

The effects of agrotechnological factors on winter wheat yield in humid cropyear

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Keywords: winter wheat, forecrop, fertilization, plant protection, yield

SUMMARY

The effects of crop rotation, nutrient supply and crop protection technologies, as well as the appearance of the main ear- and leaf-diseases (powdery mildew, helminthosporium leaf spot, leaf rust, fusarium) were studied on the crop yields of winter wheat variety MV Pálma during the 2009/2010 crop year. The experiments were conducted in triculture (pea – wheat – corn) and biculture (wheat – corn), at five nutrition levels, with the use of three crop protection technologies (extensive, conventional and intensive) at the Látókép Research Site of the University of Debrecen, Centre of Agricultural Sciences. Our results proved that the appearance of leaf- and ear-diseases were significant in the wheat cultures during the 2009/2010 crop year, because of the rainy, warmer than usual weather, the lodging, and the huge vegetative mass developed. The most severe infections by the four examined diseases after pea and corn pre-crops were observed at extensive crop protection levels, when fertilizers were used at the highest dose.

Following corn pre-crop, in the case of all the three crop protection technologies the maximum rate of wheat yield results were achieved at $N_{150}+PK$ level. The highest yield was reached at intensive crop protection level (6079 kg ha^{-1}). In triculture, in case of all the three crop protection technologies the maximum yields were achieved at $N_{50}+PK$ level; in extensive technology 5041 kg-ha^{-1} yield, in conventional technology 6190 kg ha^{-1} yield was realised, while in the intensive technological model the yield was 7228 kg ha^{-1} .

The relationship between yield and fertilizer amounts, the rate of pathogen contaminations, crop protection technologies and pre-crops was defined with correlation analysis in case of different crop rotations during the 2009/2010 crop year. Based on the results of the experiment, we found that in stands after corn pre-crop strong positive correlation was established between the crop protection level and the crop yield (0.543), the nutrient levels and the emergence of the four examined pathogens, and between the nutrient levels and the yield (0.639). Extremely strong positive correlation was observed between crop protection and yield (0.843) in triculture. Strong positive correlation was detected between the nutrient levels and the presence of the four examined pathogens, as well as between nutrient and lodging (0.688). Strong negative correlation was between the crop protection level and the four examined diseases both in biculture and triculture.

Review of scientific literature

The yield of winter wheat is affected by many factors such as biological, genetical, ecological conditions and agrotechnological factors.

The climate of Hungary is suitable for wheat production, but there are more favourable and less favourable production sites (NAGY, 1981). The importance of climate factors is decisive for wheat yield. Crop fluctuations are principally caused by climate factors, especially the lack of precipitation (RADICS, 2003). Precipitation is the most variable element of climate, its uncertainty can be characterised by the fact that in the most humid years the amount of precipitation can be three times higher than in the driest years (BOCZ, 1996). SZÁSZ (1973) states that high crop yields can only be obtained when climate conditions – primarily water supply – satisfy the plants' needs. MÁRTON (2004) searched the effects of fertilizers, liming and precipitation on winter wheat yield and established that in humid years the crop yield was lower than in case of drought damage. The optimal precipitation and the corresponding yields varied between 449-495 mm and $1.7\text{-}3.4 \text{ t ha}^{-1}$. In humid cropyear the high precipitation increases the damage caused by infections. The rainy and cold summer of year 1933 has assisted to the appearance of stripe rust (*Puccinia striiformis*) (UBRIZSY, 1965). According to PEPÓ (2004), the degree of leaf- and ear- diseases is determined by the season. When the precipitation ranged between 200-250 mm during spring and at the beginning of summer (April, May, June), the diseases occurred significantly. KOVÁCS (1996) states that the protection against *Fusarium* ear blight is determined by the number of rainy days from ear formation till harvest. If this values ranges between 20-23 days, serious diseases can be expected.

The baking quality of wheat is determined up to 25 % by the elements of direct effect (especially fertilization and plant protection), and up to 16 % by the elements of indirect effects (pre-crop, sowing, harvest) of the agrotechnological factors (PEPÓ, 2005). Among the external agrotechnological factors, nutrition supply has the greatest effect on the wheat quality in the given cropyear, as winter wheat is one of the most demanding and responsive culture (GYÓRI ÉS GYŐRINÉ MILE, 1998). The quantity of fertilizer doses applied and their effectiveness are affected by many factors, such as season, soil cultivation and soil properties. Nutrient content, nutrient supply capacity of soil and nutrient supplement of precrops should also be taken into consideration (PEPÓ ÉS RUZSÁNYI, 1990). The nutrient dose modifying effect of precrop is complex. The best precrops are those harvested in the summer, such as leguminous crops (except soyabean), rape, hemp. The harvesting time of these crops lasts from July till the middle of August (GYÓRI and GYŐRINÉ MILE, 1998). BOCZ and SÁRVÁRI (1981); VÁRNAI et al. (1985) emphasize the fact that wheat yield can be higher by 0.8-0.9 t/ha after

pea, and this amount can be higher by 0.3-0.5 t/ha after corn, compared to wheat monoculture. According to KÁPOSZTA's (1971) results if wheat is grown in consecutive years the fertilizer, especially the N-demand increases. However, the present of excessive N amount over the physiological optimum causes excessive development of vegetative mass, weakens the plant tissue and enhances mycosis (BOCZ, 1996). Breeding for resistance against fusarium, powdery mildew, rust- and foot-diseases is considered the most important strategy in winter wheat production (PEPÓ ÉS RUZSÁNYI, 1990).

Materials and Methods

The experiments were conducted as part of the long-term trial adjusted by Prof. Dr. László Ruzsányi in 1983, in triculture (pea – wheat – corn) and biculture (wheat – corn), at five nutrition levels, with the use of three crop protection technologies (extensive, conventional and intensive) at the Látókép Research Site of the Centre of Agricultural Sciences, University of Debrecen. The research area is located on the Hajdúság loess ridge, 15 km from Debrecen, along Route 33. The wheat variety used in the long-term trial was Mv Pálma, which was sown at 5.8 million germs/ha.

The soil of the research site is plain and homogen, its genetic soil type is calciferous chernozem. Starting state data show that the soil-physical category of the soil is loam, its pH value is almost neutral, phosphorus supply is medium, and potassium supply is medium – good. Humus content is medium, the thickness of humus layer is about 80 cm. Estimated depth to groundwater is 3-5 m.

The agrotechnical interventions applied in the trial met the requirements of modern wheat cultivation. In the extensive, conventional and intensive plant protection technologies the crops were protected against weeds with the combination of Solar 0.2 l/ha + Duplosan DP 1.5 l/ha + Mezzo 10 g/ha. In extensive plant protection technology no pest or disease control measures were applied. In the stock where conventional plant protection technology was applied, Tango Star was used in a 0.8 l/ha dose (May 25th, 2010.), while pest control measures were not applied. Regarding the intensive technology, Tango Star (May 3rd, 2010) and Juwel TT (May 25th, 2010) were applied against pathogens in 0.8 l/ha and 1.2 l/ha doses, respectively, but pest prevention measure was not applied either.

The weather of crop year 2009/2010 was significantly extreme in respect of winter wheat growth. Following the dry weather of early autumn the precipitation of the whole crop year (except March) was much higher than the average. The rainy weather set in at the end of October was favourable in respect of the growth, the strengthening and the preparation for winter of the wheat cultures. The wheat stands tolerated well the severe winter weather under snow cover. Precipitation, spring and early summer weather were prosperous for the vegetative growth of the crops, however, owing to the huge amount of precipitation the occurrence of plant diseases and lodging were significant. During the humid cropyear the yield results were average or less than average, depending of the treatments. *Table 1.* summarizes the tendency of the meteorological factors during the crop year of 2009/2010.

Table 1.

Meteorological parameters in the vegetation period of winter wheat (precipitation, mean monthly temperature, Debrecen, 2010.)

Month	Precipitation (mm)			Month	Temperature (°C)		
	2009/2010.	30-year average	Difference 2010.		2009/2010.	30-year average	Difference 2010.
October	79,3	30,8	48,5	October	11,4	10,3	1,1
November	78,3	45,2	33,1	November	7,6	4,5	3,1
December	54,9	43,5	11,4	December	2,3	-0,2	2,5
January	48,8	37	11,8	January	-1,1	-2,6	1,5
February	58,6	30,2	28,4	February	0,5	0,2	0,3
March	14,4	33,5	-19,1	March	7,6	5	2,6
April	83,9	42,4	41,5	April	11,6	10,7	0,9
May	111,4	58,8	52,6	May	16,6	15,8	0,8
June	100,9	79,5	21,4	June	19,7	18,8	0,9
Total annual precipitation (mm)	630,5	400,9	229,6	Mean annual temperature (°C)	8,47	6,94	1,53

Results and Discussion

The effect of pre-crops, fertilization and crop protection technologies were studied for the appearance of leaf- and ear-diseases and for winter wheat yield results.

The effects of the treatment on the pathological condition of wheat

Powdery mildew, helminthosporium leaf spot (HTR), leaf rust and fusarium contamination levels were examined during 2009/2010 crop year, using three plant protection technologies (extensive, conventional, intensive) of different intensity. After corn pre-crop the powdery mildew contamination of the control plots was

the lowest (2-5%) in case of the different plant protection technologies during 2009/2010 crop year. Contamination gradually increased with the increasing fertilizer doses; these doses are summarized in *Table 2*. The rate of helminthosporium leaf spot was 5-12% on the control plots. HTR-contamination showed increase with increasing nutrient levels, the most severe contamination was detected at the highest nutrient level; in case of extensive plant protection technology this reached 38%, in the conventional technological model the contamination was 29% and in intensive technology it was 15%. We can state that the highest contamination (24%) by leaf-cust was observed in case of extensive technology near the highest fertilizer doses. Severe ear fusarium contamination appeared in wheat stocks during 2010 due to the persistent precipitation and the humid air during ear formation - flowering and ripening. The degree of fusarium contamination reached 3-8% even on the control plots. Similar to the increasing trend of the other infections, this rate also showed further increase together with the increasing nutrient levels and reached 13-26% at N₂₀₀+PK nutrient level.

Table 2.

Effect of fertilisation and plant protection technology on leaf and ear diseases of winter wheat in a biculture (Debrecen, 2010.)

Plant protection technology (A)	Fertiliser rate (kg ha ⁻¹) (B)	2010.			
		Powdery mildew	HTR	Leaf rust	Spike fusarium
Non-intensive	Ø	5	12	6	8
	N ₅₀ +PK	8	17	10	13
	N ₁₀₀ +PK	12	29	14	17
	N ₁₅₀ +PK	15	35	22	22
	N ₂₀₀ +PK	16	38	24	26
Average	Ø	2	10	2	6
	N ₅₀ +PK	4	13	5	9
	N ₁₀₀ +PK	9	19	8	13
	N ₁₅₀ +PK	11	27	12	18
	N ₂₀₀ +PK	12	29	13	20
Intensive	Ø	2	5	1	3
	N ₅₀ +PK	3	8	2	6
	N ₁₀₀ +PK	4	12	4	10
	N ₁₅₀ +PK	5	14	5	12
	N ₂₀₀ +PK	5	15	5	13
LSD5% (A)		2,76	4,99	2,69	3,42
LSD5% (B)		1,68	2,90	1,64	2,08
LSD5% (AxB)		2,90	5,03	2,84	3,60

The examined four diseases reached their infection maximum at the highest nutrient level in triculture as well (after pea pre-crop). Among the plant protection technologies, the highest contamination was observed in the extensive technological model; these data are included in *Table 3*.

Table 3.

Effect of fertilisation and plant protection technology on leaf and ear diseases of winter wheat in a triculture (Debrecen, 2010.)

Plant protection technology (A)	Fertiliser rate (kg ha ⁻¹) (B)	2010.			
		Powdery mildew	HTR	Leaf rust	Spike fusarium
Non-intensive	Ø	6	19	9	7
	N ₅₀ +PK	10	28	14	11
	N ₁₀₀ +PK	15	36	21	15
	N ₁₅₀ +PK	21	42	29	20
	N ₂₀₀ +PK	24	48	31	24
Average	Ø	4	14	5	5
	N ₅₀ +PK	7	19	7	9
	N ₁₀₀ +PK	10	26	10	10
	N ₁₅₀ +PK	14	30	15	12
	N ₂₀₀ +PK	15	32	17	17
Intensive	Ø	2	7	2	2
	N ₅₀ +PK	3	9	3	5
	N ₁₀₀ +PK	5	14	4	6
	N ₁₅₀ +PK	6	17	6	10
	N ₂₀₀ +PK	7	18	9	11
LSD5% (A)		2,57	4,91	3,42	3,04
LSD5% (B)		1,56	2,89	1,82	1,85
LSD5% (AxB)		2,70	5,01	3,15	3,20

The rate of powdery mildew infection reduced in the conventional and intensive crop protection technologies, and was extremely enhanced by the increased fertilizer doses. According to this, the most severe powdery mildew contamination (24%) was experienced at the highest fertilizer dose in extensive crop protection technology. The same can be stated about helminthosporium leaf spot as well. The disease was reduced moderately by simple protection (i.e. usual technology), and significantly by double stock protection (intensive crop protection). Leaf-rust contamination increased continuously as well with the increase of fertilizer doses, and achieved the highest value (31%) at level N₂₀₀+PK in the extensive crop protection technology. The intensive technology decreased the infection rate efficiently, that is, it was only 9% even in case of the highest fertilizer dose. Similar results were obtained when fusarium infection was tested as in biculture crop rotation, after corn pre-crop. The contamination rates varied between 2-24% depending on the crop protection technologies and nutrient treatments. The results proved that the appearance of leaf- and ear-diseases were extremely significant in wheat cultures during the 2009/2010 crop year, owing to the rainy, warmer than usual weather, the lodging, and the huge vegetative mass developed.

The effects of the treatments on winter wheat yield

The effect of the different crop rotation, nutrient- and crop protection treatments on winter wheat yield are summarised in *Table 4*. Following corn pre-crop, the maximum of wheat yields was achieved at N₁₅₀+PK level, in all three crop protection technologies. The largest yield was obtained in intensive crop protection technology (6079 kg ha⁻¹), since this was the treatment that most effectively reduced the occurrence of diseases, thus the yield reducing effect of diseases was moderate.

In triculture after pea pre-crop, in all three crop protection technologies the maximum rates were achieved at N₅₀+PK level; in extensive technology 5041 kg ha⁻¹ yield, in conventional crop protection 6190 kg ha⁻¹ yield was realised, while in the intensive technological model the yield was 7228 kg ha⁻¹.

Having compared the maximum crop yield of the stands after corn and pea precrops, we found that the wheat yield in triculture was 771-1149 kg ha⁻¹ higher than in biculture. The reason for that is the fact that pea increases the nitrogen supply of the soil, spares its hydrological regime, has favourable effects on the physical and chemical properties, hereby increases yield amount.

Table 4.

Effect of fertilisation and plant protection technology on the yield of the winter wheat in biculture and triculture (Debrecen, 2010.)

Plant protection technology (A)	Fertiliser rate (kg ha ⁻¹) (B)	Yield (kg ha ⁻¹)	
		Biculture 2010.	Triculture 2010.
Non-intensive	Ø	2972	4242
	N ₅₀ +PK	3671	5041
	N ₁₀₀ +PK	3842	4886
	N ₁₅₀ +PK	4176	4742
	N ₂₀₀ +PK	3836	4530
Average	Ø	3162	4885
	N ₅₀ +PK	4223	6190
	N ₁₀₀ +PK	5292	5804
	N ₁₅₀ +PK	5419	5645
	N ₂₀₀ +PK	5194	5367
Intensive	Ø	3316	5607
	N ₅₀ +PK	4669	7228
	N ₁₀₀ +PK	5437	6990
	N ₁₅₀ +PK	6079	7087
	N ₂₀₀ +PK	5648	6849
LSD5% (A)		420,91	449,63
LSD5% (B)		256,14	273,61
LSD5% (AxB)		443,64	473,90

The results by Pearson correlation-analysis

The relationship between yield and fertilizer amounts, the rate of pathogen contaminations, crop protection technologies and precrops during crop year 2009/2010 was defined with correlation analysis in case of different crop rotation technologies.

Table 5. contains the data relating to biculture. Based on the results of the experiment, in cultures after corn precrop strong positive relationship was established between the crop protection technology and the yield (0.543), the nutrient levels and the emergence of the four examined pathogens and between the nutrient levels and the yield amount (0.639). Very strong positive correlation was observed between the fertilizer levels and lodging (0.760). Strong negative correlation was between the crop protection technology and the four examined

diseases. The correlation between the specific technology was lowest with fusarium and highest with leaf-rust infection.

Table 6. contains the results by Pearson's correlation-analysis relating to triculture. Very strong positive correlation was observed between the crop protection technology and the yield (0.843). Strong positive correlation was observed between the nutrient levels and the emergence of the four examined pathogens, as well as between the nutrient supply and lodging (0.688). Strong negative correlation was found between the crop protection technology and the four examined diseases, as well as between the yield and HTR- infection (-0.537) and leaf-rust infection (-0.553). Moderate negative correlation was between the yield amount and fusarium (0.382) and powdery mildew (0.497) infection, respectively.

Table 5.

Correlation between the analysed parameters in the biculture (Debrecen, 2010.)

	Plant protection technology	Fertiliser rate	Yield	Powdery mildew	HTR	Leaf rust	Spike fusarium	Lodging
Plant protection technology	1	0,000	0,543(**)	-0,620(**)	-0,605(**)	-0,686(**)	-0,516(**)	0,420(**)
Fertiliser rate		1	0,639(**)	0,619(**)	0,672(**)	0,591(**)	0,766(**)	0,760(**)
Yield			1	0,059	0,085	-0,050	0,228	0,792(**)
Powdery mildew				1	0,923(**)	0,926(**)	0,864(**)	0,151
HTR					1	0,924(**)	0,896(**)	0,197
Leaf rust						1	0,859(**)	0,081
Spike fusarium							1	0,349(**)
Lodging								1

Table 6.

Correlation between the analysed parameters in the triculture (Debrecen, 2010.)

	Plant protection technology	Fertiliser rate	Yield	Powdery mildew	HTR	Leaf rust	Spike fusarium	Lodging
Plant protection technology	1	0,000	0,843(**)	-0,652(**)	-0,735(**)	-0,727(**)	-0,568(**)	0,461(**)
Fertiliser rate		1	0,143	0,632(**)	0,585(**)	0,567(**)	0,709(**)	0,688(**)
Yield			1	-0,497(**)	-0,537(**)	-0,553(**)	-0,382(**)	0,486(**)
Powdery mildew				1	0,923(**)	0,939(**)	0,901(**)	0,085
HTR					1	0,936(**)	0,896(**)	0,047
Leaf rust						1	0,896(**)	-0,039
Spike fusarium							1	0,152
Lodging								1

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