STUDY OF CROPYEAR EFFECTS IN CEREAL CROP MODELS

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Abstract

In non-irrigated treatment the maximum yields of winter wheat were 5590 kg ha^{-1} in biculture (maize-wheat) and 7279 kg ha^{-1} in triculture (peas-wheat-maize) in 2007 year characterized by water-deficit stress. In 2008 (optimum rain amount and distribution) the maximum yields were 7065 kg ha^{-1} (biculture) and 8112 kg ha^{-1} (triculture) in non irrigated conditions. The fertilization surpluses of wheat were 2853-3698 kg ha^{-1} (non- irrigated) and 3164-5505 kg ha^{-1} (irrigated) in a dry cropyear (2007) and 884-4050 kg ha^{-1} (non-irrigated) and 524-3990 kg ha^{-1} (irrigated) in an optimum cropyear (2008). The optimum fertilizer doses varied $N_{150-200}$+PK in biculture and N_{50-150}+PK in triculture depending on cropyear and irrigation. The optimalization of agrotechnical elements provides 7,8-8,5 t ha^{-1} yields in dry cropyear and 7,1-8,1 t ha^{-1} yields of wheat in good cropyear, respectively.

Our scientific results proved that in water stress cropyear (2007) the maximum yields of maize were 4316 kg ha^{-1} (monoculture), 7706 kg ha^{-1} (biculture), 7998 kg ha^{-1} (triculture) in non irrigated circumstances and 8586 kg ha^{-1}, 10 970 kg ha^{-1}, 10 679 kg ha^{-1} in irrigated treatment, respectively. In dry cropyear (2007) the yield-surpluses of irrigation were 4270 kg ha^{-1} (mono), 3264 kg ha^{-1} (bi), 2681 kg ha^{-1} (tri), respectively. In optimum water supply cropyear (2008) the maximum yields of maize were 13 729-13 787 (mono), 14 137-14 152 kg ha^{-1} (bi), 13 987-14 180 kg ha^{-1} (tri) so there was no crop-rotation effect. We obtained 8,6-11,0 t ha^{-1} maximum yields of maize in water stress cropyear and 13,7-14,2 t ha^{-1} in optimum cropyear on chernozem soil with using appropriate agrotechnical elements.

Keywords: cereals, cropyear, crop models

INTRODUCTION

In wheat production, yield quantity and the different agronomic traits are equally determined by ecologic (weather, soil), biological (genotype) and agrotechnical (crop rotation, nutrient supply, water supply, plant protection) factors. From these factors the abiotic (weather, nutrient- and water-supply) and biotic (diseases, pests, weeds) are especially important. According to SZÁSZ (2002) the frequency of dry cropyears increased from 22,5 % to 52,6 % in Hungary in the last 150 years. The results of OLSEN and BINDI (2002), BIRKÁS et al. (2006), VÁRALLYAY (2007), BALOGH and PEPÓ (2008) showed that as a result of global climate change the yield of crops have dropped and yield fluctuation has increased.

The yield of maize is significantly changes on farm and plot level as well, which shows the high sensitivity of the plant for ecologic and agrotechnical factors (PEPÓ et al. 2006).

To some extent, the negative influence of climatic factors can be reduced by appropriate hybrid selection (SÁRVÁRI 1995, PEPÓ et al. 2007) and by appropriate agrotechnical management. In dry years the role of irrigation is especially significant in ensuring high yields of maize (RUZSÁNYI 1990, PEPÓ et al. 2008).

MATERIALS AND METHODS

Our long-term experiment was set up in 1983 on chernozem soil on the Látókép Research Station of the University of Debrecen in the Hajdúság region (Eastern Hungary). The following factors were examined in the long-term experiment:

- crop rotation: biculture (maize, wheat), triculture (pea-wheat-maize)
- fertilization: control, N = 50 kg ha^{-1} P_2O_5 = 35 kg ha^{-1}, K_2O = 40 kg ha^{-1}, and 2-3-4 folds of this dose
- irrigation: irrigated and non irrigated (2007 = 100 mm; 2008 = 0 mm) treatments

The weather was significantly different in the two examined years. Compared to the many-year average, the weather in 2007 was warm, dry and specifically draughty, while in 2008 it was nearly optimal for wheat production (*Table 1*).

Table 1.

Meteorological data of vegetation period

	October	November	December	January	February	March	April	May	June	Average Total
Temperature (oC) 30 year average	10,3	4,5	-0,2	-2,6	0,2	5,0	10,7	15,8	18,7	6,9
2007. year	11,3	6,2	2,2	3,7	4,1	9,1	12,6	18,4	22,2	10,0
2008. year	9,7	3,5	-0,6	1,0	3,0	6,2	11,4	16,8	20,6	8,0
Rainfall (mm) 30 year average	30,8	45,2	43,5	37,0	30,2	33,5	42,4	58,8	79,5	400,9
2007. year	22,9	9,2	5,0	23,9	53,2	14,0	3,6	54,0	22,8	208,6
2008. year	71,4	40,9	29,8	26,4	4,6	41,7	74,9	47,6	140,1	477,4

The structure of the multifactorial experiment is as follows:

- crop rotation: monoculture (maize), biculture (wheat-maize), triculture (peas-wheat-maize)
- fertilization: control, one-, two-, three- and fourfold amounts of the basic dosage of N=60 kg ha^{-1}, P_2O_5=45 kg ha^{-1}, K_2O=45 kg ha^{-1}
- irrigation: not irrigated and irrigated

During the vegetation period of 2007, irrigation was applied 4x50 mm (200 mm) in the irrigated treatment (between early May and late June). In 2008 year we did not applied irrigation.

Table 2 contains the 30 year average of the most important meteorological parameters (rainfall, temperature) and these parameters in the cropyears of 2007 and 2008.

Table 2.

Meteorological data of vegetation period

	April	May	June	July	August	September	Average Total
Temperature ºC 30 year average	10,7	15,8	18,7	20,3	19,6	15,8	16,8
2007. year	12,6	18,4	22,2	23,3	22,3	14,0	18,8
2008. year	11,4	16,8	20,6	20,4	20,6	14,8	17,4
Rainfall (mm) 30 year average	42,4	58,8	79,5	65,7	60,7	38,0	345,1
2007. year	3,6	54,0	22,8	39,7	77,6	86,1	283,8
2008. year	74,9	47,6	140,1	144,9	34,2	42,2	483,9

RESULTS AND DISCUSSION

The yields of winter wheat in 2007 and 2008 well reflect the weather stress effects and the interrelation of those agrotechnical factors which modify (decrease or increase) it (*Table 3*). The dry cropyear of 2007 had unfavourable effect on the vegetative and generative growth and yield formation of winter wheat. The stress caused by the unfavourable dry cropyear could significantly be decreased by optimal use of agrotechnical factors. In the dry cropyear of 2007 among agrotechnical factors the irrigation, fertilization and crop rotation had significant influence on the yields of wheat. In 2007 the yields of wheat ranged between 1892-5590 kg ha^{-1} (non-irrigated) and between 2330-7835 kg ha^{-1} (irrigated) in biculture, and between 4426-7279 kg ha^{-1} (non-irrigated) and 5328-8492 kg ha^{-1} (irrigated) in triculture, respectively (*Figure 1*). Our results proved that in dry cropyear (2007) the yield increasing effect of irrigation itself was extremely moderate without sufficient nutrient supply. In 2007 in the control treatment (abiotic stress caused by nutrient deficiency) the yield increase generated by irrigation was moderate and ranged between 438 kg ha^{-1} (biculture) and 902 kg ha^{-1} (triculture). Contrary, in the optimal NPK treatment the yield increase by irrigation was significantly higher. The yield increase caused by irrigation was 2630 kg ha^{-1} in biculture (after maize forecrop which had higher water uptake) and 1579 kg ha^{-1} in triculture (after pea forecrop that has lower demand for water).

Table 3.

The effects of cropyears and agrotechnical elements on the yields of winter wheat (Debrecen, 2007-2008, chernozem soil)

Treatments	**2007**		**2008**	
	Non irrigated	**Irrigated**	**Non irrigated**	**Irrigated**
Biculture Ø	1892	2330	3015	2892
N_{50}+PK	3420	4002	5043	4870
N_{100}+PK	5048	5932	6260	6517
N_{150}+PK	5590	6926	7065	6882
N_{200}+PK	5205	7835	6772	6585
Triculture Ø	4426	5328	7228	7350
N_{50}+PK	6273	7012	8112	7874
N_{100}+PK	6913	8492	6346	6108
N_{150}+PK	7279	8016	6036	6242
N_{200}+PK	6842	7582	5440	5149
$LSD_{5\%}$	**872**			

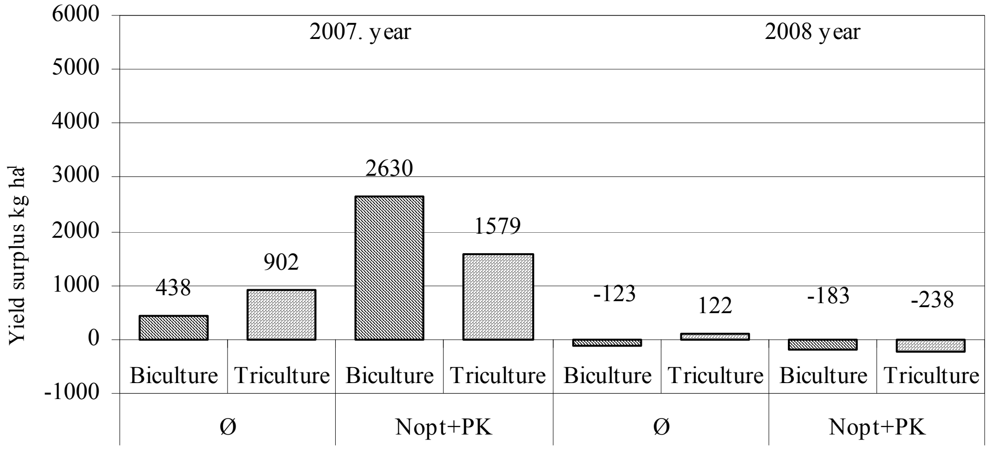

Fig 1: The effect of irrigation on the yield surpluses of winter wheat
(Debrecen, 2007-2008)

The yield increasing effect of fertilization and the optimal fertilizer dose were equally influenced by cropyear, crop rotation and irrigation. Compared to the control treatment, the yield surpluses of the optimal NPK dose treatment in 2007 were 3698 kg ha^{-1} (non-irrigated) and 5505 kg ha^{-1} (irrigated) in biculture, while the yield surpluses were significantly lower in triculture, 2853 kg ha^{-1} in non-irrigated treatment and 3164 kg ha^{-1} in irrigated treatment, respectively. In 2008 irrigation was not applied, so the crop rotation determined the yield increase caused by fertilization. This year the yield increase caused by fertilization was 4050 kg ha^{-1} (non-irrigated) and 3990 kg ha^{-1} (irrigated) in biculture and 884 kg ha^{-1} (non-irrigated) and 524 kg ha^{-1} (irrigated) in triculture, respectively (*Figure 2*).

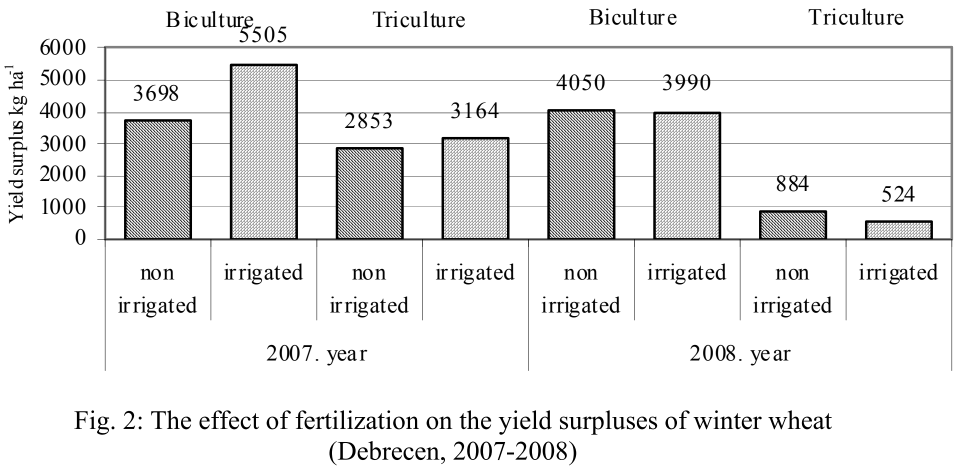

Fig. 2: The effect of fertilization on the yield surpluses of winter wheat
(Debrecen, 2007-2008)

In our long-term experiment the yields of maize were primarily determined by abiotic stress (meteorological factors) (*Table 4*). In the dry cropyear of 2007, in natural circumstances (if no irrigation was applied) the yields of maize ranged between 2685-4316 kg ha^{-1} yields in monoculture, 6258-7706 kg ha^{-1} in biculture and 6716-7998 kg ha^{-1} in triculture. In years with favourable climatic conditions the yields difference among the different crop rotation systems was minimal and not significant. In 2008 no irrigation was necessary. The yields of maize ranged between 9154-13 787 kg ha^{-1} (non-irrigated) and 8830-13 729 kg ha^{-1} (irrigated) in monoculture, 11 613-14 137 kg ha^{-1} (non-irrigated) and 12 314-14 152 kg ha^{-1} (irrigated) in biculture, and 11 291-13 987 kg ha^{-1} (non-irrigated) and 10 874-14 180 kg ha^{-1} (irrigated) in triculture.

In the control treatment in 2007 the yield surpluses of irrigation ranged between 1486-2525 kg ha^{-1}, in the optimal fertilization treatment it ranged between 2681-4270 kg ha^{-1}. The highest yield increases were obtained in the most unfavourable monoculture system concerning the water management of the soil, while in crop rotation systems involving low water consuming crops the yield-increasing effect of irrigation was moderate (in biculture 2155-3264 kg ha^{-1}, in triculture 1436-2681 kg ha^{-1} as results of irrigation).

Table 4.

Effects of cropyear and agrotechnical elements on the yields of maize
(Debrecen, 2007-2008, chernozem soil)

	Monoculture		**Biculture**		**Triculture**	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**
Non irrigated Ø	2685	9154	6258	11613	6716	11291
N_{60}+PK	3465	11057	7012	13740	7998	13323
N_{120}+PK	4316	13494	7706	14137	7062	13987
N_{180}+PK	2691	13787	7096	14003	6802	13351
N_{240}+PK	2487	13058	6829	13688	6630	13423
[illegible] Ø	5210	8830	8413	12314	8152	10874
N_{60}+PK	7105	10827	9735	13709	10358	13576
N_{120}+PK	8449	12964	10970	14152	10679	13857
N_{180}+PK	8586	13729	9965	13859	9880	14180
N_{240}+PK	8007	13372	9189	13600	9918	13245
$LSD_{5\%}$	**825**					

Our results prove that in dry year (2007) the yield increasing effect of fertilization was lower than in humid year (2008). In dry year compared to the control treatment fertilization caused only moderate yield increase (1282-1631 kg ha^{-1} according to the crop rotation system) in non-irrigated circumstances. In treatments where irrigation was applied the yield increasing effect of fertilization was significantly higher, almost twice compared with the non-irrigated treatment. In humid year (2008) the yield increase generated by fertilization was determined by the crop rotation system. Significantly high yield increase was obtained in monoculture (4633-4899 kg ha^{-1} yield increase compared with the control), but the values were good in biculture (1838-2524 kg ha^{-1} yield increase) and triculture (2696-3306 kg ha^{-1} yield increase) as well.

CONCLUSIONS

In dry year (2007) in non-irrigated circumstances the maximum yields of winter wheat were 5590 kg ha^{-1} in biculture, 7279 kg ha^{-1} in triculture, while in the cropyear with favourable water supply (2008) the maximum yields were 900-1500 kg ha^{-1} higher (7065 kg ha^{-1} in biculture, 8112 kg ha^{-1} in triculture). In dry cropyear (2007) in biculture the $N_{150-200}$+PK and in triculture the $N_{100-150}$+PK treatments proved to be optimal, while in the cropyear with favourable water supply the N_{150}+PK (biculture) and N_{50}+PK fertilization treatments proved to be optimal, respectively.

In dry cropyear there was strong interaction between water and nutrient supply. The yield surpluses of maize were significantly lower in the control treatment (1436-2525 kg ha^{-1}) than in the optimal NPK treatment (2681-4270 kg ha^{-1}). The yield increasing effect of fertilization was primarily influenced by the cropyear and modified by crop rotation and irrigation.

The cropyear, as abiotic stress modified the optimum fertilizer dose of maize grown in different crop rotation systems. In dry years lower fertilizer doses ($N_{120-180}$+PK [mono], N_{180}+PK [bi], N_{60-180}+PK [tri]) proved to be more efficient than in humid years (N_{180}+PK; N_{180}+PK; $N_{120-180}$+PK), respectively. The scientific results of our long-term experiments proved that applying appropriate agrotechnical elements the abiotic stress effects caused by weather can be moderated but cannot be eliminated. In the dry cropyear of 2007 the maximum yield of maize with optimal fertilizer dose and irrigation was 8586-10970 kg ha^{-1}, while in favourable cropyear (2008) it ranged between 13729-14180 kg ha^{-1}.

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