. Crop fluctuations are principally caused by climate factors, especially the lack of precipitation [2]. Precipitation in May was the factor most consistently related to leaf disease intensity, and adding another two weather factors further improved the degree of explanation [3]. Weather factors in the preceding growing season influenced growth stage, powdery mildew and brown rust. Fungicide treatment of winter wheat is prevalent and recommended almost routinely against leaf diseases. The yield increases and hence the resulting net returns from fungicide use are highly variable within and between years. These variations raise questions about whether, when and how fungicides should be used [4]. Winter wheat is one of the crops with the highest reaction to fertilization. In the recent decades a significant increase in yields has been achieved by the use of higher-yielding varieties and the application of fertilization [5].

The optimum N fertilization rates in the dry, normal and wet years increased following an increasing sequence of 45, 135 and 180kg N ha^{-1}. These results have significant implications for optimizing N fertilization and maximizing yield [6]. Stability analysis combined with the trend analysis indicated that integrated use of fertilizer N and P was better than their sole application in increasing and sustaining the productivity of rainfed winter wheat [7]. Different preceding crops have also a major effect on crop yields.

The N fertilization significantly extends the LAI of wheat, the Leaf Area Density (LAD), as well as the fact that the leaf area formation influences the amount of crop [8], [9].

There were differences in LAI values caused by nitrogen supply in 2007 and 2008 as well [10]. 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 [11]. The direct pre-crop affected the grain-yield of winter wheat in a significant extent, but the composition of the crop-rotation system did not have any significant effect [12].

Wheat following oilseed rape achieved nearly 9.5 t ha^{-1}, whereas the second wheat crop following wheat yielded about 0.9 t ha^{-1} and the third wheat crop following 2 years of wheat about 1.9 t ha^{-1} less compared with wheat after oilseed rape [13].

II. Material and Methods

The experiments were carried out at the Látókép experimental station of the Centre for Agricultural and Applied Economic Sciences, University of Debrecen on chernozem soil in a long term winter wheat experiment. The experimental site is located in north-eastern part of Hungary, on the area of the aeolain loess of the Hajdúság (N: 47º33', E: 21º27'). 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 80cm. Estimated depth to groundwater is 3-5m (see Table I). As forecrop rotation, we set up two models: a biculture (wheat and corn) and a triculture (pea, wheat and corn). We applied three levels of nutrients during the fertilization process (control, $N_{50}P_{35}K_{40}$ and $N_{150}P_{105}K_{120}$). We spread 100% of phosphor and potassium fertilizer and 50% of nitrogen fertilizer in autumn, in 11:15:17 complex form.

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TABLE I
EXPERIMENTAL SOIL DATA

Soil layes (cm)	pH value	Soil physical structure	$CaCO_3$ %	Humus content %	Total N %	NO_3+NO_2 ppm	P_2O_5	K_2O
							AL soluble	
							ppm	ppm
0-25	6.46	43.0	0	2.76	0.150	6.20	133.4	239.8
25-50	6.36	44.6	0	2.16	0.120	1.74	48.0	173.6
50-75	6.58	47.6	0	1.52	0.086	0.60	40.4	123.0
75-100	7.27	46.6	10.2	0.90	0.083	1.92	39.8	93.6
100-130	7.36	45.4	12.7	0.59	0.078	1.78	31.6	78.0

During the application of fertilizer in spring we spread 50% of the nitrogen fertilizer in form of 34% NH_4NO_3. We used general pest control technologies, Tango Start 0.8 l/ha dose at the beginning of flowering, while we did not do any pest control. The experimental parcels were set up in random arrangements in four repetitions. The wheat variety used in the long-term trial was GK Csillag. The most important agrotechnical and meteorological data is summarized in Table II.

TABLE II
METEOROLOGICAL PARAMETERS IN THE VEGETATION PERIOD OF WINTER WHEAT (DEBRECEN, HUNGARY, 20112012)

Month	Precipitation, mm	30-year average	Difference
October	18.1	30.8	-12.7
November	0	45.2	-45.2
December	71.1	43.5	27.6
January	28	37	-9
February	17.8	30.2	-12.4
March	1.4	33.5	-32.1
April	20.7	42.4	-21.7
May	71.9	58.8	13.1
June	91.7	79.5	12.2
Total precipitation	**320.7**	**400.9**	**-80.2**
	Temperature, ^{0}C	30-year average	Difference
October	8.6	10.3	-1.7
November	0.6	4.5	-3.9
December	1.5	-0.2	1.7
January	-0.6	-2.6	2
February	5.7	0.2	5.5
March	6.3	5	1.3
April	11.7	10.7	1
May	16.4	15.8	0.6
June	20.9	18.8	2.1
Mean temperature	**7.9**	**6.9**	**1**

In the case of the 2011/2012 cropyear, 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, November and December were cooler compared with the average over a period of time.

The research focused on the effects of previous cropping and fertilizers on the LAI, rhythm of the dry matter, leaf disease intensity and amount of yield.

Vegetal sampling was made six times (23 March, 19 April, 9 May, 22 May, 14 July, 25 June), from which we could calculate the total dry weight of the plants. The assimilation efficiency highly depends on the leaves, usually on the size of green area (LA= Leaf Area), which used to be characterized by the Leaf Area Index (LAI). The SunScan Canopy Analysis Systems (SS1) mobile indicator was used to determine the leaf area. The measurements were applied six times in 2012 (23 March, 19 April, 9 May, 22 May, 14 June, 25 June) and this meant eight measurements by repetition.

For the definition of leaf disorders' infection dynamics and interactive effects of agrotechnical factors, we examined the degree of powdery mildew infection *(Erysiphe graminis* F. sp. *tritici)*, on helminthosporiosis (HTR) and leaf rust infection *(Puccinia recondita)*.

III. RESULTS AND DISCUSSION

The generated total dry matter weight in the examined rearing year was 737.6-1254.4g m^{-2} in the control treatment, in the N_{150}+PK treatment between 1569.6-1917.2g m^{-2}, depending on previous crops. This previous crop highly influenced the degree dry weight formation and dynamics. The dry weight formation of wheat was in case of peas as preceding crop almost twice as high (1254.4g m^{-2}) as after corn (737.6g m^{-2}) as preceding crop. The intense formation of dry weight took place in May, the LAI maximum was reached end of May at the time of flowering and grain filling. After maize and pea forecrop also, N fertilization had a significant effect on leaf area index dynamics and its maximum up to the treatment N_{150}+PK, significant differences were found between the three fertilization treatments. In both crop rotations, the maximum leaf area index was measured at flowering-grain filling in winter wheat stands (see Fig. 1). Considerably higher leaf area index was measured in triculture applied the control treatment (2.8 m^2m^{-2}), than in biculture (2.0 m^2m^{-2}). These results are explicable by the fact that peas increase the nitrogen supply of the soil, have water saving properties on the soil and have a beneficial effect on the soils chemical and physical state. In this way it could help the winter wheat in the formation of dry weight and sufficient LA.

The results of infection dynamics' examinations showed that in the 2011/2012 cropyear the leaf disorders appeared later, spread moderately and stayed on a low level in the wheat stands (1-6%). This was also in coherence with the weaker vegetative development of the stands, as well as with the averagely dryer and warmer spring weather (in March 1.4mm precipitation fell, the long years' average is 33.5mm; in April 20.7mm precipitation fell with a long years' average of 42.2mm), which did not show favour toward the appearance of

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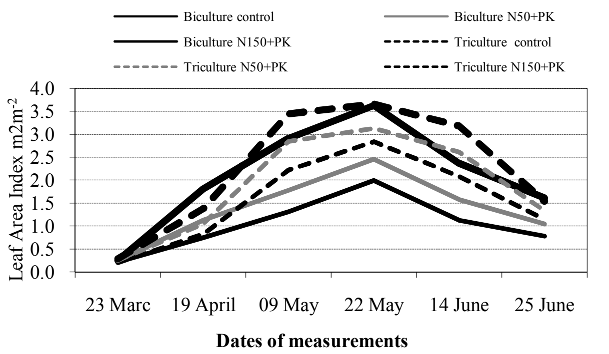
diseases. However the extremely rainy weather in 2009/2010 was favourable not only for the vegetative development of the stand, but also increased the occurrence of leaf-, stalk- and ear-diseases and a high degree of lodging was observed [14]. The powdery mildew infection appeared beginning-middle of May in the stands and showed a moderate inflectional dynamics until mid-June. The fertilization usage slightly increased the level of infection, in case of N_{150}+PK treatment bi-plantation with 4%, in case of tri-plantation with 6%. The helminthosporiosis (HTR) usually infects in humid vintages, however is – at different levels - always present in the plantations [15].



Dates	23 Marc	19 April	09 May	22 May	14 June	25 June
LSD $_{5\%}$ crop rotation	0,1	0,6	0,8	0,5	0,7	0,3
LSD $_{5\%}$ fertilization	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

Fig. 1 Effect of fertilization and pre-crops on Leaf Area Index (LAI) of winter wheat (Debrecen, 2011/2012)

The high precipitation in May (71.9mm with a long years' average of 58.8mm) and June (91.7mm with a long years' average of 79.5mm) helped the development of HTR infection. The infection rate of HTR was the highest at the point of the highest nutrient content of the soil, after peas as preceding crop it reached 24%. In the control treatment only moderate HTR infection was measured (9-12%). Due to the dry, warm spring weather and the weaker vegetative development the leaf rust infection appeared in mid-June, the infection level stayed low (1-10% depending on fertilization and preceding crops). Leaf rust infection maximum was reached in case of the N_{150}+PK treatment, 7% at biculture, and 10% at triculture (see Table III).

We reached a crop yield between 2429-5015kg ha^{-1} on the control parcel, depending on crop rotation system. In case of the winter wheat's biculture we reached a crop yield between 5490-8109kg ha^{-1}, in triculture between 6554-8203kg ha^{-1}, depending on the amount of fertilizer. Crop rotation had a positive effect on the triculture, so a higher crop yield was reached, however at the level of N_{150}+PK fertilizer at peas as previous crop no statistical proven crop yield raising effect is to be seen. We reached a crop yield between 2429-5015kg ha^{-1} on the control parcel, depending on crop rotation system. In case of the winter wheat's biculture we reached a crop yield between 5490-8109kg ha^{-1}, in triculture between 6554-8203 kg ha^{-1}, depending on the amount of fertilizer. Crop rotation had a positive effect on the triculture, so a higher crop yield was reached, however at the level of N_{150}+PK fertilizer at peas as previous crop no statistical proven crop yield raising effect is to be seen (see Fig. 2).

TABLE III
EFFECT OF FERTILIZATION ON LEAF DISEASES OF WINTER WHEAT IN A BI- AND TRICULTURE (DEBRECEN, HUNGARY, 2011/2012)

Fertilization	Repetition	Powdery mildew %	Helminthosporiosis %	Leaf rust %
		17 June	17 June	24 June
		Biculture		
control	I.	2	12	2
	II.	1	11	1
	III.	0	7	0
	IV.	1	6	1
	mean	**1**	**9**	**1**
N50+PK	I.	4	8	3
	II.	1	9	0
	III.	1	14	2
	IV.	2	13	3
	mean	**2**	**11**	**2**
N150+PK	I.	3	22	10
	II.	6	20	6
	III.	2	14	5
	IV.	5	16	7
	mean	**4**	**18**	**7**
		Triculture		
control	I.	4	10	4
	II.	1	15	2
	III.	1	9	1
	IV.	2	14	1
	mean	**2**	**12**	**2**
N50+PK	I.	2	12	2
	II.	3	17	2
	III.	6	11	4
	IV.	5	16	4
	mean	**4**	**14**	**3**
N150+PK	I.	5	19	8
	II.	4	19	7
	III.	8	27	13
	IV.	7	31	12
	mean	**6**	**24**	**10**
LSD $_{5\%}$	Crop rotation	3,8	7,9	3,6
LSD $_{5\%}$	Fertilization	1,6	4,1	1,8
LSD $_{5\%}$	kölcsönhatás	2,3	5,8	2,6

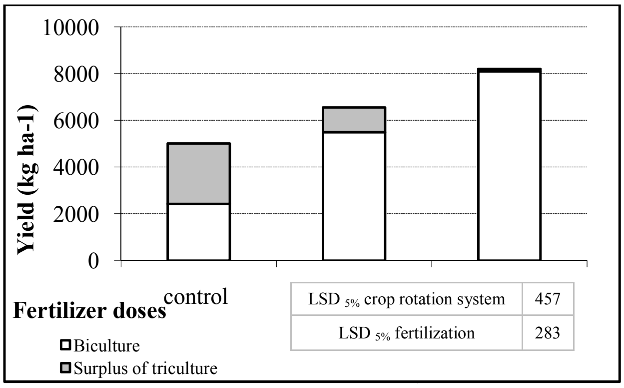


Fig. 2 Effect of fertilization on the yield of the winter wheat in biculture and triculture (Debrecen, 2011/2012)

IV. Conclusion

Long term field experiments' results proved that the previous crop fundamentally determines size, rate and dynamics of the dry matter formation in the spring time vegetation period.

The LAI index and crop results of winter wheat can be influenced mainly by raising the fertilizer amount. In the examined rearing year the effect of crop rotation was the most significant in case of N_{50}+PK treatment and in the control section. In case of the N_{150}+PK treatment the positive effects of peas as forecrop were not that significant in the results of LAI index and crop results at winter wheat.

Dry and warm weather resulted moderate appearance of diseases in the stands.

In the 2011/2012 crop year leaf diseases did not appear significantly in the wheat stands, which prove the research results of [16]. The leaf diseases are determined by the properties of the crop year and in case that the precipitation amount is between 200-250 mm in the spring and summer months (April, May, June) the diseases significantly appear [16].

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