THESES OF DOCTORAL (PhD) DISSERTATION

STUDY OF EFFECTS OF MAJOR AGROTECHNICAL FACTORS IN WINTER WHEAT PRODUCTION

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1. Introduction

Wheat is the most important and one of the ancient cereal crops in the world. Its genetic centre is the Black sea basin and Western Asia. Thanks to its excellent adaptation capability, it is produced from the tropical regions to nearly the poles.

Until 1980 the production area increased and reached 240 million hectares. After that, due to the emergence of more intensive varieties and the developed agrotechniques it dropped. From 1980 the average wheat yield started to increase all over the world. As a result of the higher yields and the smaller production area, wheat production has tripled in 40 years. (It was 222 million tons in 1961 and 624 million tons in 2004).

In Hungary, winter wheat is produced in almost every farm. The production area has been stabilized at 1.1-1.2 million ha in the last decades. The average yield was 1-1.5 t ha^{-1} until the 1950-1960s, from the 1960s it started to grow both in the world and in Hungary. In Hungary the average yield reached and even exceeded that of the European. A fundamental change came in the '90s when the EU average increased from 5 t ha^{-1} to 6 t ha^{-1}, while in Hungary due to the input decrease, caused by the economic difficulties, it dropped from 5 to 3 t ha^{-1}. From the 1990s a significant decrease started in agrotechniques in the national wheat production, with the following signs: the amount of fertilizers and the quality of soil cultivation, as well as plant protection have decreased. Today the quality of agrotechniques is extremely homogenous. Most farms use low-input technologies, but in some cases the standard of agrotechniques approaches that of the Western European.

2. Topic of interest

Hungary's EU accession significantly affects the circumstances of wheat production. The expectations towards wheat production, i.e. supplying the country with good-quality product and providing export commodity, are still the same. However, the market circumstances, the expectations, the regulation system and the subsidies have changed, and the industry players have to face a new situation. We have to decide which way to improve our wheat production. There are two alternatives: either to produce high quantities with minimum quality parameters in order to exploit the intervention opportunities, or to produce average or high amounts of extra quality wheat for the solvent and quality-oriented national and international markets.

In a short term the quantity- and quality oriented and the technological models can exist side by side, but in a long term the quality-oriented model seems to be viable. In this sense, the fact that wheat production has three dimensions might cause difficulties. We have to consider the production technology, the production circumstances and the quality of the end product, which requires more intensive and professionally managed technologies. Quality production means not only the production of hard grain, high-quality wheat for bread, because wheat for other purposes (pasta, quick frozen pastry, biscuits, hamburger and organic products) is also required.

The role of production inputs significantly differs in the quality or quantity oriented wheat production. Ecologic factors account for 1/3 of the quality of wheat (weather 22%, soil 10%). Choosing the right variety is the basis for wheat production (27% influences). Fertilization and plant protection account for 25%, while indirect factors account for 16% of the quality of wheat. Thus, with conscious production, we can determine 70 % of the quality of wheat (variety, agrotechniques) if the ecologic factors are not extreme (PEPÓ, 2006*).

Professional nutrition supply has an important role in both the quality and quantity-oriented wheat production. Wheat is one of our crops that are very sensitive for nutrition supply; therefore the harmonized supply of macro-, mezo- and microelements is a key factor of production. High yields and quality can be reached only with harmonised NPK fertilization.. However, the appropriate nutrient supply raises several plant protection issues. Besides nutrient supply, plant protection is the other critical factor. Professional plant protection influences not only the quantity but the quality of wheat.

Forecrop, nutrient supply and the intensity of plant protection play an important role in the quantity and quality. Irrigation is not commonly used in wheat production, but in arid years it has a perspective in intensive farming.

3. Material and methods

3.1. The soil characteristics and water conditions of the research site

The research was conducted at the Látókép farm and Regional Research Institute of the University of Debrecen, Centre of Agricultural Sciences. The research institute is situated by Road 33, 15 km from Debrecen in the Hajdúság region. The soil of the research site is calcareous chernozem developed on loess with deep mould layer. The soil texture is loam.

The depth of the fertile layer is 80-90 cm, in which 40-50 cm evenly contains humus. The average humus content is 2.76 %. $CaCO_3$ appears in the soil profile in the transition level at 75 cm. Lime is usually visible on the soil particles as calcareous coating, in this layer the lime content ranges from 10 to 13 %. The pH (KCl) in the cultivated layer ranges between 6.3 and 6.5.

Analysing the water management characteristics of the soil of the research area, we found that typically to chernozem soils, it has favourable water management characteristics. According to Várallyay's classification, it belongs to category IV., i.e. soil with good water management and water holding capacity.

The minimum field water capacity (VKmin) ranges between 33.65 and 46 %, the non-available water (HV) ranges between 8.5-15.7 % in the 0-200 cm soil layer.

Soil water table is in 3-5 m depth, the soil can store a substantial amount of water.

3.2. The experimental treatments

The polifactor field trial was set by prof. Dr. László Ruzsányi in 1983. Compared to the original experiment, the treatments were changed in 2003. We changed those soil cultivation treatments which have little effect on the product yield, compared to plant protection ones. We analysed the effect of crop rotation, nutrient supply, plant protection and water supply on the product yields.

<u>Crop rotation systems:</u>

We used two plant protection systems:

- biculture: corn-wheat
- triculture: pea-wheat-corn.

<u>Nutrient supply:</u>

We analysed five nutrient levels both in biculture and triculture (Table 1).

100% of the phosphorus and potassium fertilizers and 50% of the nitrogen fertilizer was supplied in autumn; the remaining was supplied in spring.

Table 1. *Fertilizer doses of the biculture and triculture crop rotation system*

Treatment	Actor (kg ha^{-1})		
	N	P_2O_5	K_2O
1	0	0	0
2	50	35	40
3	100	70	80
4	150	105	120
5	200	140	160

Plant protection technologies

We analysed the effectiveness of three plant protection technologies (extensive, average and intensive).

In the extensive plant protection technology no protection was used against pests and diseases and weed control was done by the following chemicals: Solar 0.2 l ha^{-1} + Duplosan DP 1.5 l ha^{-1}+ Granstar 5 g ha^{-1}.

Weed control in the average plant protection technology was done by the same combination of agents as in the extensive technology, and here disease protection was used with Tango Star 1.0 l/ha dose (at the start of flowering). Pest control was not applied.

In the frame of the intensive plant protection technology weed control was done by Solar 0.1 l ha^{-1}+ Duplosan DP 1.5 l ha^{-1}+ Granstar 5 g ha^{-1}, and pest control was done twice with Tango Star 1.0 l ha^{-1} (in 1-2 node state) and Juwel 1.0 l ha^{-1} (at the start of flowering). No pest control was applied in this technology either.

Irrigation

As the amount of precipitation was sufficient in 2003/2004, 2004/2005, 2005/2006, irrigation was not used either in I_2 or I_3 varieties. Only in the arid 2006/2007 crop year was irrigation applied according to the following:

- I_1 treatment: no irrigation,
- I_2 treatment:
  - 23 April 2007, 25 mm
  - 23-24 May, 25 mm
- I_3 treatment:
  - 23 April 2007, 50 mm
  - 23-24 May, 50 mm.

3.3. Agrotechniques applied in the research

We applied the commonly used soil preparation techniques in the experiment. Sowing was done by Sulky sowing machine, harvesting by Sampo plot combine harvester. Depending on the crop year, the time of sowing and harvesting was 4-12 October and 26 June - 16 July, respectively.

3.4. Weather conditions in the research year and the effect on plant growing

The 2003/2004 crop year was favourable for wheat production. The amount of precipitation increased the 30 year average by 52.1 mm in the growing season, while the average temperature was 0.3 ºC lower than the average. The 2004/2005 crop year was also favourable for wheat production. The amount of precipitation was 43.5 mm higher and the temperature was 0.3 ºC lower than the 30 year average. The 2005/2006 crop year was average for wheat production. Spring arrived late, thus the growing of plants started only at the end of March. The amount of precipitation was 40.7 mm higher and the temperature was 0.2 ºC lower than the average. In the arid 2006/2007 crop year the precipitation was less then half of the 30 year average (248.3 mm), while the average temperature was 2.9 ºC higher.

3.5. Sampling, processing, and the analysis of the results

Plant diseases were recorded several times in spring, which allowed us to determine the infection dynamics. Because of the content limit, we described the maximum values of the different leaf and ear diseases in the given crop year. When determining the leaf samples, we publish the percent values of the infected leaf area. In each repetition, the value of 1 m^2 leaf area is given. Out of leaf diseases we determined powdery mildew (*Blumeria graminis f. sp. tritici*), tan spot (*Dreschlera tritici repentis*) and leaf rust (*Puccinia recondita*). Out of the ear diseases fusarium, as the most important disease in the research, was visually determined. An ear was regarded infected if the ear area, where the fusarium symptoms occur exceeded 15%. Accordingly, the percent value of fusarium infection stands for the percent piece of the infected ears in the tables.

In the experiment we examined the stalk bending of wheat stands. Stalk bending was determined and recorded on plots in each repetition. Stalk bending was recorded if the bending exceeded 45º. The % value of bending stalks was calculated for land unit. Accordingly, 0 % bending represents a culture with excellent stalk strength, while 100 % means that the culture is totally bent. During harvesting we determined the moisture content of the grain, and we used this number to standardize and calculate the values of the harvested grain per site to 14%. As the tables show the standardized kg ha^{-1} crop yields.

1.5-1.5 kg samples were taken for baking analysis after harvesting. The harvested grain was cleaned and according to the Hungarian Standard baking parameters (valorigraph value: MSZ ISO 5530-3/1995; wet gluten content: MSZ ISO 5531:1993; gluten spreading: MSZ 6369/5:1997; falling number: MSZ ISO 3093:1995) were determined in the accredited laboratory of the University of Debrecen, Centre of Agricultural Sciences and Engineering, Institute of Food Science, Quality Assurance and Microbiology.

The data was analysed by an IBM computer with Windows XP operation system and Microsoft Office Excel and the correlation was calculated by SPSS 13.0 program, the variance analysis was done according to Sváb.

4. Evaluation of the results

4.1. Effect of the forecrop on the pathology, stalk bending, yield quality ad quantity of wheat

Table 2 shows the infection data in the average of the 4 research years. In each examined year, powdery mildew occurred in greater extent in stands grown after favourable pea forecrop. The maximum value of infection in biculture was 26% in the average of 4 research years. In triculture these value was higher (34%), due to the fact that pea as a forecrop saved water and supplied the soil with nitrogen.

Tan spot also occurred in higher extent in stands grown after pea forecrop in each examined year. In biculture the highest infection was 37%. In triculture, because the stand is richer and the microclimate is damper grown after pea forecrop, the infection value was 46 % respectively. Examining the leaf rust infection, we found that it was higher in the richer stands grown after pea forecrop (48%) then in stands grown after corn forecrop (30%).

In 2004 and 2007, the dry weather of the flowering stage was not favourable for fusarium, therefore no infection was observed. In May 2005 the dry warm weather in the flowering and earing stages was not favourable for fusarium, but in July the crops received rainfall several times, therefore slight fusarium infection occurred. In 2006 the fusarium infection was serious due to the cold and rainy weather at the end of May - start of June.

Contrary to other diseases, fusarium infection was higher in stands grown after corn forecrop due to the soil-born infection sources. The highest infection rate was 16% in 2005 and 27% in 2006, while in triculture it was 14% in 2005 and 19% in 2006.

Table 2. *The effects of fertilizer doses and plant protection technologies on leaf disease of winter wheat (Debrecen 2004-2007)*

Plant protection technologies	Fertilizer doses (kg ha^{-1})	Powdery mildew		Tan spot		Leaf rust		Fusarium	
		Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture
Extensive	Ø	3	11	11	24	7	21	4	5
	N_{50}+PK	7	15	16	31	12	27	6	6
	N_{100}+PK	15	25	27	36	21	35	9	7
	N_{150}+PK	23	32	34	42	27	43	11	8
	N_{200}+PK	26	34	37	46	30	48	11	8
Average	Ø	2	6	6	10	3	5	3	4
	N_{50}+PK	4	9	10	14	5	6	4	4
	N_{100}+PK	9	15	14	18	7	10	5	5
	N_{150}+PK	13	17	17	22	11	14	6	6
	N_{200}+PK	15	19	20	23	12	16	7	6
Intensive	Ø	1	2	3	4	1	2	2	2
	N_{50}+PK	2	4	6	7	2	3	3	2
	N_{100}+PK	5	7	9	10	3	5	4	3
	N_{150}+PK	7	8	11	12	5	7	4	4
	N_{200}+PK	9	10	13	14	6	9	5	4

In 2004 the favourable weather resulted in sufficient vegetative mass and both in biculture and triculture stalk bending was observed. The most significant stalk bending was 72% in biculture and 100 % in triculture. In 2005 the high precipitation in April, May and June resulted in sufficient vegetative mass, and from May the bending of crops was observed, which became even more severe in June and July (until harvesting). In triculture the extra nitrogen in the soil resulted in greater stalk bending (100%) than in biculture. Since in 2006 spring arrived late (end of March), the stalk bending of plants was not significant. In triculture stalk bending reached 70% while in biculture it was under 20%. Due to the drought in 2007, stalk bending was not virtually observed (Table 3).

Table 3. *The effects of fertilizer doses and plant protection technologies on stalk bending of winter wheat (Debrecen 2004-2007.)*

Plant protection technologies	Fertilizer doses (kg ha^{-1})	Stalk bending (%)									
		2004		2005		2006		2007		average of 4 years	
		Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture
Extensive	Ø	0	0	0	8	0	0	0	0	0	2
	N_{50}+PK	0	24	0	78	0	0	0	0	0	26
	N_{100}+PK	1	48	59	95	0	0	0	0	15	36
	N_{150}+PK	23	69	91	100	0	6	0	0	29	44
	N_{200}+PK	39	97	100	100	0	11	0	0	35	52
Average	Ø	0	0	0	5	0	0	0	0	0	1
	N_{50}+PK	0	45	0	89	0	0	0	0	0	33
	N_{100}+PK	17	68	76	100	0	10	0	0	23	45
	N_{150}+PK	52	80	100	100	0	32	0	0	38	53
	N_{200}+PK	63	100	100	100	9	59	0	0	43	65
Intensive	Ø	0	0	0	39	0	0	0	0	0	10
	N_{50}+PK	0	50	0	85	0	15	0	0	0	38
	N_{100}+PK	14	79	97	97	0	36	0	0	28	53
	N_{150}+PK	68	97	100	100	9	66	0	0	44	66
	N_{200}+PK	72	100	100	100	18	71	0	0	48	68

In 2004 the sufficient vegetation period and the favourable weather conditions resulted in stands with sufficient vegetative mass, which based the physiologic and agronomic conditions for excellent yield production. In triculture the product yields were higher (7697-9130 kg ha^{-1}) than in biculture (7012-7862 kg ha^{-1}) as it is shown in Table 4.

Table 4. *The effects of fertilizer doses and plant protection technologies on yield of winter whaet (Debrecen 2004-2007.)*

Plant protection technologies	Fertilizer doses (kg ha^{-1})	Yield (kg ha^{-1})									
		2004		2005		2006		2007		average of 4 years	
		Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture
Extensive	Ø	2435	6625	3604	7173	2351	4946	1773	4573	2541	5829
	N_{50}+PK	4755	**7697**	5925	**8082**	3579	5524	3219	6025	4369	**6832**
	N_{100}+PK	6864	6998	**7744**	7649	5135	5759	4762	6447	6126	6713
	N_{150}+PK	**7012**	6405	7493	7169	5606	**6028**	**4974**	**6578**	**6271**	6545
	N_{200}+PK	6520	6561	7366	6978	**6096**	5741	4525	6372	6127	6413
Average	Ø	2564	7042	3299	7384	2563	4973	1892	4426	2580	5956
	N_{50}+PK	4978	**8543**	6060	**8657**	4344	6099	3420	6273	4700	7393
	N_{100}+PK	**7647**	8278	**8352**	7704	5805	6771	5048	6913	6713	**7417**
	N_{150}+PK	7237	7792	8073	7396	6751	**7035**	**5590**	**7279**	**6913**	7376
	N_{200}+PK	6628	8026	7466	7045	**7052**	6846	5205	6841	6588	7189
Intensive	Ø	2657	7052	3233	7908	2575	5669	1758	4750	2556	6345
	N_{50}+PK	5431	**9130**	6674	**9191**	4454	6870	3525	6743	5021	**7983**
	N_{100}+PK	**7862**	8592	8350	7975	6172	7178	5243	7258	6907	7751
	N_{150}+PK	7304	8464	**8552**	7873	7160	7604	**5780**	**7428**	**7199**	7842
	N_{200}+PK	6397	8171	7818	7654	**7653**	**7939**	5516	7276	6846	7760

The extra yield of stands grown after pea forecrop on the control plots was 4188-4395 kg ha^{-1}, exceeding that of the values in biculture by 265-272%. At N_{50}+PK fertilizer level this value dropped to 2942-3699 kg ha^{-1}, which is 162-172 % higher than that in biculture. The reason is that this fertilization dose can eliminate the effect of the unfavourable corn forecrop. The difference between the maximum product yields was 865-1268 kg ha^{-1} in favour of the pea forecrop. In 2005, the relatively early and significant stalk bending negatively affected the grain production, resulting in lower yields. This is obvious if we compare the extra yield of triculture to biculture, since contrary to the earlier years the yield was higher on the control plots by 199-245 % and at the N_{50}+PK fertilization level by 136-143 %. In this year the biggest difference between the highest yield values was 338-639 kg ha^{-1}. In 2006 the product yields were average because due to the quick temperature increase in April the tillering of stands was retarded, thus the number of productive side shoots and the number of ears per land unit decreased. The dry and warm weather in the second half of July was also unfavourable for grain production, the hot weather significantly depressed the grain filling in the ear tops. In this year the yield of the richer stands after pea forecrop was higher, with the following rates: 2410-3094 kg ha^{-1}, 1845-2416 kg ha^{-1}, 624-1006 kg ha^{-1}, in the Ø, N_{50}+PK and N_{100}+PK treatments, respectively. Regarding the highest yields, the extra yield of triculture was 286 kg ha^{-1}observed only in the intensive plant protection technology. In the extensive and average plant protection technology in triculture, these values were 17 and 68 kg ha^{-1}, respectively. In 2007 the arid weather had unfavourable effect on vegetative growth and ear development. The dry and warm weather in June shortened the grain filling stage and resulted in a yield loss. The biggest difference between the two forecrops manifested in the low fertilization treatments (Ø: 2800-2992 kg ha^{-1}, N_{50}+PK 2806-3218 kg ha^{-1}). The highest yield was 5780 kg ha^{-1} in biculture and 7428 kg ha^{-1} in triculture, which is a 1848 kg difference.

The product yields were as follows: the highest yield was obtained in 2005 (in biculture: 7744-8552 kg ha^{-1}, triculture: 8082-9191 kg ha^{-1}), the yield was slightly lower in 2004 (in biculture: 7012-7862 kg ha^{-1}, in triculture: 8082-9191 kg ha^{-1}), in 2006 the yield was 6096-7653 kg ha^{-1}in biculture and 6028-7939 kg ha^{-1}in triculture. The lowest yield was observed in the draughty 2007 year: it was 4974-5780 kg ha^{-1} in biculture and 6578-7428 kg ha^{-1} in triculture.

The valorigraph value and the gluten content were higher in stands grown after pea forecrop every year of the experiment.

The gluten spreading was not obvious in 2004, and it was higher in stands grown after corn forecrop in 2005 and in stands grown after pea forecrop in 2006 and 2007. The change in the falling number was not obvious either. We observed higher values in the triculture in 2005 and 2007 and in the biculture in 2006.

Table 5 *The effects of fertilizer doses and plant protection technologies on the quality of winter wheat (Debrecen 2004-2007.)*

Plant protection technologies	Fertilizer doses (kg ha^{-1})	Valorigraph value		Wet gluten (%)		Gluten spreading (mm)		Falling number (s)	
		Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture
Extensive	Ø	36.0	47.1	20.3	24.5	2.8	2.5	312	340
	N_{50}+PK	40.7	54.3	22.9	28.7	2.8	2.6	328	353
	N_{100}+PK	50.4	57.3	27.8	31.2	3.0	3.2	347	365
	N_{150}+PK	47.4	57.8	27.6	32.0	3.7	3.1	338	361
	N_{200}+PK	54.8	56.8	30.2	31.4	3.7	3.0	347	353
Average	Ø	40.4	42.6	22.0	22.3	2.5	2.4	305	339
	N_{50}+PK	42.0	52.0	24.6	27.0	2.9	2.5	323	347
	N_{100}+PK	50.9	55.6	29.8	31.6	3.0	3.5	357	359
	N_{150}+PK	53.4	53.3	30.4	32.7	3.8	3.2	347	352
	N_{200}+PK	53.2	53.8	30.7	33.2	4.2	3.4	349	349
Intensive	Ø	36.9	44.1	24.7	23.7	2.6	3.1	313	341
	N_{50}+PK	40.2	51.6	22.0	28.7	2.9	2.8	322	338
	N_{100}+PK	52.6	53.2	30.7	31.2	3.8	3.2	354	349
	N_{150}+PK	46.9	52.3	29.6	33.6	3.6	3.4	342	350
	N_{200}+PK	49.6	54.0	30.3	33.9	3.9	3.4	335	337

4.2. The effect of fertilization on the pathology, stalk bending, yield quality and quantity of wheat

In each year we found that by increasing the fertilizer doses the infection rates also increased (Table 2). The infection with powdery mildew was 1-19 % on the control plots and was 9-34% on the highest fertilization level (N_{200}+PK). Due to the fertilization, the infection with tan spot increased from 3-24% to 10-55%. The same tendency was observed with leaf rust and fusarium (Leaf rust: Ø 1-21%, N_{200}+PK 6-48%, fusarium: Ø 4-10%, N_{200}+PK 9-22%).

By increasing the fertilizer doses the stem bending also increased, on the control plots only in triculture was a slight stalk bending observed (Table 3). When higher fertilizer doses ($N_{150-200}$+PK) were supplied, stalk bending was observed in most stands in humid years (30/-70-100%).

Increasing the fertilization doses resulted in growing yields in each of the investigated years; however, after a certain level it caused yield depression (Table 4). The highest yields were harvested in biculture at $N_{100-150}$+PK (7012-7862 kg ha^{-1}) and in triculture at N_{50}+PK (7697-9130 kg ha^{-1}) in 2004. These values exceeded the values of the control plots by

4575-5212 kg ha^{-1} in biculture and 1072-2078 kg ha^{-1} in triculture. In 2005 the highest yields were harvested in biculture at $N_{100-150+PK}$ (7744-8552 kg ha^{-1}) and at triculture at N_{50}+PK (8082-9191 kg ha^{-1}). These values exceeded the values of the control plots by 4140-5319 kg ha^{-1} in biculture and 909-1283 kg ha^{-1} in triculture. In 2006 we observed maximum yields of stands grown after corn forecrop at N_{200}+PK (6096-7653 kg ha^{-1}) and in stands grown after pea forecrop at N_{150+PK} (6028-7939 kg ha^{-1}). Compared to the control plots, the extra yield of the best yielding fertilizer dose was 3745-5078 kg ha^{-1} in the stands grown after corn forecrop, and 1082- 2270 kg ha^{-1} in the stands grown after pea forecrop. In 2007 in both crop rotation types the maximum yield was realized at N_{150}+PK (in biculture: 4974-5781 kg ha^{-1}, in triculture: 6578-7428 kg ha^{-1}). Fertilization resulted in 4082-4936 kg ha^{-1} and 2336-2954 kg ha^{-1} extra yield in biculture and triculture, respectively.

Fertilization increased the valorigraph value (Table 5).

The maximum gluten content (32-37%) was obtained at the highest fertilization levels in 2004, 2005 and 2006. In the dry 2007 year the highest gluten content was observed in biculture at N_{100}+PK and in triculture at N_{200}+PK. The reason is that after the water-demanding corn forecrop, only little water remained in the soil, therefore the wheat stands could not take up the fertilizers.

As a result of fertilization, the gluten spreading increased in most cases in each of the four years.

The change in the falling number was not obvious.

4.3. Effect of plant protection on the pathology, stalk bending, yield quality and quantity of wheat

By intensifying the plant protection techniques we could moderate the different leaf- and ear diseases (Table 2). In the stands where extensive plant protection techniques were applied, the powdery mildew infection was 3-34%, which we could decrease down to 2-19% by a single fungicide treatment and to 1-10% by a double fungicide treatment. Tan spot infection was also decreased by using modern plant protection techniques (extensive 11-46%, average 6-23% and intensive 3-14%). When no plant protection was used, the infection rates of leaf rust were the highest (7-48%), which we could improve by applying the average (3-16%) or the intensive (1-9%) plant protection techniques. Fusarium was observed in 2005 and 2006, the infection rates improved from 10-23% to 6-14% by the average and to 2-10% by the intensive plant protection techniques.

As a result of plant protection treatments, we found significant difference between the stalk bending of the extensive and the average plant protection techniques (Table 3). In 2006, due to the favourable vegetative growth stalk bending was observed in most of the stands and the difference between the three plant protection techniques was significant. Due to the draught in 2007 stalk bending was slight and no significant difference was observed between the plant protection techniques.

In each of the four examined years, the highest product yields were observed in stands treated with intensive plant protection (Table 4). In 2005 the plant protection techniques resulted in 683-1005 kg ha^{-1} extra yield in biculture and 1465-2053 kg ha^{-1} in triculture. Regarding plant protection, there was no significant difference between the extra yields in the biculture, however we observed significant differences in the triculture. In 2005 the average plant protection technique resulted in 608 kg ha^{-1} extra yield in the biculture and 575 kg ha^{-1} in triculture, the intensive plant protection technique resulted in 1059 kg ha^{-1} and 1109 kg ha^{-1} extra yield. In the biculture the difference between the product yields of the stands treated with extensive and intensive techniques was significant. In the triculture the yield difference between the stands treated with common and intensive, and between the extensive and intensive plant protection technologies were significant. In 2006 the plant protection techniques resulted 1145-2198 kg ha^{-1} extra yield. The application of plant protection resulted in significant differences in the yields. In 2007 no significant difference was observed in the biculture, however in the triculture there was significant difference between the yields gained after extensive and average, and average and intensive plant protection techniques.

Plant protection did not influence any of the quality parameters clearly (Table 5).

4.4 Effect of irrigation on the pathology, stalk bending, yield quantity and quality of wheat

Irrigation was applied only in the droughty 2007 year. Irrigation contributed to the emergence of leaf diseases. The lowest infection rates were observed in the treatments with no irrigation (powdery mildew: 2-21 %, tan spot: 2-22 %, leaf rust: 1-20 %). Supplying 50 ml water provided more favourable humid microclimate in the stands, resulting more severe infection rates (powdery mildew: 2-20 %, tan spot: 4-24 %, leaf rust: 1-23 %) according to the forecrop and the fertilization rates in the average of the plant protection techniques. Since the I_3 irrigation treatment contributed to damp microclimate in the stands, the infection rates increased further (powdery mildew: 2-24 %, tan spot: 3-29 %, leaf rust: 1-26 %). However, this increase was not significant in either cases. In the stands grown after corn forecrop no stalk bending was observed as a result of irrigation. Stalk bending was observed in stands grown after pea forecrop that left higher amounts of water in the soil (I_2: 24-71 %, I_3: 34-100 %). The difference of stalk bending values between the irrigation treatments was significant.

Irrigation significantly increased the product yield (Table 6). The yields of non-irrigated plots ranged between 1808-7095 kg ha^{-1} according to the forecrop and the fertilization treatments. 50 mm irrigation water increased the product yields (2183-7959 kg ha^{-1}). The highest product yields were harvested from the plots that received the highest water dose. In the I_2 irrigation treatment, compared to the non-irrigated stands the extra yield was 575-2254 kg ha^{-1} in the biculture and 560-1086 kg ha^{-1} in the triculture, according to the fertilization doses. 100 mm irrigation water increased the product yields by 788-2480 kg ha^{-1} in the biculture and 691-1446 kg ha^{-1} in the triculture. Irrigation significantly increased the product yield in both crop rotation systems.

Table 6. *The effects of fertilizer doses and irrigation variations on the yield of winter wheat in bi- and triculture crop rotation technology (in average of plant protection technologies Debrecen 2007.)*

Irrigation variations	Fertilizer doses (kg ha^{-1})	Yield kg ha^{-1}	
		Biculture	Triculture
I1	Ø	1808	4583
	N_{50}+PK	3388	6347
	N_{100}+PK	5018	6873
	N_{150}+PK	5448	7095
	N_{200}+PK	5082	6830
I2	Ø	2183	5143
	N_{50}+PK	3877	6935
	N_{100}+PK	5666	7959
	N_{150}+PK	6530	7766
	N_{200}+PK	7336	7620
I3	Ø	2396	5274
	N_{50}+PK	4295	7062
	N_{100}+PK	5985	8319
	N_{150}+PK	7006	7952
	N_{200}+PK	7562	7527

Table 7. *The effects of fertilizer doses and irrigation variations on quality of winter wheat in biculture crop rotation technology (in average of plant protection technologies Debrecen 2007.)*

Irrigation variations	Fertilizer doses (kg ha^{-1})	Valorigraph value		Wet gluten (%)		Gluten spreading (mm)		Falling number (s)	
		Biculture	Triculture	Biculture	Triculture	Biculture	Triculture	Biculture	Triculture
I1	**Ø**	40.4	47.8	20.8	25.6	1.8	2.7	335	344
	N_{50}+PK	41.2	45.3	22.0	22.2	2.1	2.0	336	328
	N_{100}+PK	53.7	52.1	28.0	29.4	2.7	3.6	358	363
	N_{150}+PK	51.1	54.0	26.2	31.5	2.4	3.6	357	353
	N_{200}+PK	52.8	54.1	25.8	30.5	2.6	3.5	350	359
I2	**Ø**	40.8	48.3	22.4	22.4	2.0	2.1	333	359
	N_{50}+PK	44.5	49.1	26.4	22.5	2.8	2.0	341	336
	N_{100}+PK	52.7	53.9	29.4	31.1	2.8	3.3	350	371
	N_{150}+PK	52.9	54.4	28.7	27.8	2.8	2.7	339	361
	N_{200}+PK	54.4	53.1	28.9	30.0	3.0	2.9	341	367
I3	**Ø**	48.1	53.8	25.8	30.4	2.5	3.2	353	398
	N_{50}+PK	48.2	51.9	28.8	27.6	2.8	2.8	343	377
	N_{100}+PK	56.1	59.5	33.3	29.1	3.9	3.2	349	399
	N_{150}+PK	56.8	55.0	30.8	33.1	3.5	3.9	357	396
	N_{200}+PK	54.5	57.5	31.9	34.2	3.4	3.9	367	390

Irrigation did not clearly increase the valorigraph value in the biculture, but obviously increased it in the triculture, however, this increase was not significant. The increase in the gluten content in the biculture was not significant, at the same time it did not clearly change in the triculture. Irrigation did not clearly change the falling number in the biculture, but it increased in the triculture, however, this increase was not significant (Table 7).

4.5. Pearson's correlation analysis in the 4 examined crop years

2003/2004 crop year

In both crop rotation systems and in all of the three plant protection techniques the fertilization influenced powdery mildew (biculture: 0.935**; 0.940**; 0.874**, and triculture: 0.835**; 0.784**; 0.863**), tan spot (biculture:0.894**; 0.877**; 0.842**; triculture: 0.474**; 0.792**; 0.851**), leaf rust (biculture: 0.925**; 0.861**; 0.848**, triculture: 0.703**; 0.748**; 0.792**), stalk bending (biculture: 0.862**; 0.927**; 0.896**; triculture: 0.949**; 0.939**; 0.923**) at 1% significance level, because the infection and stalk bending increased as a result of the increasing fertilization doses. After maize forecrop, fertilization strongly influenced the yield (0.819**; 0.776**; 0.711**). Regarding the stands treated with extensive and intensive plant protection techniques in the biculture there was strong correlation between the product yield and the infection rates (yield and powdery mildew 0.819**, 0.709**; yield and tan spot 0.827**, 0.674**; yield and leaf rust 0.832**; 0.742**), since the higher fertilization doses increased not only the yield but also the infection rates. In the biculture, in stands treated with intensive plant protection techniques, there was medium correlation between the yield and powdery mildew (0.538**), and between the yield and tan spot (0.662**). The relation between leaf rust and the yield was only low (0.478**) According to our calculations, stalk bending increased parallel with the yield (0.512**; 0.618**; 0.495**), because supplying higher fertilizer doses increased stalk bending and the product yield as well.

In the triculture in case of all the three plant protection techniques, fertilization influenced the emergence of powdery mildew, tan spot, leaf rust and stalk bending at 1% significance level. However, this correlation was not as strong as in the case of the biculture, which was caused probably by the nitrogen remained in the soil after the pea forecrop. There was weak correlation between the stands treated with extensive plant protection techniques and fertilization (-0.351**), powdery mildew (-0.302*), tan spot (-0.291*) and stalk bending (-0.352**). The negative correlation between fertilization and crop yield is due to the pea forecrop and the good quality chernozem soil. The negative correlation between yields and infections shows that in the stands treated with extensive plant protection techniques powdery mildew and tan spot significantly decreased the yield. If average and intensive plant protection techniques were applied, the emergence of diseases did not cause yield loss.

In 2004, due to insufficient qualitative data no correlation was calculated.

2004/2005 crop year

In biculture in all of the three crop rotation systems the fertilization significantly influenced powdery mildew, tan spot, leaf rust, fusarium, stalk bending and crop yield. Among the quality parameters, the valorigraph value (0.710*, 0.551*) and the wet gluten content (0.828**, 0.602*, 0.601*) were significantly influenced by the increasing fertilization doses. The fertilization did not significantly change the other quality parameters. The relatively close correlation (0.711**; 0.837**; 0.725**) between stalk bending and fusarium in all of the three plant protection techniques is similar to that stated in the literature. In biculture under three plant protection techniques strong positive correlation was found between the diseases and the crop yield (powdery mildew: 0.920**, 0.750**; tan spot: 0.661**, 0.707**; leaf rust: 0.594**, 0.507**; fusarium: 0.647**, 0.559**), so the yield was not decreased by diseases. Fertilization, diseases and stalk bending did not influence the quality parameters under the average plant protection technique.

In triculture in all tree plant protection techniques the fertilization significantly influenced leaf- and ear diseases (powdery mildew: 0.940**;0.872**; 0.837**; tan spot: 0.896**; 0.866**; 0.850**; leaf rust: 0.575**; 0.841**; 0.798**; fusarium: 0.698**; 0.572**;0.653**), stalk bending (0.823**; 0.758**;0.805**), valorigraph value (0.703**, 0.579*, 0.698**) and gluten content (0.648**; 0.816**; 0.681**). There was negative low correlation between the yield and fertilization (-0.380**; -0.460**; -0.423**), resulting from the favourable weather, the beneficial effect of the pea forecrop and the good quality chernozem soil. Leaf and ear diseases significantly decreased the yield. Under three plant protection techniques, fertilization significantly influenced the valorigraph value (0.703**; 0.579*; 0.698**) and gluten spreading (0.648**; 0.816**, 0,681**). The falling number was not clearly influenced by any of the factors.

2005/2006 crop year

In biculture in the stands treated with extensive, intensive and common plant protection techniques the increase of fertilization doses significantly increased powdery mildew (0.881**; 0.814**; 0.651**), tan spot (0.941**; 0.900**; 0.871**), leaf rust (0.922**; 0.814**; 0.818**), fusarium (0.805**; 0.702**; 0.721**), product yield (0.961**;

0.961**; 0.968**), and out of the quality parameters the valorigraph value (0.905**; 0.821**; 0.695**), gluten content (0.958**; 0.898**; 0.914**) and gluten spreading (0.784**; 0.762**; 0.854**). Strong positive correlation was observed between the crop yields and the diseases in this case as well. None of the analysed factors changed significantly the falling number.

In triculture powdery mildew (0.905**; 0.771**; 0.820**), tan spot (0.767**; 0.829**; 0.857**), leaf rust (0.901**; 0.811**; 0.739**), fusarium (0.714**; 0.665**; 0.736**), stalk bending (0.743**; 0.918**; 0.970**), crop yield (0.713**; 0.837**; 0.902**) and gluten content (0.631*; 0.835**; 0.578**) were significantly influenced by fertilization.

2006/2007 crop year

In biculture irrigation had a slightly significant effect on the yield increase in the extensive and average plant protection techniques. In triculture, irrigation had strong influence on stalk bending and had medium influence on the crop yield. The irrigation treatments had no significant effect on leaf and ear diseases. The increase of the fertilization doses significantly influenced powdery mildew (in biculture: 0.947**, 0.926**, 0.896**; in triculture: 0.921**, 0.921**, 0.921**), tan spot (in biculture: 0.906**, 0.903**, 0.903**; in triculture: 0.899**, 0.859, 0.896**), leaf rust (in biculture: 0.949**, 0.876**, 0.826**; in triculture: 0.919**, 0.874**, 0.874**), valorigraph value (in biculture: 0.679**, 0.734**, 0.810**; in triculture: 0.559*, 0.596*), gluten content (in biculture: 0.608**, 0.616*, 0.621*; in triculture: 0.614**, 0.623*) in both crop rotation systems. Strong correlation was observed between fertilization and stalk bending in triculture. In biculture the fertilization had larger effect on yields (0.881**, 0.909**, 0.901**) than in biculture (0.671**, 0.710**, 0.710**).

5. Summary

Winter wheat is one of our crops with the largest acreage. Following our EU accession the wheat industry had to face new challenges, and the decision had to be made whether to produce high quantity of wheat with average quality parameters (for intervention) or to produce good quality wheat with average yields. Currently different production standards prevail in Hungary. Because of the extremely heterogenic production standards, there is the ground to analyse the effectiveness of the different agrotechnical factors. We have analysed the effect of various forecrops, fertilizer doses, plant protection technologies and irrigation on the pathology, product yield and quality of winter wheat in fertilization field trials on calcareous chernozem soil with good water and nutrient regime.

Concerning wheat production, the cropping years of 2004 and 2005 were favourable, 2006 was average and 2007 was draughty.

According to our four-year long experiment we can draw the following conclusions.

As it is already published in the professional literature, pea is a better forecrop for wheat than corn. The reason on the one hand is that it enriches the soil with nitrogen, on the other hand, more favourable soil and water conditions remain after pea forecrop. The infection rate with powdery mildew and spot and leaf rust of wheat stands grown after pea forecrop was higher than that of after corn forecrop. The infection rate of ear fusarium was higher in biculture, because its spreading was enhanced by soil borne factors.

Stalk bending was also more significant in triculture.

The extra yield resulted from pea forecrop was 4-8 % (340-640 kg ha^{-1}), 10-16 % (680-1270 kg ha^{-1}) and 15-19 % (1030-1190 kg ha^{-1}) in good, average and draughty years, respectively. Analysing the quality parameters we found that the valorigraph number and gluten content was higher in the stands grown after pea forecrop. Even the sample with the highest valorigraph value was classified in B1 quality group. The highest gluten contents were observed in 2004 and 2006 (32-37%). Due to the unfavourable weather in 2005 and 2007, the gluten could not formulate.

Forecrops not clearly influenced the gluten spreading and the falling number.

The data in the technical literature state that the increase of fertilization doses increased the presence of leaf- and ear diseases (powdery mildew, tan spot, leaf rust and fusarium) as well. The highest infection rates were always observed parallel with the highest fertilization doses (N_{200}+PK). Stalk bending also increased as a result of the increasing fertilization doses. The highest product yields were observed in biculture in the favourable years at $N_{100-150+PK}$ (2004 and 2005), while in the unfavourable years (2006 and 2007) at N_{200}+PK. In triculture as a result of the nitrogen supplementation provided by the pea forecrop, the highest yields were observed in the favourable years at N_{50}+PK (2004 and 2005), while in the unfavourable years (2006 and 2007) at $N_{100-150+PK}$. This yield is higher than in biculture as I have already mentioned in connection with the forecrops.

Compared to the control plots, in favourable years (2004 and 2005) the yield of stands grown after corn forecrop doubled after supplying N_{50}+PK. At the same fertilization level the wheat yield was 13-30 % higher after pea forecrop than that of the control plots. In biculture at N_{100} +PK and N_{150}+PK fertilization levels the yield was the double-triple of the control plots' yield. In triculture this amount caused yield depression. In biculture the N_{150}+PK and N_{200}+PK fertilizer doses caused 2.4-3 times and 2.6–3.2 times higher yields. In all of the four research years the pea forecrop and the lower fertilizer doses contributed to the higher yields.

In all of the research years the gluten content increased parallel with the increasing fertilizer doses. In 2004-2006, the highest fertilizer doses ($N_{150-200}$+PK) caused the highest yields, in 2007, due to the insufficient precipitation, the highest gluten content was observed at N_{100}+PK in biculture and N_{200}+PK in triculture. The reason is, that after corn forecrop little water remained in the soil and plants could not utilize the fertilizer in the draughty year.

Gluten formation improved with the increasing fertilizer doses. Fertilization did not clearly change the valorigraph number and the falling number.

As the intensity of plant protection technologies, were increased the leaf and ear diseases were significantly suppressed. Powdery mildew and tan spot infection was decreased to its half by a single fungicide treatment, and to its one third by a double treatment. Leaf rust infection decreased to its one third by average plant protection and to its one sixth by intensive plant protection methods. The years 2005 and 2006 favoured fusarium infection. A single treatment decreased the infection to its half; a double treatment decreased it to its one third.

In 2004 and 2005 there were significant differences between the stalk bending of extensive and average, and extensive and intensive plant protection techniques. In 2006 we observed significant differences between the stalk bending of each three plant protection techniques. In 2007, due to the draughty weather no stalk bending was observed.

In the favourable year of 2005, the extra yield of the average and intensive plant protection methods was 7-8% (570-600 kg ha^{-1}) and 11-14% (800-1100 kg ha^{-1}), respectively. In the years of 2004 and 2006, the yield after the average plant protection technique was 9-17% (635-1000 kg ha^{-1}) higher, while the yield after the double fungicide treatment was 12-32% (850-1910 kg ha^{-1}) higher than that of the non-treated stands. In the draughty year of 2007 the single treatment increased the yields by 8-12% (560-690 kg ha^{-1}), while the double treatment by 11-13%, compared to that of the untreated stands. The fungicide treatments successfully decreased the leaf and ear diseases, thus the yield-decreasing effect of these infections did not prevailed and extra yield was harvested.

None of the quality parameters were clearly influenced by crop production.

Among the examined years irrigation was reasonable only in the draughty 2007 year. Irrigation caused a little increase of leaf diseases (1-2%) and this increase was not significant. In biculture no stalk bending was observed, however in triculture the stands treated with higher fertilizer doses bent (I_2 treatment: 27-71%, I_3 treatment: 34-100 %). The yields of the control plots also increased as an effect of the 50 mm irrigation water by 36 % in biculture and by 12% in triculture. Considering the maximum yields, as a result of 50 mm irrigation water, the yields increased by 35% in biculture and by 12 % in triculture, compared to the maximum yields on the non-irrigated control plots. 100 mm irrigation water increased the maximum yield by 39% in the stands grown after corn forecrop and by 17 % after the stands grown after pea forecrop, compared to the maximum yields on the non-irrigated control plots. Irrigation significantly increased the yield in both crop rotation systems. We can state that the yield increase was higher after corn forecrop, however this value was still under the yields of the stands grown after pea forecrop. The reason is that pea leaves more water in the soil, so wheat can more easily absorb nutrients that enhance vegetative and generative growth.

The valorigraph number did not change clearly in the biculture, in the triculture it clearly increased, but the increase was not significant. The gluten content and gluten spreading increased in biculture, but the increase was not significant, and it did not change clearly in the triculture. The falling number did not change clearly in the biculture but it increased in triculture, however, not significantly.

The correlation analysis showed that fertilization significantly influences leaf and ear diseases, stalk bending, yield, valorigraph value and falling number. The exception was that in a favourable year (2003/2004) in triculture there was negative weak correlation between the yields of the plots treated with extensive plant protection technique and fertilization, infection with powdery mildew and tan spot, and stalk bending. The negative correlation between fertilization and yield is resulted from the favourable pea forecrop and the good quality chernozem soil. The negative correlation between the yields and the diseases shows that under extensive plant protection treatment powdery mildew and tan spot significantly decreased the yield. In the average and intensive plant protection techniques the infections could not decrease the yields. In the triculture, even in the favourable 2004/2005 year there was negative correlation between the yields and fertilization, resulted from the favourable weather, the good quality chernozem soil and the favourable pea forecrop.

The correlation between the crop year and the forecrop can be observed especially if there is insufficient rainfall. Significantly higher yields (1030-1190 kg ha-1) were harvested after a less water-demanding plant.

The crop year has a significant effect on fertilization as well, since nutrients are utilized more efficiently in humid than in arid years, when plants cannot take up sufficient nutrients. However, the harmonized nutrient supply is equally important in draught as well, since the plant undersupplied with nutrients wastes the water supply in the soil.

The close correlation between the crop year and plant protection is proved by the fact that infection rates are higher in humid than in arid years, which we could improve with a single or double fungicide treatment.

The results of our four-year-long research revealed the correlation between the forecrop and the fertilization. After a favourable forecrop, significantly less fertilizer was needed to reach higher yields and better quality.

Powdery mildew, tan spot and leaf rust infection in the stands grown after favourable pea forecrop was higher than after the less favourable corn forecrop. Both the average and the intensive plant protection techniques decreased infection rates, however, the infection rates of more viable stands grown after a good forecrop was a few percent higher, even if a plant protection technique was applied, but it did not decrease the yield significantly. Thus, if a good forecrop is used, it is reasonable to use intensive plant protection techniques in order to decrease infection rates and increase the yields.

The year of 2007 shows the interaction between forecrop and irrigation. The forecrop leaving more water in the soil responded with higher yield increase to a small amount of irrigation water than the stand grown after the water-demanding corn forecrop. The effect of the unfavourable corn forecrop could be mitigated by higher irrigation water doses.

The increasing fertilizer doses increased the infection rates as well, therefore, in intensive nutrient management, plant protection techniques play an important role in the decrease of yield losses.

In arid years irrigation increased the effectiveness of fertilizers, since in the stands well-supplied with water, the nutrient intake of the plants improved, compared to that of the non-irrigated stands.

In the irrigated stands the rate of leaf diseases increased, thus plant protection techniques became more important in order to decrease yield losses.

6. New scientific results

1. our research showed that the forecrop effect prevails on good-quality chernozem soils as well. Compared to corn forecrop, the extra yield of stands grown after pea forecrop was 2130-4478 kg ha^{-1}, 1755-3094 kg ha $^{-1}$ and 1604-1648 kg ha $^{-1}$ in favourable, common and draughty years, respectively. The valorigraph value (26-67) and the gluten content (16-36 %) was higher after pea forecrop than after corn forecrop (valorigraphic value: 12-55, wet gluten content: 15-35 %).
2. the nutrition effect also prevails even on good quality chernozem soils. The extra yields of the treatments providing maximum yields were the following: in favourable years (2004 and 2005) in biculture ($N_{100-150+PK}$) 4140-5319 kg ha^{-1} , in triculture (N_{50}+PK) 909-2078 kg ha -1, in the average 2006 year following corn forecrop (N_{200}+PK) 3745-5078 kg ha^{-1}, following pea forecrop (N_{150}+PK) 1082-2270 kg ha^{-1}, in the unfavourable 2007 year in biculture (N_{150}+PK) 3201-4022 kg h, in triculture (N_{150}+PK) 2005-2678 kg $^{ha-1)}$. Irrigation increased these extra yields by the following values: 50 mm irrigation water increased the yield in triculture by 2518-2998 kg ha $^{-1}$, in biculture by 4808-5505 kg ha^{-1}, 100 mm irrigation water increased the yield following pea forecrop by 2616-3356 kg ha $^{-1}$, following corn forecrop by 4686-5544 kg ha^{-1}.
3. our research confirmed the crop year effect on good quality chernozem soil. The highest yields were 7000-922 kg ha^{-1}, 6000-7900 kg ha^{-1} and 4900-7400 kg ha^{-1} in favourable, average and draughty years, respectively. These values prove that draught has a significant effect in yield decrease (2100-2800 kg ha^{-1}).
4. During the examination of the quality parameters we established that the applied winter wheat variety, Mv Pálma, could not reach the premium quality requirements of the EU. The highest valorigraph value (62.4-68.7) was measured in 2005, at the triculture crop rotation, at N_{50-200}+PK nutrient supply. The gluten content was the highest in 2006, at triculture crop rotation, beside $N_{100-200}$+PK nutrient supply. The values of the gluten deformation and the falling number were suitable for the extra quality, but the value of the baking quality and the quantity of gluten – belonged to the gluten deformation and the falling number – were not sufficient. The produced wheat was suitable only for the requirements of intervention.

5. very strong interaction was observed between the crop year x fertilization, crop year x plant protection and fertilization x plant protection. The highest yields were observed in biculture at $N_{100-150+PK}$ and in triculture at N_{50}+PK; in average year following corn forecrop at N_{200}+PK and following pea forecrop at $N_{150-200}$+PK; while in arid years in both crop rotation systems at N_{150}+PK. Our results cleary prove the interaction between the crop year and the emergence of diseases. The infection rates were as follows: powdery mildew 29-46 %, tan spot 42-55 %, leaf rust 32-53 % in favourable years, powdery mildew 15-18 %, tan spot 42-55 %, leaf rust 37-61 % in average years, powdery mildew 22-28 %, tan spot 20-34 %, leaf rust 21-35 % in draughty years. The interaction between the crop year and the plant protection technique is of high importance, as in humid years more intensive protection is required in order to minimize yield losses. Diseases were successfully parried by a single (powdery mildew 20-25 %, tan spot 13-25 %, leaf rust 8-17 %) and a double (powdery mildew 11-18 %, tan spot 7-15 %, leaf rust 4-9 %) fungicide treatment in humid years. Thus the yield quantities of stands treated with average and intensive plant protection techniques were 575-1465 kg ha^{-1} and 1005-2053 kg ha^{-1} higher than that of the untreated stands. The harmonization of the nutrition supply and the intensity of plant protection techniques (according to the ecologic and economic possibilities) requires expertise, since increasing the fertilization dose increases the emergence of diseases and the probability of yield loss. In humid years, compared to the untreated stands the single fungicide treatment increased yields to the following values: at N_{50}+PK level by 135-847 kg ha^{-1}, at N_{100}+PK by 608-1208 kg ha^{-1}, at N_{150}+PK by 225-1381 kg ha^{-1}; and the double fungicide treatment increased yields at N_{50}+PK by 676-1433 kg ha^{-1}, at N_{100}+PK by 606-1594 kg ha^{-1}, at N_{150}+PK by 291-2053 kg ha^{-1}. Where high fertilization doses were applied, the infection rates increased and yield depression can be observed.
6. The emergence of fusarium depends on the crop year, and is influenced by fertilization, plant protection and slightly by the forecrop. Only in two (2005 and 2006) out of the four years were plant stands infected by fusarium. Higher infection was observed in stands grown after corn forecrop, which increased parallel with fertilizer doses (Ø: 2-15%, N_{200}+PK 6-27 %). The following infection rates were observed in stands grown after pea forecrop: Ø: 3-11%, N200+PK 7-19%. Fungicides successfully parried

Fusarium infection (extensive plant protection technology: 3-27%, average plant protection technology: 1-18 %, intensive plant protection technology: 2-13 %).

7. Our results proved that the two examined long term experiment were suitable for the investigation of the effect on the yield and the quality of the permanently identical nutrient supply. The environmental charging caused by the excessive nutrient supply and crop protection chemicals could be reduced, and the quantity and quality of yield could be optimised with the establishment of optimal nutrient supply and proper plant protection. It can be observed in the experiments, which received permanently identical treatments (fore crop, nutrient supply, and plant protection), that how the different years can modify the interactions between the agro-technical parameters. The employment of an extra quality variety, which is cultivated on large area, could increase the value of the experiment, because the factors for reaching the EU premium quality could be examined.

7. Practical results

1. based on our experiment we found that in winter wheat production on chernozem soil with good nutrient and water management, out of the agrotechical factors great attention should be paid to crop rotation, nutrition and plant protection.
2. the agrotechnical and economic efficiency appropriate to the ecologic factors has a major role in wheat production. On areas with less favourable ecological capabilities the extensive, on favourable lands the intensive wheat production is reasonable.
3. our examinations revealed that in practice it is necessary to analyse and execute the agrotechnical elements (crop rotation, nutrition supply, crop production, irrigation) in interaction. This is the only way to gain sufficient quality and quantity wheat.
4. our results show that the harmonization of agrotechnical components is of great importance in order to reach sufficient quality and quantity wheat. Crop protection is of high importance in production on good quality soil together with fertilization.
5. the use of intensive technology can be the future of wheat production on production sites with good potentials.

LIST OF PUBLICATIONS IN THE TOPIC OF DISSERTATION

IF Publications

1. **HORNOK M** – Pepó P. (2005): Effects of some agrotechnical elements on yield formation in winter wheat production, Cereal Research Communications, 33. 1. 93-96. (IF: 0,32)
2. **HORNOK M** – Pepó P- Balogh Á. (2006)**:** Evaluation of quality and quantity parameters in winter wheat production on chernozem soil, Cereal Research Communications, 34. 1. 481-484. (IF: 1,037)
3. Balogh Á.– Pepó P.-**HORNOK M**. (2006): Interactions of cropyear, fertilization and variety in winter wheat management, Cereal Research Communications,. 34. 1. 389. (IF: 1,037)
4. **HORNOK M.** –Balogh Á. –Pepó P. (2007): Critcal elements of sustainable winter wheat (Triticum aestivum) management in biculture and triculture crop rotation, Cereal Research Communications, 35. 2. 481-484. (IF: 1,19)
5. Balogh Á. – **HORNOK M.** – Pepó P. (2007): Study of physiological parameters in sustainable winter wheat (Triticum aestivum L.) production, Cereal Research Communications, 35. 2. 205-208. (IF: 1,19)
6. **HORNOK M.** (2008): Effects of the most important agrotechnical elements on the yield of winter wheat, Cereal Research Communications, 36. 3. 1243-1246. (IF: 1,19)
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