AGROMETEOROLOGICAL AND AGROTECHNICAL RISKS IN MAIZE (*Zea mays* L.) PRODUCTION

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Abstract

Maize has high productivity and produces hudge vegetative and generative phytomass, but maize is very sensitive to agroecological (mainly to climatic, partly to pedological conditions) and agrotechnical circumstances. In Hungary maize is grown on 1,1-1,2 million hectars, the national average yields vary between 4-7 t ha-1 depending on the year and the intensity of production technology. The crop rotation, fertilization and plant density on the yields of maize were investigated in dry and wet cropyears in a long-term experiments on chernozem soil. The water-supplies were rainfed and irrigated. In dry cropyear the yield-surpluses of irrigation were 2.8-4.2t ha-1, in the cropyear characterized by average-good water supply the yield increasements of irrigation varied between 0.7-2.1 t ha-1, respectively. The yield-increasements of irrigation were mainly modified by crop rotation and fertilization. The optimum plant density of maize was different in the rainfed and irrigated crop technology on chernozem soil. The maximum LAI values of maize (4.0-4.8 m^2 m^{-2}) were in middle July and the SPAD values were on high level (56-59) between early July and middle August in maize production.

Key words: maize, agrotechnical elements, yield, LAI, SPAD

INTRODUCTION

Maize has high productivity, but it is very sensitive to the agroecological and agrotechnical conditions. In Hungary, maize is grown on 1.1-1.2 million hectares, the national average yield varies between 4 and 7 t ha^{-1} depending on the year and the intensity of production technology (*Pepó* et al. 2006). The impacts of weather factors (*Huzsvai* and *Nagy* 2005, *Pepó* et al. 2005), and global climate change on maize yields are of special importance (Várallyay 2007). The effect of agrotechnical elements is exerted in a complex way in the soil-plant system (Németh 2006). The effects of nutrient supply (Kovačevic et al. 2006, Izsáki 2007), plant density (Berzsenyi and Lap 2006) and irrigation (Ruzsányi 1992, Berényi et al. 2007) on the yield stability of maize are especially important. These agrotechnical factors exert their effect via interactions and not independently (Pepó et al. 2007).

The NPK fertilisers and the soil's AL-soluble, P, and K content is not only affected by the intensity of the fertilization, but also by the crop rotation and the agro-techniques applied (Andersson and Hermann 1992, Liang and MacKenzie 1994, Kovacevic et al. 2006,).

There is a close relationship between the crop yield and water supply to the crop (Plavsic et al. 2007).

A significant factor in the doubling of average yields was the use of a higher plant density (Carlone and Russel 1987). Without appropriate nutrition, fertilization the number of plants cannot be increased continuously (Nagy 1996, Russel 1991).

The nutrient-supply, fertilization have decisive roles in sustainable crop production. The nitrogen is extremely important among macroelements (*Berzsenyi* and *Lap* 2005, *Németh* 2006). The crop rotation can strongly modify the efficiency of fertilization (*Sárvári* 1995a). It is an important factor to use optimum plant density in maize production (Nagy 1989, Sárvári 1995b, Berzsenyi and Lap 2005). The efficiencies of agrotechnical factors on the yields of maize depended on the agrometeorological parameters of cropyears (Huzsvai and Nagy 2005).

MATERIAL AND METHOD

The long-term experiment was set up in 1983 on chernozem soil in the Hajdúság (eastern Hungary). Regarding the physical characteristics of the soil, 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 and its supply of potassium can be considered good.

RESULTS AND DISSCUSIONS

The different agrotechnical elements can hugly modify the yield of maize hybrids, especially important elements the crop rotation, fertilization and plant density among them.

The appropriate fertilization needs to take into consideration a lot of agrotechnical factors and other ecological circumstances (NPK contents of soil, weather condition, water supply, water reservoirs of soil etc.) and biological factors (genotypes).

Maize is a crop sensitive to ecological factors, mainly to optimum water supply. Optimum water supply is especially important in critical periods for the growth, development and yield formation of maize. The effect of water supply on the yield of maize many different agroecological (soil) and agrotechnical (croprotation, fertilization, plant density etc.) factors could modified. Two different cropyear (2004 = good water supply, 2007 = dry cropyear) were choosed to demonstrate the irrigation effects and effectiveness in maize production. In 2004 cropyear the control yields varied between 6500-7300 kg ha^{-1} in mono-, 9200-11700 kg ha^{-1} in bi- and 10500-11200 kg ha^{-1} in triculture croprotation, respectively. So in the cropyear characterized by fairly good water supply the maize could well utilized the natural nutrient resources of chernozem soil and we obtained high control yields in different croprotation. We can state that even in good water supply there were differences in the yields of different croprotation. In control treatment the yields were by 3.7-4.3 t ha^{-1} (biculture) and 3.9-4.0 t ha^{-1} (triculture) higher than in monoculture. The effect of irrigation on the yield was minimum because of good quantity and distribution of rainfall in control treatment. The other reason was the lock of nutrient supply in the control. The yield surpluses of irrigation were 0-1200 kg ha^{-1} in different croprotation in control treatment. In 2004 year the maximum yields varied between 12900-14500 kg ha^{-1} in mono-, 12300-14900 kg ha^{-1} in bi- and 12700-14300 kg ha^{-1} in triculture croprotation depending on plant density (*Table 1*). Because of favourable cropyear in 2004 we obtained high yields in N_{opt}+PK fertilizer treatments. There were very moderated differences among the different croprotations. The maximum yields were 13.4 t ha^{-1} (rainfed) and 14.2 t ha^{-1} (irrigated) in monoculture, 12.4 t ha^{-1} and 14.5 t ha^{-1} in biculture, 13.5 t ha^{-1} and 14.1 t ha^{-1} in triculture in the average of plant density, respectively. The yield surpluses of irrigation in N_{opt}+PK treatments were little bit higher than in control (800 kg ha^{-1} in mono-, 2100 kg ha^{-1} in bi- and 700 kg ha^{-1} in triculture, respectively).

We obtained different experimental results in a dry and warm cropyear (2007). The effects of croprotation on the yields of maize were very strong especially in the control treatments. In 2007 cropyear the yields of control varied between 2600-5600 kg ha^{-1} in mono-, 6000-8400 kg ha^{-1} in bi-, 6500-8200 kg ha^{-1} in triculture croprotation depending on water supply and plant density, respectively. In the N_{opt}+PK treatments the yields were the followings (depending on irrigation and plant density): in mono 3900-10242 kg ha^{-1}, in bi 7200-11000 kg ha^{-1}, in tri 7200-11100 kg ha^{-1}, respectively. The yield surpluses of irrigation were much high in dry cropyear (2007) comparing with a good water supply year (2004). Our scientific results proved that the yield increasements of irrigation were much less in control treatments (in mono 2300 kg ha^{-1}, in bi 1900 kg ha^{-1}, in tri 1000 kg ha^{-1}, respectively in average of plant density) than in N_{opt}+PK treatments (in mono 4200 kg ha^{-1}, in bi 3000 kg ha^{-1}, in tri 2800 kg ha^{-1}, respectively) because of special interaction between better nutrient and water supply in N_{opt}+PK treatment (*Table 2*).

Table 1.

Effect of agrotechnical elements on the yield (kg ha^{-1}) of maize in a good water supplied cropyear (Debrecen, 2004)

Crop rotation	Water supply	Nutrient supply	40 000 ha^{-1}	60 000 ha^{-1}	80 000 ha^{-1}	Average
Monoculture	Rainfed	Ø	6624	7139	6542	6092
	Rainfed	N_{opt}+PK	12926 (180)	12926 (240)	13850 (240)	13391
	Irrigated	Ø	7165	7157	7310	7211
	Irrigated	N_{opt}+PK	13674 (240)	14347 (240)	14453 (240)	14158
Biculture	Rainfed	Ø	9163	9740	10567	9823
	Rainfed	N_{opt}+PK	12364 (240)	12260 (180)	12521 (180)	12382
	Irrigated	Ø	10036	10426	11745	10736
	Irrigated	N_{opt}+PK	14056 (240)	14502 (240)	14925 (240)	14494
Triculture	Rainfed	Ø	10969	10489	11162	10873
	Rainfed	N_{opt}+PK	12710 (60)	13829 (180)	13895 (120)	13478
	Irrigated	Ø	10705	10483	11136	10775
	Irrigated	N_{opt}+PK	13837 (180)	14152 (240)	14322 (240)	
LSD$_{5\%}$ mono			786			
LSD$_{5\%}$ bi			903			
LSD$_{5\%}$ tri			872			

Table 2.

Effect of agrotechnical elements on the yield (kg ha^{-1}) of maize in a drought cropyear (Debrecen, 2007)

Crop rotation	Water supply	Nutrient supply	40 000 ha^{-1}	60 000 ha^{-1}	80 000 ha^{-1}	Average
Monoculture	Rainfed	Ø	3679	2685	2573	2979
	Rainfed	N_{opt}+PK	5681 (180)	4316 (120)	3874 (60)	4624
	Irrigated	Ø	5570	5210	4946	5242
	Irrigated	N_{opt}+PK	10242 (240)	8586 (180)	7690 (180)	8839
Biculture	Rainfed	Ø	6742	6258	6032	6344
	Rainfed	N_{opt}+PK	7929 (120)	7706 (120)	7156 (120)	7597
	Irrigated	Ø	8202	8413	8175	8263
	Irrigated	N_{opt}+PK	10523 (120)	10970 (120)	10205 (120)	10566
Triculture	Rainfed	Ø	7938	6716	6526	7060
	Rainfed	N_{opt}+PK	8192 (60)	7998 (60)	7214 (60)	7801
	Irrigated	Ø	7964	8152	8069	8062
	Irrigated	N_{opt}+PK	10135 (120)	10679 (120)	11080 (120)	10631
LSD$_{5\%}$ mono			582			
LSD$_{5\%}$ bi			540			
LSD$_{5\%}$ tri			647			

The number of plants is a decisive factor on the yield. To establish the number of plants per hectare, the optimal plant interval for the given hybrid must be known, i.e. the interval which the hybrid can tolerate without a decrease in yield.

Modification of the optimal plant density:

- the hybrid's genetic characteristics
- the hybrid's growing season
- the nature of the planted area
- the annual weather effect
- the level of water and nutrition

Environmental risk factors (climate change) has a huge effect on the photosynthetic capacity of maize. These agroclimatic stress factors could modify both the leaf area and the chlorophyll content of maize. Our scientific results in 2015 proved that the LAI values increased very dynamically increased between the period of mid-May and mid-July (*Table 3*). In the early development of maize (in May and in June) there were no significant differences in LAI values (in 18.05. 0.2 m^2 m^{-2}, in 18.06. 2.4-2.7 m^2 m^{-2}) concerning the different plant densities (60, 75, 90 thousand ha^{-1}). The maximum LAI (LAI_{max}) were obtained in mid-July (4.0-4.8 m^2 m^{-2}) in our experiment. Because of very drought and hot weather in July and August 2015 (environmental risk) the LAI values of maize decreased in mid-August (3.5-3.8 m^2 m^2) and late August (2.3-2.6 m^2 m^2). The reducing of maize LAI caused by natural senescens of leaves, too

Table 3.

Effect of plant density on the leaf area index (LAI) and its dynamics of maize (Debrecen, 2015)

Dates	60000 ha^{-1}	75000 ha^{-1}	90000 ha^{-1}
	LAI (m^2 m^{-2})		
18.05. 2015	0.2	0.2	0.2
18.06. 2015	2.4	2.7	2.6
06.07. 2015	3.4	4.0	4.0
15.07. 2015	4.0	4.4	4.8
13.08. 2015	3.5	3.5	3.8
27.08. 2015	2.3	2.6	2.5

The relative chlorophyll content (SPAD values) are also important from the aspect of photosynthetic capacity of maize. Our experimental data of SPAD (*Table 4*) show that there was a dynamic increasement between mid-May and early-July (18.05-06.07.) in the SPAD values of maize. During this period the SPAD values increased from 31.3-33.0 to 54.9-57.9 depending on the plant densities. We obtained stable SPAD values between early-July and mid-August except the high plant density (90000 ha^{-1}) treatment in 13.08. date. During early-July and mid-August the SPAD values varied between 54.6-58.7. In the end of August we found a huge decreasement in SPAD values because of drought, hot weather and maturity of maize.

Table 4.

Effect of plant density on the relative chlorophyll content (SPAD) and its dynamics of maize

(Debrecen, 2015)

Dates	60000 ha^{-1}	75000 ha^{-1}	90000 ha^{-1}
	SPAD (m^2 m^{-2})		
18.05. 2015	32.2	31.3	33.0
18.06. 2015	40.7	39.9	39.8
06.07. 2015	57.9	57.3	54.9
15.07. 2015	58.7	56.3	54.6
13.08. 2015	56.4	55.4	47.3
27.08. 2015	32.3	23.1	14.7

CONCLUSIONS

Maize is a sensitive crop to climatic conditions, mainly to water supply (quantity and distribution of rainfall). Our long-term experiment data proved that there were strong interactions between the cropyear and agrotechnical elements (irrigation, croprotation, fertilization, plant density) even on chernozem soil characterized by excellent physical and chemical properties. In a good water supplied cropyear (2004) we obtained high control yields (mono=6100-7200 kg ha^{-1}, bi=9800-10700 kg ha^{-1}, tri=10800-10900 kg ha^{-1}, respectively in average of plant density) and very excellent yields in N_{opt}+PK treatments (mono=13400-14200 kg ha^{-1}, bi=12400-14500 kg ha^{-1}, tri=13500-14100 kg ha^{-1}, respectively). In good cropyear there was moderated croprotation effect in N_{opt}+PK treatments. In a dry and warm cropyear (2007) our scientific results proved that the croprotation had high modification effects on the yields of maize both in control and N_{opt}+PK treatments. In 2007 year the yields (in average of plant density) were in monoculture 3000-5200 kg ha^{-1} (control) and 4600-8800 kg ha^{-1} (N_{opt}+PK), in biculture 6300-8300 kg ha^{-1} and 7600-10600 kg ha^{-1}, in triculture 7100-8100 kg ha^{-1} and 7800-10600 kg ha^{-1}, respectively. Our research results proved that there were special interactions between the water and nutrient supply in maize production. The optimum plant densities were 80000 ha^{-1} in a year (2004) characterized by good water supply and it varied between 40-80000 ha^{-1} in a drought cropyear (2007).

Our experiments proved that the increasement of LAI was very dynamic in May and June and the LAI_{max} values were obtained in the middle of July (4.0-4.8 m^2 m^{-2} in 2015). The increasement of relative chlorophyll content (SPAD) was significant in May and June and it remained on high level (56-59) between early July and middle August. We found no significant effect of plant density on the SPAD values of maize.

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