Thesis of doctoral (PhD) dissertation

THE EFFECT OF CROP ROTATION AND NUTRIENT SUPPLY ON SOME PHYSIOLOGICAL AND AGRONOMICAL PARAMETERS, JUST AS YIELD OF WINTER WHEAT GENOTYPES

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1. INTRODUCTION

One of the main challenges of the 21st century is to develop and use the concept of sustainable development that enables the satisfaction of next generations' food demand. Cereals are classed among the most important field crops both world- and nationwide. Winter wheat is of specific importance on the most parts of the Earth, because its production is possible even in case of extreme soil conditions and ecological circumstances due to its extraordinary adapting ability. 1994 LÁNG stated: 'Basic human needs shall be ensured for all habitants of the Earth, however, at the same time natural resources shall be managed so that next generations will be able to satisfy their demands as well. It is definitely hard to fulfil, because Earth population is already 5.5 billion and around 2020 it can even reach 8 billion'. His calculations were future-proof, because nowadays – in 2016 – Earth population is over 7.4 billion people. Some forecasts suppose that Earth population will increase to 8.3 billion until 2030, while till 2050 to 9 billion people (ANTAL, 2005). According to the prediction of UN (2012) Earth population will be close to 11 billion people till the end of the 21st century. Due to anthropogenic actions the size of production area of high worth decrease drastically worldwide and these effects are irreversible (deforestation, soil acidification, road construction etc.). Due to economic interests agriculture has become an intensive sector in the 21st century that cannot be profitable in a sustainable way without any yield loss. At present winter wheat is produced on 218 million hectares. Average yield amounts have increased in contrast to the level of 1961 by more than 2 t ha^{-1}.

Expenditures on nutrient supply have significantly decreased since the 90's in Hungary. This is the result of several reasons. Although mineral fertilizer application has increased again in the 2010's, today's application level is still considered as low. In contrast to Western-European countries an unfavourable tendency can be observed in the application of crop rotation in Hungary as well. Our national crop production system has been simplified to the production of cereals and oil plants. Unfavourable effects lead to the decrease of yield amounts due to the mutual effect of complex factors' negative components. Hungary plays a minor role in international market, however, depending on the given crop year 3-5 million tons of winter wheat is produced in the country. Beside the inland consume and the satisfaction of animal husbandry demand 0.5-2 million tons are exported year by year.

Both yield average and cropping area have decreased after the transition. From the aspect of soil, temperature and precipitation conditions Hungary is explicitly suitable for winter wheat production by the joint application of adequate agrotechnology, biological basis and plant protection management. Winter wheat is produced on 1.0-1.1 million hectares in Hungary with altering yield amounts that are affected negatively by mainly extreme dry or even wet weather conditions.

2. OBJECTIVES

The present Ph.D. dissertation aims to help both Hungarian farmers and researchers to get a more exact knowledge on plant production factors in the future that may lead to the production of higher and more stable yield amounts.

The objectives of the present research work were to study and evaluate:

- the effect of crop rotation and nutrient supply on soil moisture content and the development of soil penetration resistance in winter wheat populations
- the effect of crop year, agrotechnical and biological factors on the agronomic properties of winter wheat
- the effect of crop year, crop rotation and nutrient supply on plant pathology properties of winter wheat
- the effect of agrotechnical factors, variety and crop year on the physiological properties of winter wheat
- the yield amounts of different winter wheat varieties in different crop years in case of the application of diverse agrotechnical factors (crop rotation, nutrient supply)
- the effect of crop year, agrotechnical and biological factors on yield quality of winter wheat

2. MATERIALS AND METHODS

2.1. Location and soil properties of the experimental site

The present experimental research work was carried out at the Látókép Plant Production Research Site of the University of Debrecen that is located 15 km far from Debrecen, next to the main road Nr. 33 towards Hortobágy. The experimental soil is a calcareous chernozem soil type of good quality and agricultural condition, that has slightly acid pH

[pH_{KCl}: 6.3-6.5] and that is level and flat. Its plasticity acc. to Arany ranges in similar interval from soil surface to a depth of 100-130 cm (43.0-47.6).

Soil pH value (measured in KCl) is considered as favourable (6.46) and shows increasing tendency under a depth of 50 cm. Soil pH value varies between 7.27 and 7.36 in the deeper soil layers. Humus content (%) is the highest in the upper 0-25 cm soil layer: 2.76. AL-extractable P_2O_5 content is considered as medium, while its AL-extractable K_2O content is rather favourable.

The present experimental work was carried out in a long-term field experiment between October 2012 and July 2015. The long-term experiment was set up in 1983 by dr. Ernő Bocz and dr. Péter Pepó. After the first experimental year – that was used for setting up – the experiment has been carried out according to the original settings from the autumn 1984. The size of the plots is 2×5 m^2 that is 10 m^2. Treatments were set up in four replications, in split-split-plot experimental design. Nutrient supply treatments of the experiment are shown in **Table 1**.

Table 1: Applied fertilizer dosages of the experimental treatments (Debrecen, 2013-2015)

Treatment	**N**	**P_2O_5**	**K_2O**
	kg ha^{-1}		
0	0	0	0
1	30.0	22.5	26.5
2	60.0	45.0	53.0
3	90.0	67.5	79.5
4	120.0	90.0	106.0
5	150.0	112.5	132.5

In the present study the interactive effect of pre-crops, fertilization and varieties was evaluated in the crop years 2013-2015. The effect of following pre-crops was studied: sweet corn, maize and sunflower.
Four genotypes from national breeder institutes were involved into the experiment during the three-year study that were: GK Öthalom, GK Csillag, Mv Csárdás, Mv Toldi.

2.3. Methods used in the experimental work

In the present research work soil resistance and moisture content were measured in the control and N_{120}+PK nutrient supply treatments in four replications. Measurements were executed 4 times in each treatment plot: in the autumn period, early spring, at the flowering stage and after harvest. A Penetronik 2.0 hand device was used for the measurements. In the studied years 2013-2015 altogether 24 measurements were taken in each treatment.

The development of wheat leaf rust (*Puccinia triticina*), tan spot (Helminthosporium tritici-repentis) and powdery mildew (Erysiphe graminis) infection was monitored in June of each vegetation year. In order to describe the overall infection rate complex infection index (CII) was used. It is a value without dimension and explains the susceptibility of varieties towards infections. Using the software Microsoft Excel the size of the area encircled by the studied pathogens was represented in a radial diagram.

Different plant physiological parameters (LAI, SPAD, LAD, RCAD) were monitored in winter wheat populations in different phenological phases of the studied crop years.

Leaf area index (LAI) of winter wheat was determined using a portable leaf area mesurement device (SunScan Canopy Analysis Systems SS1) four times in the studied vegetations that were stem elongation (BBCH 30-37), flowering (BBCH 61-69), fruit development (milk stage – BBCH 71-79) ripening (dough stage – BBCH 83-89). LAI was measured six times in each plot in case of each measurement period that was altogether 24 measurements per treatment.

Relative chlorophyll content was measured with a Konica Minolta SPAD 502Plus portable hand device in the same phenologocal phases as LAI. It was measured in case of 20 plants per plot in the following way: until heading the most developed leafs were measured, while after heads were developed flag leaves were taken for the measurements.

Leaf area durability (LAD) values were determined using the method of BERZSENYI (2013): LAD = $[(L_1 + L_2) * (t_1 - t_2)] / 2$.

Photosynthesis is influenced by several treatments and factors (crop year, pre-crop, nutrient supply treatment, variety, plant pathological infections, leaf durability and its chlorophyll content). In order to confirm the effect of the mentioned factors a new plant physiological index was introduced that was relative chlorophyll content durability that informs about the days when plant photosynthesis is enabled. Relative chlorophyll content durability (RCAD) was calculated in the different phenological phases upon relative chlorophyll content (SPAD) using the following formula: $[(SPAD_1 + SPAD_2)* (t_1-t_2)] / 2 + [(SPAD_2 + SPAD_x)* (t_2-t_x)] / 2$

Quality parameters of winter wheat were determined in the Institute of Food Science, just as in the Agricultural Laboratory Centre of the University of Debrecen. Baking quality index (measured with valinograph), wet gluten content (%), wet gluten spread (mm h^{-1}) falling number (s) and water absorption (%) were measured among quality parameters. Experimental plots were harvested by a Sampo plot combine harvester, grain yield amounts were uniform recalculated to a moisture content of 14%.

Experimental results were processed using the software Microsoft Office 2013 Excel® and SPSS® for Windows 13.0 with ANOVA and Pearson correlation analysis tests. Results were analysed with one- and two-way analysis of variance according to the method described by SVÁB (1981). Furthermore, polinomial regression analysis was calculated. Optimum values were determined using quadratic linear eqations according to the floowing formula described by SARLANGUE et al. (2007):

$$y = a + bx + cx^2 \text{, where } x = -b / (2 * c)$$

3. RESULTS AND DISCUSSION

3.1. Study of soil moisture content and penetration soil resistance of winter wheat populations in case of the application of different agrotechnical factors

The effect of soil resistance on yield amount could not be verified. This is probably due to the favourable effect of the calcareous chernozem soil type that was affected by the pre-crop and precipitation conditions as well.

The positive role of winter precipitation was confirmed in the present soil moisture content measurements as well. No statistically significant difference was found between the studied agrotechnical elements in the early spring phase. In the early spring period soil depth affected soil moisture content at a significance confidence level of $P<0.01$. Our results confirmed that soil moisture content was increased significantly by a higher amount of precipitation. Soil moisture content measured in the control treatment was higher than that of the N_{120}+PK that was due to the effect of pre-crop on the soil properties. In the crop year of 2015 the unfavourable effect of maize as pre-crop on soil moisture content has been confirmed.

Table 2: Analysis of agrotechnical factors affecting soil moisture content using Pearson correlation analysis (Debrecen, 2014-2015)

Crop year	Factors	Soil moisture content	Yield
2014	Yield	0.003(ns)	-
	Pre-crop	0.041(ns)	-0.267(**)
	Nutrient treatment	0.018(ns)	0.851(**)
	Measurement time	0.486(*)	0.000(ns)
2015	Yield	0.123(ns)	-
	Pre-crop	-0.273(*)	-0.242(*)
	Nutrient treatment	0.034(ns)	0.970(**)
	Measurement time	0.052(ns)	0.000(ns)

(**) Correlation significant at a level of $LSD_{1\%}$ confidence interval, (*) Correlation significant at a level of $LSD5_{\%}$ confidence interval, (ns) Not significant

The present experimental results confirmed medium positive correlation between soil moisture content and sampling time in the crop year of 2014. In the crop year of 2015 weak negative correlation was found between soil moisture content and the applied pre-crop. The statistical analysis confirmed a weak negative relationship (r = -0.242* - 0.267*) between yield and pre-crop (**Figure 2**), just as strong positive correlation between yield and nutrient supply (r = 0.851* - 0.970*).

3.2. Study of the effect of agrotechnical, biological and ecological factors on winter wheat plant pathological characteristics

Complex infection index (CII) was determined in case of the studied pre-crops and varieties. Complex infection index (CII) can be calculated according to the following formula:

CII= (LR*HTR)/2 + (HTR*PM)/2

Abbreviations of the formula: LR: Leaf rust (%), HTR: Helminthosporium tan spot (%), PM: Powdery mildew (%)

According to our results it can be stated that infection index values of the novel varieties (GK Csillag, Mv Toldi) were lower than those of the older varieties (GK Öthalom, Mv Csárdás). The lowest infection index was determined in case of the variety GK Csillag among the varieties involved into the study (**Table 3**).

Table 3: The effect of agrotechnical factors on the complex infection index of winter wheat varieties (Debrecen, 2013-2015)

Variety	Pre-crop								
	Sweet corn			Sunflower			Maize		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
GK Öthalom	100.9	464.4	24.4	42.7	312.0	67.6	100.0	330.0	56.3
GK Csillag	45.9	202.7	25.6	50.6	208.4	65.4	86.7	188.9	48.2
Mv Csárdás	75.8	212.5	65.0	78.0	215.9	128.3	106.7	204.7	80.0
Mv Toldi	25.7	330.0	37.9	26.0	207.8	66.7	68.9	244.6	60.0

The effect of agrotechnical elements on the studied pathogens was evaluated using Pearson correlation analysis (**Table 4**).

Table 4: The study of agrotechnical elements affecting plant pathological properties of winter wheat using Pearson correlation analysis (Debrecen, 2013-2015)

Crop year	Factors	Leaf rust	Helminthosporium tan spot	Powdery mildew
2013	Yield	0.714(**)	0.798(**)	0.532(**)
	Pre-crop	0.080(ns)	0.149(ns)	0.014(ns)
	Nutrient supply	0.817(**)	0.863(**)	0.630(**)
	Variety	-0.176(*)	-0.186(*)	-0.046(ns)
2014	Yield	0.419(**)	0.569(**)	0.554(**)
	Pre-crop	-0.175(*)	-0.033(ns)	-0.134(ns)
	Nutrient supply	0.618(**)	0.828(**)	0.808(**)
	Variety	-0.504(**)	-0.126(ns)	0.065(ns)
2015	Yield	0.694(**)	0.729(**)	0.486(**)
	Pre-crop	0.069	0.194(*)	0.113(ns)
	Nutrient supply	0.807(**)	0.846(**)	0.663(**)
	Variety	-0.077(ns)	0.79(ns)	0.224(*)

(**) Correlation significant at a level of $LSD_{1\%}$ confidence interval, (*) Correlation significant at a level of $LSD5_{\%}$ confidence interval, (ns) Not significant

The effect of pre-crops – among the studied agrotechnical elements – could not be verified with a weak positive relationship regarding leaf rust and tan spot in the crop years of 2013 and 2014. The studied plant pathological parameters showed medium and strong correlations with nutrient supply treatments and yield amounts and this relationship was influenced by weather conditions of the given crop year. In the crop years of 2013 and 2014 weak negative (-0.176*), just as medium negative (-0.504*) correlation was defined between leaf rust infection and variety.

3.3. Study of agrotechnical, biological and ecological factors of physiological parameters of winter wheat

In the present research work the development and dynamics of leaf area index (LAI) and relative chlorophyll content values were determined during the vegetation period.

Figure 1 shows leaf area index (LAI) values in the monitored four phenological phases regarding the average of the applied pre-crops, varieties and nutrient supply levels. No significant difference was found between the pre-crops sweet corn and sunflower in the stem elongation phenological phase of winter wheat development (1.6 $m^2 m^{-2}$). The lowest values were measured after the pre-crop maize in the analysed measurement times.

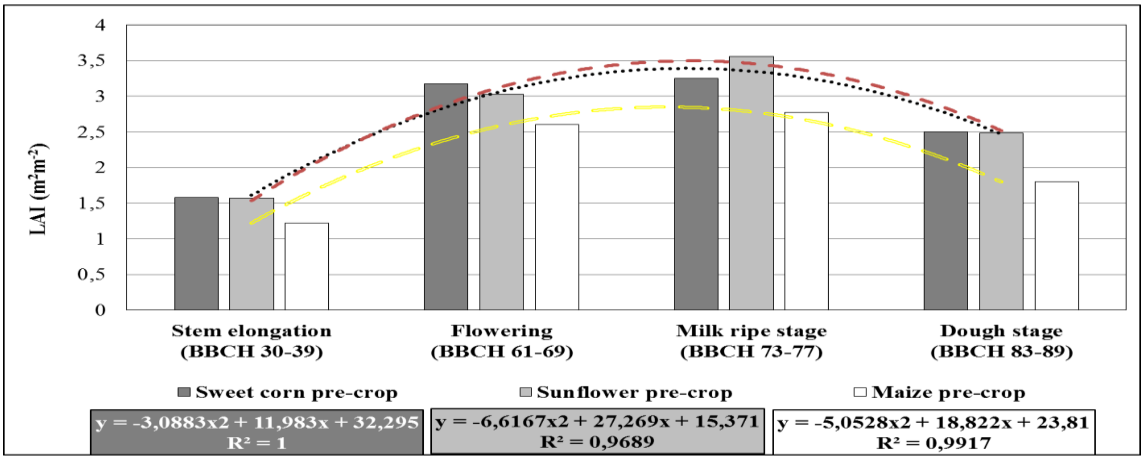

Figure 1: Development of leaf area index (LAI) values of winter wheat regarding the average of crop-years, nutrient supply levels and varieties in different phenological phases of the vegetation (Debrecen, 2013-2015)

Figure 2 shows the development of SPAD values in different phenological phases regarding the average of the applied pre-crops, varieties, nutrient supply levels and the studied crop years. No significant difference was found between the studied phenological phases. Maximal SPAD values were measured in the phenological phase of flowering.

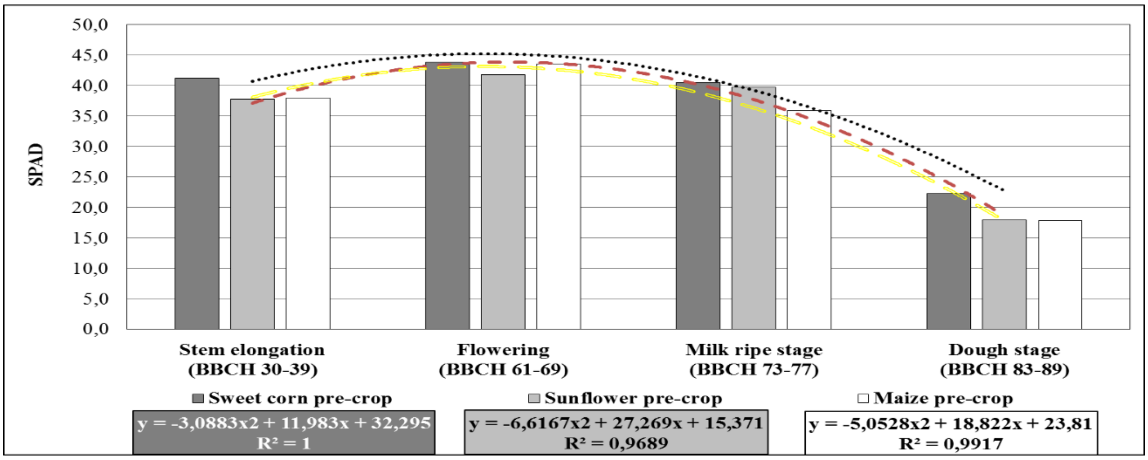

Figure 2: Development of relative chlorophyll content (SPAD) values of winter wheat regarding the average of the studied crop years, nutrient supply levels and varieties in different phenological phases (Debrecen, 2013-2015)

Analysing the pre-crops it has been stated that winter wheat populations sown after sweet corn proved to be the most favourable. SPAD values of winter wheat populations with maize and sunflower as pre-crops were different in the flowering and milk phenological stages. Significant decrease was observed in the fruit development (milk ripe) populations with maize pre-crop. In contrast to winter wheat populations with favourable pre-crops (sweet corn) more expressed decrease of SPAD values was observed in populations with unfavourable pre-crops. Pearson correlation analysis was run for the studied crop year in order to define the relationship between agrotechnical elements and plant physiological index values (**Table 5**).

Due to the strong positive effect of plant physiological index values on yield amounts agrotechnical elements have significant effect in winter wheat production. In the studied crop years (2013-2015) it has been stated that leaf area index (LAI), relative chlorophyll content (SPAD), leaf area durability (LAD) and relative chlorophyll content durability (RCAD) showed strong positive correlation with nutrient supply treatments and yield amount (at a confidence level of $P < 0.01$).

Table 5: Study of agrotechnical factors affecting winter wheat plant physiological parameters using Pearson correlation analysis (Debrecen, 2013-2015)

Crop year	Factors	LAI	SPAD	LAD	RCAD
2013	Yield	0.805(**)	0.876(**)	0.795(**)	0.895(**)
	Pre-crop	0.50(ns)	-0.273(**)	0.097(ns)	-0.245(*)
	Nutrient supply	0.856(**)	0.858(**)	0.854(**)	0.880(**)
	Variety	0.118(ns)	0.125(ns)	0.113(ns)	0.111(ns)
2014	Yield	0.764(**)	0.826(**)	0.741(**)	0.829(**)
	Pre-crop	-0.158(ns)	-0.105(ns)	-0.154(ns)	-0.128(ns)
	Nutrient supply	0.871(**)	0.871(**)	0.867(**)	0.867(**)
	Variety	0.085(ns)	0.104(ns)	0.090(ns)	0.68(ns)
2015	Yield	0.834(**)	0.837(**)	0.808(**)	0.846(**)
	Pre-crop	-0.320(**)	-0.222(**)	-0.339(**)	-0.222(**)
	Nutrient supply	0.774(**)	0.851(**)	0.745(**)	0.855(**)
	Variety	0.093(ns)	0.208(*)	0.086(ns)	0.206(*)

(**) Correlation significant at a level of $LSD_{1\%}$ confidence interval, (*) Correlation significant at a level of $LSD5_{\%}$ confidence interval, (ns) Not significant

In the crop year of 2013 weak negative correlation (r = -0.273*) was found between SPAD, just as RCAD values and pre-crops. In 2015 the selected pre-crop showed weak negative correlation (r = -0.320**, -0.222**; -0.339**; -0.222**) with the studied plant physiological index values (LAI, SPAD, LAD, RCAD). In the studied crop years no effect of the applied variety could be verified on the studied plant physiological index values neither in favourable, nor in unfavourable crop years.

Due to the strong positive effect of the studied factors on yield amounts the significant effect of nutrient supply treatments on the studied parameters can be concluded. The effect of plant physiological index values on yield amount could be verified with correlation analyses in case of different pre-crops.

3.4. Complex evaluation of winter wheat yield affecting agrotechnical factors in the studied crop years

The effect of main agrotechnical factors that affect winter wheat yield was studied in the present three-year research work (2013-2015). The effect of pre-crop choice was confirmed which can be modified by ecological factors.

Table 6: Yield differences of winter wheat in contrast to treatments with the pre-crop sweet corn regarding the average of the studied varieties and crop years (Debrecen, 2013-2015)

Yield difference (%) in contrast to treatments with sweet corn as pre-crop						
Pre-crop	Nutrient supply level					
	Control	N_{30}+PK	N_{60}+PK	N_{90}+PK	N_{120}+PK	N_{150}+PK
	%					
Sweet corn	100.0	100.0	100.0	100.0	100.0	100.0
Sunflower	92.3	86.3	96.6	96.6	97.9	98.6
Maize	66.8	72.6	82.5	85.3	90.5	92.6

In contrast to yield amounts of winter wheat populations sown after sweet corn as pre-crop yield amounts varied in populations with sunflower as pre-crop in a rather narrow (86.3 – 98.6%), while in those with maize as pre-crop in a far lower and wider (66.8 - 90.5%) interval (**Table 6**).

The medium ($r = 0.668^{**}$) and strong positive ($r = 0.879^{**} - 0.941^{**}$) effect of fertilization on yield amount has been confirmed using Pearson correlation analysis. Weak negative relationship was found between pre-crop and yield amount in two crop years. According to our results the effect of the applied variety could not be confirmed (**Table 7**).

Table 7: Analysis of the effect of agrotechnical factors on winter wheat yield amounts using Pearson correlation analysis (Debrecen, 2013-2015)

Crop year	2013	2014	2015
Factors	Yield		
Pre-crop	-0.181(*)	-0.123(ns)	-0.308(*)
Nutrient supply	0.941(**)	0.668(**)	0.879(**)
Variety	-0.61(ns)	0.19(ns)	-0.29(ns)

(**) Correlation significant at a level of $LSD_{1\%}$ confidence interval, (*) Correlation significant at a level of $LSD5_{\%}$ confidence interval, (ns) Not significant

Regarding the average of the studied crop years the comparative analysis of the varieties (**Figure 3**) confirmed the effect of pre-crop. In case of the pre-crops sweet corn and sunflower the genotypes GK Öthalom, GK Csillag and Mv Toldi were classified into the group with good nutrient utilization and good fertilizer reaction.

Maize pre-crop had negative effect on the development of yield amount in case of the studied varieties. The lowest yield amount regarding the studied treatments was measured in case of the variety Mv Csárdás.

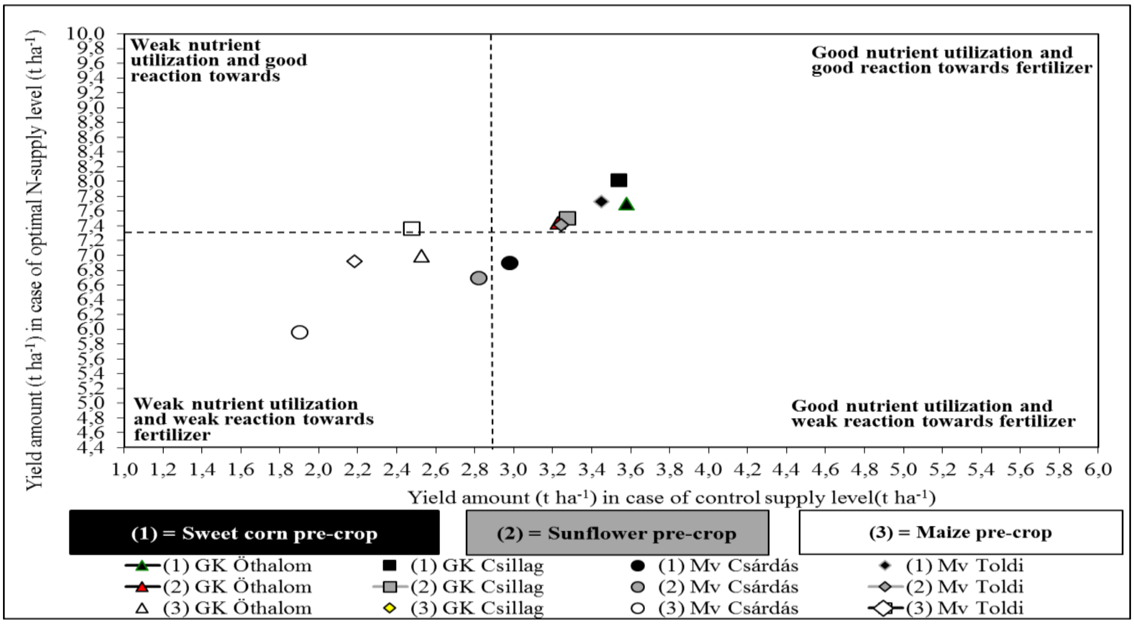

Figure 3: The role of crop year, pre-crop, fertilization and variety in the development of winter wheat yield by partitioning the components of variance (Debrecen, 2013-2015)

Analysing the components of variance the role of the crop year, variety and agrotechnical elements in the development of maximal yield amounts was evaluated regarding the average of the studied crop years. It has been stated that mineral fertilization (53%) and crop year (32%) had significant effect in this regard. According to the results of the present study on calcareous chernozem soil type pre-crop affected yield surplus to an extent of 13%. Variety – among the studied factors – had an effect to 2% (**Figure 4**).

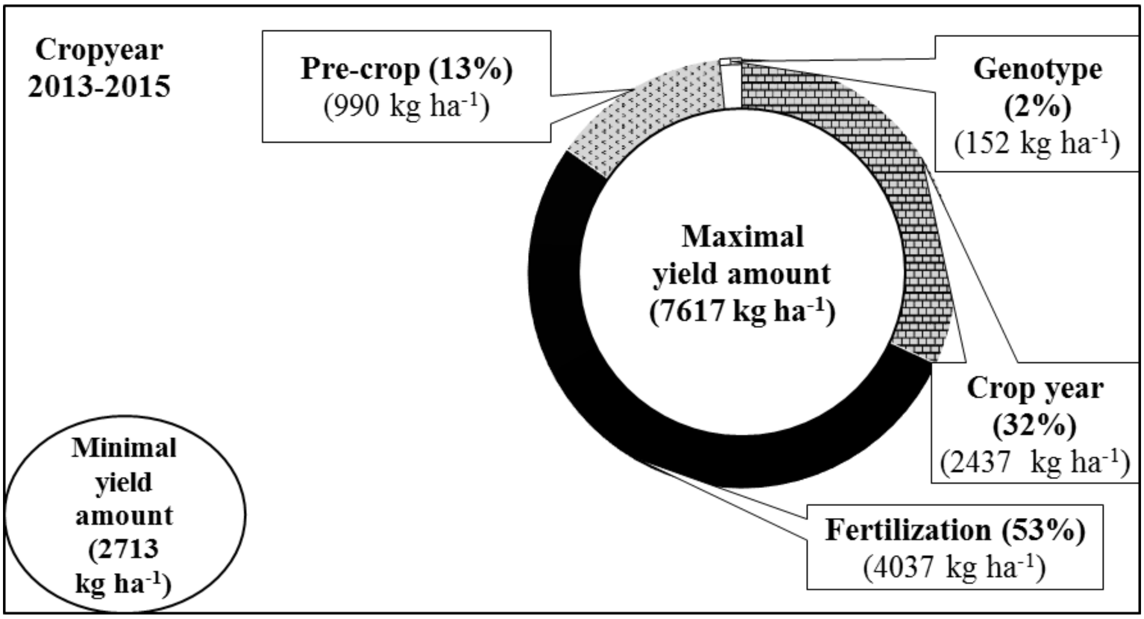

Figure 4: The role of crop year, pre-crop, fertilization and variety in the development of winter wheat yield by partitioning the components of variance (Debrecen, 2013-2015)

3.5. Complex evaluation of winter wheat yield quality affecting agrotechnical factors in the studied crop years

Yield quality of winter wheat populations with sweet corn pre-crop was evaluated in a complex way. The relationships between quality parameters, agronomical, plant pathology parameters, just as plant physiological index values and yield amounts was evaluated using Pearson correlation analysis. In the crop year 2014 medium positive correlation was confirmed between lodging and falling number, just as water absorption (r = 0.439**), while in 2015 between lodging and quality index (measured with valinograph) and water absorption (r = 0.663**). In an unfavourable crop year (2013) verifiable difference was found regarding the variety and the studied quality parameters in all treatment combinations, while in favourable crop years (2014-2015) difference between the studied varieties was confirmed regarding wet gluten spread and falling number. The applied variety affected the development of quality parameters to a significant extent. In the present study Mv Toldi proved to be the best variety, while the lowest values of the studied parameters were measured in case of the variety GK Öthalom in both favourable and unfavourable crop years. In comparison to the results of TÓTH et al. (2006) the variety GK Öthalom produced variable quality parameters in the present study.

In case of the unfavourable crop year (2013) the applied variety showed medium and strong correlation with the studied quality parameters. Weak positive correlation was found between variety and wet gluten spread (r = 0.367*) in case of a favourable crop year (2014). Strong relationship was confirmed between falling number and variety (r = 0.834**). In the crop year of 2015 correlation was found between variety and wet gluten spread (r = 0.811**), just as between variety and falling number (r = 0.418**).

The effect of plant pathological parameters on quality parameters was significantly affected by the crop year. No statistically verifiable difference was confirmed between leaf rust and water absorption, just as between powdery mildew infection and falling number in the crop years 2013 and 2014. Quality index and water absorption capacity showed medium positive correlation with Helminthosporium tan spot and powdery mildew infection in the crop years 2014 and 2015.

In the crop year of 2013 LAI and LAD – among the studied plant physiological index values – showed statistically verifiable relationship with wet gluten spread, falling number and water absorption, while in 2014 with quality index and water absorption. LAI and LAD showed medium and strong correlation with the studied quality parameters in 2015.

According to the results of Pearson correlation analysis SPAD and RCAD values were medium positive correlated with falling number, water absorption, while in 2014 with quality index and water absorption. In the crop year 2015 medium or strong positive correlation was confirmed for LAI, LAD, SPAD and RCAD values in the analysis of quality parameters.

Medium weak (r = 0.374**) correlation was determined between wet gluten spread and yield amount in 2013. Yield and quality index, just as water absorption showed weak positive correlation with each other (r = 0.467**) in 2014. In the crop year 2015 strong positive correlation was found between yield, quality index and water absorption (r = 0.862**), while medium positive correlation was confirmed between yield, wet gluten spread and falling number (r = 0.582**–0.618**).

5. NEW AND NOVEL SCIENTIFIC RESULTS

1. Optimal NPK dosage of different winter wheat genotypes was determined in case of the application of different pre-crops (sweet corn, sunflower, maize). Maize proved to be the most unfavourable pre-crop (winter wheat populations produced lower yield maximum values even in case of the application of higher fertilizer dosages). Regarding the average of the studied crop years and nutrient supply treatments winter wheat yield amount of populations with sunflower pre-crop was 5% lower after, while of those with maize pre-crop was 17% lower than that of populations with sweet corn pre-crop.
2. Novel genotypes (GK Csillag, Mv Toldi) exceed performance of older genotypes (GK Öthalom, Mv Csárdás) regarding several different parameters (plant pathology, plant physiological, yield and quality parameters).
3. In case of the application of the standard fungicide population treatment (2-times fungicide treatment of the population) HTR showed the highest differences among the studied pathogens depending on the crop year, genotype and fertilizer dosage. The complex infection index (CII) elaborated in the present research work can be successfully applied for the characterization of varieties, crop year and fertilizer treatments.
4. Plant physiological parameters (LAI, SPAD), just as relative chlorophyll content durability (LAD, RCAD) are suitable for the characterization of crop years, genotypes and fertilizer effects. The relationship, correlation between these physiological parameters and yield amounts of winter wheat varieties proved to be strong.
5. Dividing the components of variance it has been stated that mineral fertilization affects yield increment of winter wheat varieties to 53%, while crop year to 32%, pre-crop to 13% and variety to 2% regarding the average of the studied crop years.
6. Regarding the baking parameters of winter wheat medium positive ($r = 0.538^{**}$) and strong positive ($r = 0.751^{**}$) correlation was found between quality index and nutrient supply, while strong positive correlation was confirmed between wet gluten content and nutrient supply treatments ($r = 0.802^{**}$).

6. USEFUL RESULTS FOR THE PRAXIS

1. On the calcareous chernozem soil type in case of the application of adequate agrotechnical management the application of novel winter wheat varieties is recommended due to their higher productivity (5.5-9.1 t ha^{-1}), higher resistance towards plant diseases and better agronomic properties.
2. Novel winter wheat varieties have better adapting ability that is possible to be realized even in case of unfavourable crop years and unfavourable pre-crops (in case of the variety GK Csillag 1429 kg ha^{-1}, while in case of the genotype Mv Toldi 2500 kg ha^{-1} yield surplus was produced in contrast to the variety Mv Csárdás after the pre-crop maize in the crop year 2013).
3. Complex analysis (the joint study of several quality parameters) of the genotype is essential for the practical definition of quality wheat production.
4. Winter wheat yield amount was affected by the studied pre-crops as follows (in descending order): sweet corn (5.97 t ha^{-1}) > sunflower (5.68 t ha^{-1}) > maize (4.99 t ha^{-1}).
5. In case of average crop years plant physiological parameters of winter wheat populations at the development stages of flowering (BBCH 61-69) and fruit development (milk ripening – BBCH 73-77) can be used for the prediction of wheat yield amounts.
6. In case of the application of favourable sweet corn pre-crop more favourable yield can be produced by lower mineral fertilizer optimum (N_{103}+PK) (regarding the average of crop years and varieties 7.6 t ha^{-1}) than after the less favourable sunflower (by optimum dosage of N_{120}+PK 7.3 t ha^{-1}) or maize pre-crops (in case of optimum fertilizer dosage of N_{125}+PK 6.8 t ha^{-1} maximal yield was produced).

LIST OF PUBLICATIONS

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Candidate: Gergely Szilágyi
Neptun ID: HWVQB2
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List of publications related to the dissertation

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