ENVIRONMENTAL RISK FACTORS IN DIFFERENT CROP MODELS

Pepó Peter*

Institute of Crop Sciences, FAFSEM, CAAES, University of Debrecen

Abstract

Cereals are currently the World's most important field crops and they have determinative part in Hungarian crop production, too. Yield levels of winter wheat were determined mostly by climatic effects (environmental risks) of cropyears – limited partly by water deficiency in interaction with other external, agrotechnical factors. Our long-term experimental results proved that the optimum agrotechnical elements (crop rotation, fertilization, crop protection etc.) have decision role in the reducing of the harmful environmental factors (risks) in cereal production. The two major determining factors were the fertilization and crop rotation in wheat and maize production. Our long-term experimental results proved that winter wheat could adapt better to the environmental risks (climate change, soil properties etc.) than maize.

Key words: environmental risk, crop models, adaptation, cereals

INTRODUCTION

Nowadays, the local effects of global climate change have to be considered seriously. On the one hand, this means a reduction in the amount of precipitation, its extreme distribution, the increase in temperature and more frequent and more severe extreme weather phenomena. The frequency of different year types had significantly changed for the last 150 years in Hungary (since the starting of exact meteorological measurements). The former 22% frequency of dry years increased to 52% recently, that is – statistically – every second year is dry, which is unfavourable for crop production.

Olesen and Bindi (2002) pointed out that the yield of field crops had reduced and the yield fluctuation had increased as a result of climate change. According to *Brown and Rosenberg* (1999), a 7% yield reduction (as an average of the different climate change scenarios) can occur in World crop production in the near future. *Menzhulin et al.* (1995) forecast a 20% and 30% yield reduction in the case of an increase in annual average temperature by +2^{o}C and +4^{o}C, respectively.

Numerous Hungarian and foreign literature data proved that a smaller or larger yield fluctuation should be expected between the different years even at a favourable agrotechnical level (*Szabó et al.* 1987, *Lorenzetti and Pitzalis* 1994, *Hrezo* 1996, *Takac* 1996, *Lopez-Bellido et al.* 2001).

The unfavourable weather effects can be moderated by a proper fertilization (*Sonko and Sonko* 1980, *Pelikan et al.* 1986, *Budennyi and Polesko* 1994, *Pepó* 2002a, *Fowler* 2003).

In numerous cases, the unfavourable weather effects result indirectly in a yield reduction of wheat. From among these indirect effects the lodging and higher disease infections can be yield reducing factors (*Fitt et al.* 1988, *Pepó* 2002b, *Pietravalle et al.* 2003).

The degree of yield reduction caused by unfavourable weather can differ greatly (*Pepó* 2005). Accoding to *Kosminski et al.* (1994), yield loss varied between 2 and 40% depending on the year.

MATERIAL AND METHOD

The long-term experiment was set up in 1983 on chernozem soil in Hajdúság (eastern Hungary). As regards its soil physical properties the area can be classified as loam and has a nearly neutral pH value (pH_{KCl} = 6,46). It has a medium level humus content (2.8%) and a humus depth of about 80 cm. Its supply of phosphorous is medium (133 mg kg^{-1}) and its supply of potassium can be said to be a good one (240 mg kg^{-1}). The structure of the polifactorial 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 dose of
  N = 50 kg ha^{-1}, P_2O_5 = 35 kg ha^{-1}, K_2O = 40 kg ha^{-1} (wheat)
  N = 60 kg ha^{-1}, P_2O_5 = 45 kg ha^{-1}, K_2O = 45 kg ha^{-1} (maize)
- irrigation: Ö=not irrigated, $Ö_2$=irrigated with half dose, $Ö_3$=irrigated with full
- other agrotechnical elements
  crop protection (extensive, average, intensive) in wheat
  plant density (40, 60, 80 thousand ha^{-1}) in maize

RESULTS AND DISSCUSIONS

The agro-ecological conditions of wheat production had changed significantly in the past decades. This partly meant a –generally negative – change in the soil parameters (physical, chemical and biological). Unfortunately, the physical structure of the soils deteriorated, their pH and nutrient content decreased and the microbial soil life became less active (environmental risk). Even more negative changes have occurred in the weather. The amount of precipitation diminished, temperatures increased and weather extremes became more frequent (environmental risk). Our long-term results also proved that the yield of the same genotype (GK

Öthalom) changed significantly both in the control (non-fertilized) and the optimum fertilization treatment due to the year effect (*Figure 1*).

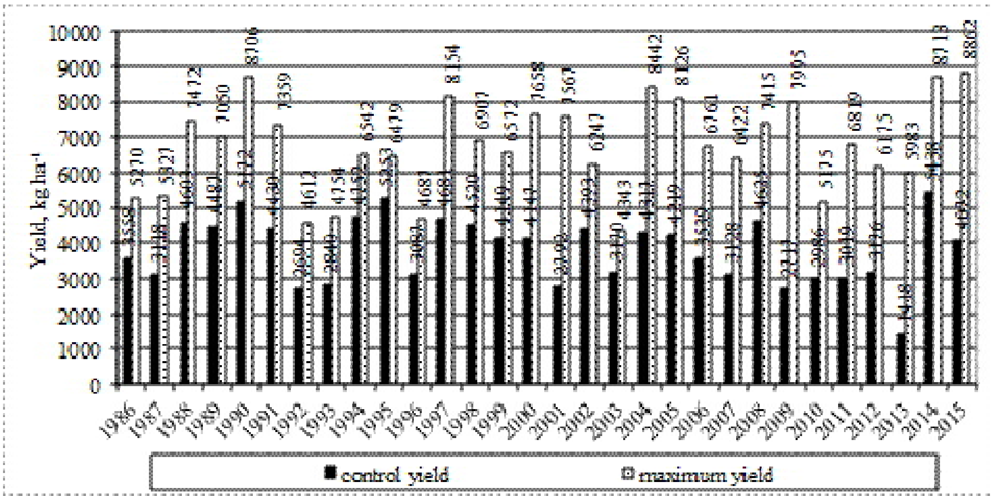

Fig. 1 The effect of fertilization on the yield of GK Öthalom variety (Debrecen, 1986-2015)

In the control treatment- under optimum agrotechnique – yields varied between 1418 and 5253 kg ha^{-1}. This meant a difference of 3835 kg ha^{-1} between the worst (dry, warm) and best (optimum water supply and temperature). In optimum fertilizer treatments, yields ranged from 4343 kg ha^{-1} to 8862 kg ha^{-1}, meaning a difference of 4519 kg ha^{-1}.

The effect of years on yield quantity and quality cannot be eliminated, but with the application of a modern production technology, we aim to minimize the unfavourable, negative effects (environmental risks) and to maximally exploit the favourable, positive effects. Our research proved that the unfavourable effects of extreme weather can be moderated partly by a proper variety selection and partly by the application of a modern, optimal, site- and variety-specific technology.

The long-term experiment provides an opportunity to determine the effects of crop rotation on wheat yields (*Table 1*). In the studied long period, the ratio of dry years, average years and years with favourable water supply was 39%, 43% and 18%, respectively. In biculture (after maize forecrop), the wheat yield was considerably lower than in triculture (after pea forecrop) in all three year types. The difference between the two crop rotations was especially high in dry years. In a dry year, the average wheat yield was 5127 kg ha^{-1} without irrigation in the optimum NPK treatment, while in triculture, the yield was 6549 kg ha^{-1} (the difference was 1422 kg ha^{-1}). In an average year, the obtained yields were 7179 kg ha^{-1} in biculture and 7238 kg ha^{-1} in triculture (a difference of 59 kg ha^{-1}).

Table 1

The effects of cropyear, irrigation and fertilization on the yield ofwinter wheat (Debrecen, 1986-2008)

BICULTURE

	Fertilization	**Dry (9 years)**	**Average (10 years)**	**Rainy (4 years)**
		Yield (kg ha^{-1})		
Non irrigated	Ø	2240	2980	3368
	N_{opt} +PK	5127	7179	7500
Irrigated	Ø	2717	3065	3120
	N_{opt} +PK	6550	7216	7264

TRICULTURE

	Fertilization	**Dry (9 years)**	**Average (10 years)**	**Rainy (4 years)**
		Yield (kg ha^{-1})		
Non irrigated	Ø	2240	2980	3368
	N_{opt} +PK	5127	7179	7500
Irrigated	Ø	2717	3065	3120
	N_{opt} +PK	6550	7216	7264

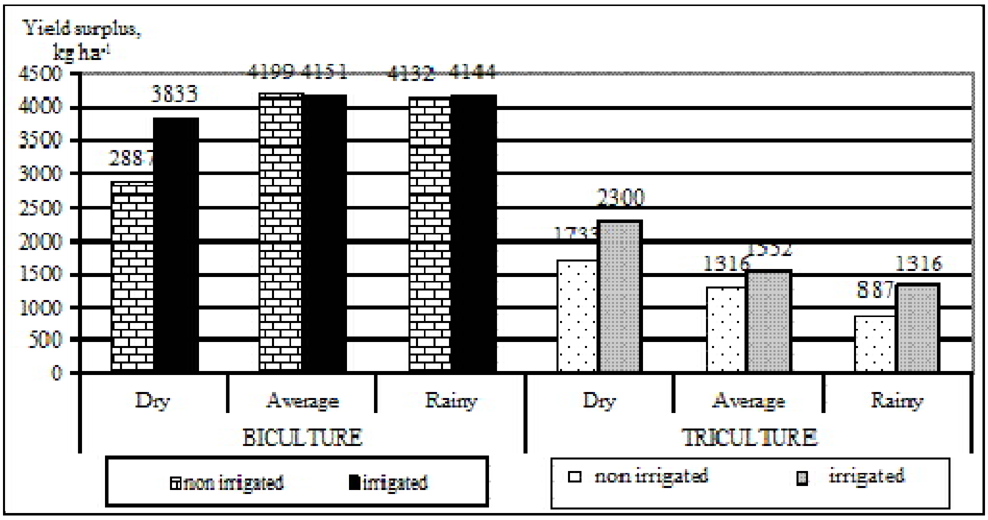

Fig. 2 Yield surpluses of fertilization in winter wheat
(Debrecen, 1986-2008, chernozem soil)

Fertilization has a determining role in the production technology of winter wheat, because directly or indirectly, it influences the effect and efficacy of all the other agrotechnical elements. Our long-term experiments on chernozem soil proved that the yield level of wheat and the efficacy or yield-increasing effect of fertilization were greatly influenced by crop rotation and water supply. In the polyfactorial long-term experiments in the optimum NPK treatment without irrigation, the maximum yield ranged between 5100 and 7500 kg ha^{-1} in biculture and between 6600 and 8300 kg ha^{-1} in triculture. The yield of the control was much lower (2200-3400 kg ha^{-1}) in biculture than in triculture (4800-7400 kg ha^{-1}). Accordingly, the yield-increasing effect of fertilization varied between 2900 and 4200 kg ha^{-1} in biculture and between 900 and 2300 kg ha^{-1} in triculture depending upon the year (*Figure 2*).

For environmental and economic considerations, it is important to know the optimum N+PK dosages in the different crop rotation systems. In our long-term experiment, the optimum dosages on chernozem soil as an average of years were

N = 110-150 kg ha^{-1} +PK in biculture (after maize as a forecrop)

N = 40-100 kg ha^{-1} +PK in triculture (after peas as a forecrop).

The different wheat genotypes differ not only in yield potential, quality and abiotic stress tolerance (e.g. drought tolerance), but also in their response to the different agrotechnical elements. From among these, one of the most important tasks is to determine the variety-specific fertilizer response of winter wheat genotypes.

From the data series of several decades, the results of 2009 year are presented here. In the control, yields of the varieties varied between 2383 and 4618 kg ha^{-1}, that is there were twofold differences between the varieties.

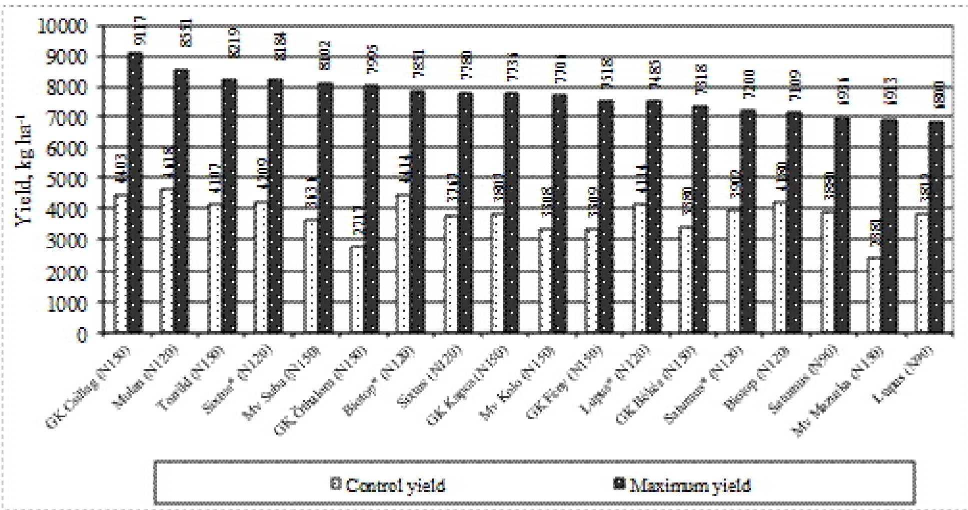

Fig. 3 The control and maximum yields of different winter wheat varieties (Debrecen, 2009)

Part of the varieties could utilize less the natural nutrient stock of chernozem soils (Mv Mazurka, GK Öthalom), while others utilized it very effectively (e.g. Mulan, Bitop, GK Csillag) (*Figure 3*). There were large differences also in the maximum yields of the varieties. In 2009, the difference between the highest (GK Csillag, 9117 kg ha^{-1}) and lowest yield

(Lupus, 6800 kg ha^{-1}) was 2317 kg ha^{-1}. The fact that the optimum N+PK dosage of wheat varieties varied between 90-120-150 kg ha^{-1} N+PK also draws the attention to the importance of variety-specific fertilization. This means that the species-specific N+PK optimum value should be determined specifically for each variety.

CONCLUSIONS

Our scientific results proved that the environmental and agrotechnical factors have the risks in crop production. Both in the favourable and dry years, fertilization (49% and 48%) and crop rotation (31% and 28%) had a determining importance. The role of crop protection increased in rainy years (17%), while in dry years, the effect of irrigation became higher (15%). Year had a 23% share in determining winter wheat yields. The role of crop rotation was similar (23%), while fertilization had the highest impact on yields (38%). As an average of the years, the role of other agrotechnical elements was significantly lower (crop protection 13%, irrigation 3%).

The same evaluation was also done for maize. According to our results, the ecological sensitivity of maize to the year was considerably higher (43%) than that of winter wheat (23%). The effects of the agrotechnical elements on yield were also different. However, the two major yield-determining factors were fertilization and crop rotation in both crops. According to our results, winter wheat could adapt better to the changing climate conditions than maize.

Our long-term experiments provided an opportunity for a comparative analysis of wheat production models of different intensity in different years. In the extensive crop production model, the yield of winter wheat varied between 1773 and 3014 kg ha^{-1} in biculture (maize-wheat) and between 4573 and 7220 kg ha^{-1} in triculture (peas-wheat-maize). In these extensive models, the yield fluctuation of winter wheat was very high in both crop rotation systems in the different years (difference, D = 5447 kg ha^{-1}). When the intensive crop production model was applied, the yield of winter wheat was considerably higher than that of extensive models. By the application of an intensive wheat production model, the yields varied between 7669 and 9839 kg ha^{-1} in biculture and between 7977 and 10635 kg ha^{-1} in triculture during the experimental period (2004-2009). By applying the intensive crop production model, the effect of year on yields could be greatly moderated. In intensive technologies, the yield fluctuation due to the year effect (environmental risk) reduced to its half (difference, D = 2966 kg ha^{-1}). By optimizing the agrotechnical factors and applying an intensive technological model, the yield of winter wheat ranged within the 8000-10000 kg ha^{-1} interval on chernozem soil in a small plot experiment.

Acknowledgments

The researches were partly supported by TÁMOP-4.2.2.D-15/1/KONV-2015-0029 project.

REFERENCES

1. Brown, R.A.-Rosenberg, N.J.: 1999. Climate change impacts on the potential productivity of corn and winter wheat in their primary United States growing regions. Climate Change. 41: 1, 73-107.
2. Budennyi, Y.V.-Polesko, Y.A.: 1994. Efficiency of fertilizers applied to winter wheat in a crop rotation in relation to meteorological conditions. Khimiya v Selskom Khozyaistve. 8. 9-15.
3. Fitt, B.D.L.-Goulds, A.-Polley, R.W.: 1988. Eyespot (Pseudocercosporella herpotrichoides) epidemiology in relation to prediction of disease severity and yield loss in winter wheat a review. Plant Pathology. 37: 3, 311-328.
4. Fowler, D.B.: 2003. Crop nitrogen demand and grain protein concentration of spring and winter wheat. Agronomy Journal. 95 (2): 260-265.
5. Hrezo, F.: 1996. Cropping systems under conventional and organic fertilization in East Slovakia lowlands. Vedecke Prace Vyskumneho Ustavu Zavlahoveho Hospodarstva v Bratislava. No. 22. 75-90.
6. Kosminski, C.-Borin, M.-Attin, M.: 1994. Climatic risk to crops in Poland. Proceedings of the third congress of the European Society for Agronomy, Padova University, Abano-Padova, Italy, 18-22 September 1994. 818-819.
7. Lopez-Bellido, L.-Lopez-Bellido, R.J.-Castillo, J.E.-Lopez-Bellido, F.J.: 2001. Effects of long-term tillage, crop rotation and nitrogen fertilization on bread-making quality of hard red spring wheat. Field Crops Research. 72 (3): 197-210.
8. Lorenzetti, M.C.-Pitzalis, M.: 1994. Yearly variability of meteorological factors and production of winter wheat in a large area. Annali della Facolta di Agraria, Universita degli Studi di Perugia. 48: 225-241.
9. Menzhulin, G.V.-Koval, L.A.-Badenko, A.L.: 1995. Potential effects of global warming and carbon dioxide on wheat production in the Commonwealth of Independent States. Climate change and agriculture: Analysis of potential international impacts. Proceedings of a symposium sponsored by the American Society of Agronomy in Minneapolis, MN, 4-5 Nov. 1992. Organized by Division A-3 (Agroclimatology and Agronomic Modeling) and Division A-6 (International Agronomy). ASA Special Publication. No. 59, 275-292.
10. Olesen, J.E.-Bindi, M.: 2002. Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy. 16 (4): 239-262.
11. Pelikan, M.-Dudas, F.-Stankova, M.: 1986. The role of major nutrients in the formation of technological quality in wheat. I. Yield and milling characteristics. Acta Universitatis Agriculturae Brno, A-Facultas Agronomica. 34: 2, 143-151.
12. Pepó, Pé.: 2002a. A tápanyagellátás szerepe a fenntartható, többfunkciós növénytermesztésben. Acta Agronomica Hungarica. Jubileumi tudományos ülés. 245-254.
13. Pepó, Pé.: 2002b. Az őszi búza fajtaspecifikus tápanyagellátása csernozjom talajon. In: Pepó-Jolánkai: Integrációs feladatok a hazai növénytermesztésben. MTA, Budapest. 105-110.

14. Pepo, P. (2005): New issues in modern crop production. Sustainable Agriculture Across Borders in Europe, Debrecen-Oradea, 2005. május 6. (Szerk.:A. Jávor, J. Kátai, J. Tamás), 21-28.
15. Pietravalle, S.-Shaw, M.W.-Parker, S.R.-Van Den Bosch, F.: 2003. Modeling of relationships between weather and Septoria tritici epidemics on winter wheat: A critical approach. Phytopathology. 93 (10): 1329-1339.
16. Sonko, L.I.-Sonko, M.P.: 1980. The presence of nutrients in an ordinary chernozem under winter wheat in relation to preceding crops, weather conditions and fertilizer effectiveness. Agrokhimiya. No. 10. 66-71.
17. Szabó, M.-Ángyán, J.-Forgács, M.-Tirczka, I.: 1987. Magyarország klimatikus adottságainak biometriai elemzése az őszi búza termésátlaga és minősége szempontjából. Növénytermelés. 36:1. 17-30.
18. Takac, J.: 1996. Production potential and irrigation requirements in the Zitny ostrov region. Vedecke Prace Vyskumneho Ustavu Zavlahoveho Hospodarstva v Bratislava. No. 22, 199-215.