DIFFERENT MAIZE (*ZEA MAYS* L.) AGROTECHNICAL MODELS ON CHERNOZEM AND LOAMY SOILS

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Abstract

Our long-term experiments on chernozem and loamy soils proved that the crop rotation, fertilization, planting technology, irrigation and weed control are the most important element in the different agrotechnical crop models of maize (Zea mays L.). The yields of maize can be hold stable on the yield level of 11-12 t ha^{-1} and agronomy efficiency can be ensured by the optimum management of the key agronomic elements both on chernozem and loamy soils.

Key words: maize, agrotechnical models, agronomical elements, sowing time, grain moisture content.

INTRODUCTION

Maize is a crop playing a decisive role in arable plant production of Hungary. The small grain cereals and maize have together 65-67 % of Hungarian arable land. Maize production has been dramatically changed during the last couple decades. Nowadays it is a basic requirement not only to obtaine good agronomic and economic efficiencies but to built up sustainable, environmental friendly crop management based on scientific, experimental results.

According to Győrffy's (1976) findings out of the production factors influencing corn crops the ones listed below had the following shares: fertilization 27 %, variety 26 %, cultivation 24 %, plant population 20 % and deep tillage 3 %.

The nutrient-supply, fertilization have decisive roles in agrotechnical models. The nitrogen is extremely important among macroelements (Berzsenyi, 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, Lap, 2005). The efficiencies of agrotechnical factors on the yields of maize depended on the agrometeorological parameters of cropyears (Huzsvai, Nagy, 2005).

The uses of maize (both the main and the by-products) are very diverse. In the world and Hungary, the primary use is as an energy-rich feedingstuff for animals, but in developing countries having food hygienics problems about 80-90% of the yield is used for human nutrition.

In the world, the sowing area and yield of maize will increase until 2018 (Figure 1), mainly due to the increase in bioethanol production.

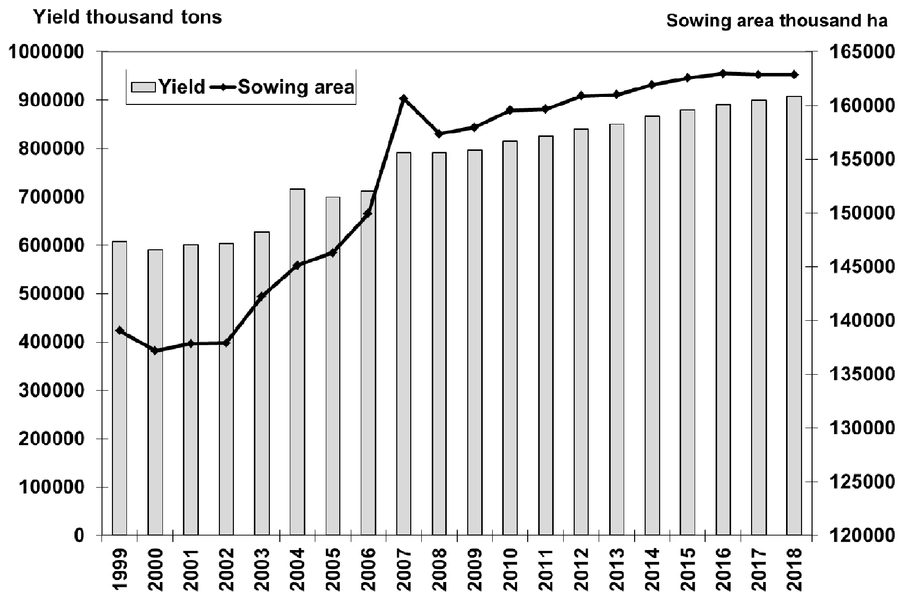

Fig. 1. Global sowing area and yield of maize in 1999-2018
(Fapri, estimated data from 2009)

The optimum sowing time is strongly influenced by the climate and soil factors and determined by the cold tolerance of the hybrid at germination.

Several Hungarian authors stressed the importance of early sowing, according to them, safer and higher yields and earlier ripening can be expected when good-quality seeds are sown at an early sowing date, than at the standard or late sowing dates (Pethe, 1817; Balázs, 1889; Cserháti, 1921).

The above statement has special significance today and the notion became more valuable, as the soil temperature reaches or exceeds 10 °C already at the beginning of April (around 5-10 April) due to global warming. There are maize hybrids with good cold test values (above 90%), which have a good cold tolerance at germination (Sárvári, 1999).

Earlier, the heat threshold value for assimilation in maize was determined as 10 °C and it is still used today. However, the heat threshold value for assimilation in maize has become lower as it adapted to the temperate zone. Based on recent domestic calculations, this value can be around 6-8 °C in the case of certain hybrids. Studying the heat threshold at emergence, a value as low as 4 °C was determined for some hybrids, while it was 8 ^{o}C for others (Rácz, Marton, 2005). When testing six genetically different inbred strains at 10 ^{o}C, there were significant differences between the early cold tolerance of the strains (Marton et al., 1997). The reduction in the heat threshold of maize was reported by others also, therefore, its modification was suggested (Bunting, 1976). The strains from different genotypes have different cold tolerance.

There is a correlation between sowing date and yield, but there is a very tight significant correlation between sowing data and grain moisture content at harvest (Sárvári, 1999). Hybrids with a longer season have a higher potential yield, but due to the continuously increasing energy prices, the drying costs can be so high which cannot be compensated by the turnover from extra yield (Marton et al., 1999; Marton et al., 2004; Szél, 2005).

The relationship between sowing date and yield is greatly influenced by the distribution of precipitation during the vegetation period. When the second half of the season was rainy, the higher yields were obtained at the late sowing date, because the late stand could utilize well even the rains in August, while the stand with early sowing could utilize it less, because its lower leaves had already dried. However, the grain moisture content at harvest was 5-8% lower at the earlier sowing date, which means an outstanding economic advantage (Sárvári, Futó, 2001; Molnár, Sárvári, 2002).

MATERIAL AND METHOD

Our long-term experiment was set up in 1983 on a chernozem soil in Hajdúság (East-Hungary). The structure of polifactorial long-term experiment is the followings: crop rotation, fertilization, plant density, irrigation.

The weed-control experiments were carried out between 1996-2013 years. In this paper we publish the yields of maize and weed-covering of 2004-2006 years.

The sowing date experiments were set up in a randomized block design with three repetitions for each sowing date. The FAO 200-300 and FAO 400-500 hybrids were tested at plant densities of 72 thousand plants ha^{-1} and 65 thousand plants ha^{-1}, respectively. The forecrop was maize. The gross and net parcel sizes were 21 m^2 and 17 m^2, respectively.

Soil preparation, chemical weed control and mechanical control were the same as described above for the study of plant density and fertilizer response.

We studied the yield, the grain moisture content at harvest, plant height, date of male and female flowering, changes in the yield elements in relation to sowing date. Due to size limits, I evaluate here only the relationships between sowing date and yield and between sowing date and grain moisture content at harvest.

RESULTS AND DISCUSSION

Maize is a sensitive field crop to agroecological and agrotechnical factors, too. We have to harmonize the ecological, biological and agrotechnical factors in the sustainable maize production to obtain optimum yields and yield-stabilities. The key elements of maize crop models has been studied for more than twenty years in different mono- and multifactorial long-term experiments on chernozem soil in Hajdúság. The scientific results of these experiments have proved that the most important, critical elements of maize production models are the followings: crop rotation, fertilization, irrigation, plant density and weed control. The ecological factors (cropyear) can strongly modify the effects of the above mentioned agrotechnical elements.

The multifactorial long-term experiments started in 1983. The Table 1 contains the most important average yields between 1986-2006 years. Fairly extreme cropyears can be found during this 21 year long period: the proportion of drought years were 48 %, the average cropyears were 38 % and the rainy cropyears were only 14 %, respectively. The effects of cropyears were significant on the yields of maize in every crop rotation. The yields of control (no fertilizers) varied between 4800-8300 kg ha^{-1} in dry cropyears, 6600-9800 kg ha^{-1} in average cropyears and 8100-11300 kg ha^{-1} in rainy cropyears depending on crop rotation. The maize yields were in optimum fertilizer treatments in the same cropyear types between 5800-8700 kg ha^{-1}, 9600-11400 kg ha^{-1} and 12800-13100 kg ha^{-1}, respectively. We obtained the strongest effects of cropyears in monoculture of maize: the maximum yield was 5.8 t ha^{-1} in monoculture in dry cropyear, but in average cropyear it was 9.6 t ha^{-1}, in rainy cropyear it was 12.8 t ha^{-1} in optimum fertilizer treatments, respectively. The unfavourable effects of drought cropyear were the strongest on maize yields in monoculture and we obtained much more moderated effects on yields in bi- and triculture crop rotation.

The efficiency of fertilization was modified by the cropyear and the crop rotation, too. The yield surpluses of maize were low (400-1000 kg ha^{-1}) in dry cropyears and they were much bigger in average (2300-3000 kg ha^{-1}) and in rainy cropyears (1800-4700 kg ha^{-1}), respectively. The biggest fertilization effects were in monoculture and the lowest ones were in triculture in the average of years (Table 1).

Table 1

The effects of crop rotation, cropyear and fertilization on the yields of maize
(Debrecen, chernozem soil, non-irrigated, 1986-2006)

Crop rotation Fertilizer tr.	**Yield (kg ha^{-1})**					
	Dry cropyear (10 years)		**Average cropyear (8 years)**		**Rainy cropyear (3 years)**	
Monoculture						
Control	4 800	1000 *	6 600	3000 *	8 100	4700 *
Nopt+PK	5 800		9 600		12 800	
Biculture						
Control	8 300	400 *	9 100	2300 *	10 300	2100 *
Nopt+PK	8 700		11 400		12 400	
Triculture						
Control	6 700	500 *	9 800	2400 *	11 300	1800 *
Nopt+PK	7 200		11 200		13 100	

* yield-surpluses

According to our results the following fertilizer doses may be considered as agronomically optimal on chernozem soil in sustainable maize production:

triculture N = 60-120 kg ha^{-1} + PK
biculture N = 100-140 kg ha^{-1} + PK
monoculture N = 140-180 kg ha^{-1} + PK

Maize needs fairly big quantity of water (500-600 mm) during its vegetation period. The critical periods of water supply are tasseling, silking and early grain formation in maize production. Our long-term experimental data proved that the yield surpluses of irrigation were between 4-5 t ha^{-1} in drought cropyears, 1-2 t ha^{-1} in average and 0-0,4 t ha^{-1} in rainy ones, respectively. According to our scientific results we can state that the maize yield can be stabilized on the level of 11-12 t ha^{-1} by using optimum nutrient- (fertilization) and water-supply (irrigation) independently from the cropyears in the agrotechnical models of maize on chernozem soil (Table 2).

Weed control is a decisive element in sustainable maize production, too. Presowing, preemergens, early and normal postemergens herbicides and their combinations could be efficiently used in maize weed control. It is very important to determine the composition of weed species and to adapt the herbicides to weeds found on the field. The yields of control (2 x cultivator) varied between 6600-7200 kg ha^{-1} in average of years and the weed-coverings were 63-68 % in control treatment. In average of herbicides the yields of maize were 10-11 t ha^{-1} in 2004, 2005 and 2006 years, too (Table 3). It means that the yield surpluses of herbicides were 3000-4000 kg ha^{-1} comparing with the control and the weed-covering of herbicide treatments varied between 3-7 % in 2004, 1-5 % in 2005 and 1-8 % in 2006, respectively.

Table 2

The effects of irrigation, cropyear and crop rotation on the yield of maize
(Debrecen, chernozem soil, 1986-2003) (optimum fertilizer treatment)

Crop rotation	Yield (kg ha^{-1})					
	Dry cropyear (10 years)		Average cropyear (7 years)		Rainy cropyear (1 year)	
Monoculture						
non-irrigated	5 761	+5446 *	9 408	+1280 *	12 473	-6 *
irrigated	11 207		10 688		12 467	
Biculture						
non-irrigated	8 658	+3417 *	11 100	+771 *	11 661	+414 *
irrigated	12 075		11 871		12 075	
Triculture						
non-irrigated	7 240	+4251 *	10 165	+1079 *	12 801	+456 *
irrigated	11 491		11 244		13 257	

* yield-surpluses

Table 3

The effect of weed-control on the yield of maize
(Debrecen, 2004-2006)

Treatment	Weed-covering (%)	Yield (kg ha^{-1})
2004 year		
Control (2x cultivator)	68,1	7 208
Herbicide treatments	3,8-7,0	10 392-11 113
2005 year		
Control (2x cultivator)	63,2	7 023
Herbicide treatments	1,6-4,9	10 737-11 041
2006 year		
Control (2x cultivator)	68,3	6 617
Herbicide treatments	1,3-8,2	11 036-11 453

There is a tight correlation between sowing date and the amount of yield, but there is an even stronger, significant correlation between sowing date and grain moisture content at harvest.

Those hybrids which have a good cold tolerance at germination (with a cold test value above 90%) can be sown 10-15 days earlier than the sowing time considered optimal formerly (20 April-6 May).

As a result of global warming, the soil temperature was above 10 ^{o}C already around 10 April in recent years. Consequently, the optimum sowing date interval of the very early and early hybrids became even wider. Hybrids with a longer season have a higher potential yield, but the extra yield cannot compensate the higher drying costs. Via an earlier sowing, the grain moisture content at harvest can be reduced in the case of the FAO 400-500 hybrids also.

If the hybrids with good cold tolerance and germination had been sown 10-15 days earlier in the different years, then their grain moisture content was 4-5% and 6-10% lower than at the optimum sowing date and at the late sowing, respectively, which has great economic advantages. The yield of hybrids with inferior cold tolerance at germination was reduced by even 2 t ha^{-1} at an early sowing depending upon the year (e.g. Lipesa 1998), therefore, it is essential to include the cold test value on the label of the seeds for the applicability of a hybrid-specific technology.

When the sowing date was earlier, male and female flowering happened 4-5 days earlier as an average of the hybrids and years, furthermore, the grain moisture content was already lower at the beginning of physiological ripening at the end of August. As a result of these, the grain moisture content at harvest was favourable even under average water release dynamics.

Hybrids with a good cold tolerance at germination (good cold test value) were e.g. Felicia, Clarica, Monalisa, Reseda, PR37K85, PR37W05.

Cold tolerance at germination was not favourable in the case of hybrids such as Lipesa, Danella, PR36B08, PR36B97, PR36M53, PR35P12.

There exists a tight correlation between sowing date and yield, however, it is greatly influenced by the distribution of precipitation during the vegetation period. In the majority of years, higher yields were obtained when an early or the optimum sowing date was applied which is in agreement with the findings of Berzsenyi et al. (1998). However, if there was more precipitation in the second half of the season (July, August), then the higher yields were obtained at late sowing (e.g. 1997, 2002). It can be explained by the fact, that at a later sowing, the maize stand is still green (even the bottom leaves) and if the weather becomes rainy, they can still utilize the available water. At an early or optimum sowing date, the stand becomes dry, in a favourable case only the bottom leaves, in worse cases even the upper leaves and they could not utilize the late precipitation (Figure 2).

However, the grain moisture content at harvest was considerably higher at a later sowing. Hybrids with a longer season have a higher potential yield, however, the costs of drying may consume a significant part of the profit from extra yield.

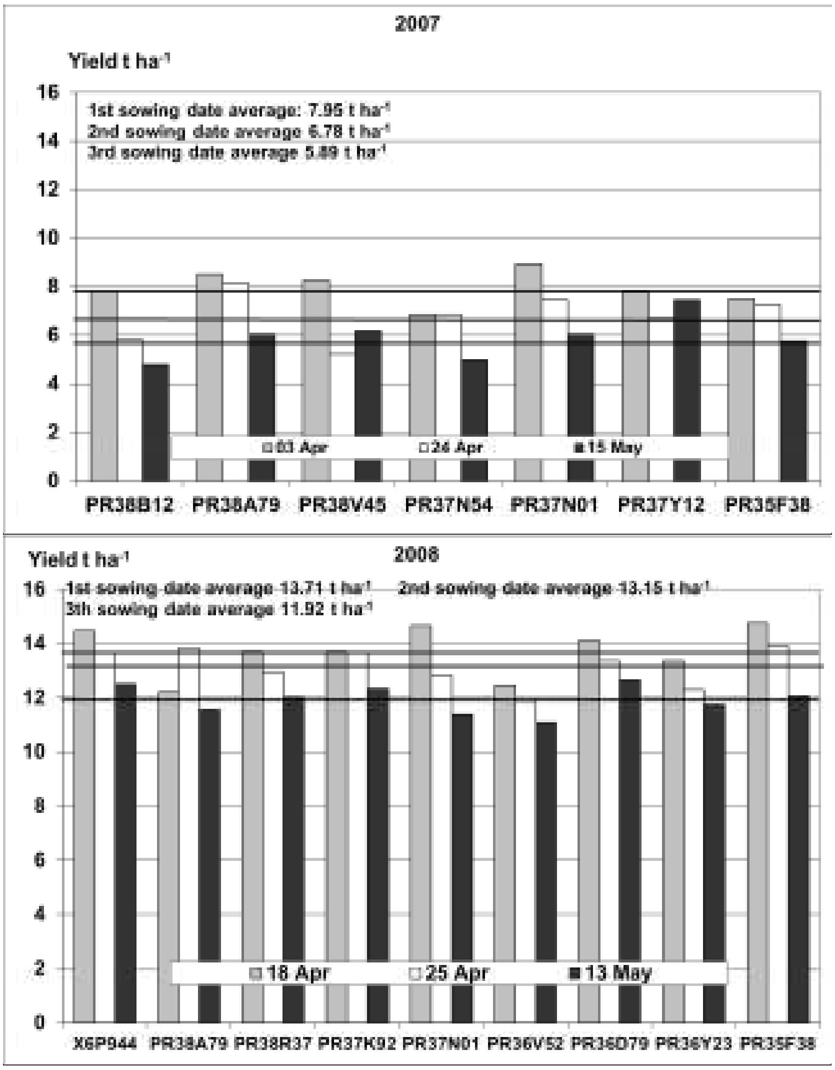

Fig. 2. The effect of sowing date on the yield of maize hybrids in Hajdúböszörmény

CONCLUSIONS

In different maize crop models it is very important to determine precisely the agroecological conditions (weather, soil) and to choose the genotype to them and to harmonize the level of agrotechnical elements with ecological and biological circumstances. According to our long-term experimental results the key-elements of maize crop models are crop rotation, fertilization, irrigation, plant density and weed-control. The yields of maize can be hold stable on the yield level of 11-12 t ha^{-1} and the agronomy efficiency can be ensured by the optimum management of the above mentioned agronomic key elements on chernozem and loamy soils.

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REFERENCES

1. Balázs Á., 1889, Növénytermelés. Mosonmagyaróvár, 2, Köt. 92 p.
2. Berzsenyi Z., Ragab A.Y., Dang Q.L., 1998, A vetésidő hatása a kukoricahibridek növekedésének dinamikájára 1995-ben és 1996-ban, In: Növénytermelés, 2, Budapest, pp. 165-180.
3. Berzsenyi Z., Lap D.Q., 2005, Műtrágyázás x növényszám interakció hatása a kukorica (Zea mays L.) hibridek szemtermésére és termésstabilitására tartamkísérletben, Növénytermelés 54, 1-2, pp. 35-53.
4. Bunting E.S., 1976, Accumulated temperature and maize development in England, J. Agric. Sci. Camb., pp. 557-583.
5. Cserháti S., 1921, Növénytermelés, Budapest.
6. Győrffy B., 1976, A kukorica termésére ható növénytermesztési tényezők értékelése. Agrártudományi Közlemények, 35, pp. 239-266.
7. Huzsvai L., Nagy J., 2005, Effect of weather on maize yields and the efficiency of fertilization, Acta Agronomica Hungarica, 53, 1, pp. 31-39.
8. Marton L.Cs., Szundy T., Nagy E., 1997, A kukorica (Zea mays L.) fiatalkori hidegtűrésének értékelése hőmérsékleti gradiens kamrában, Növénytermelés, 46, 6, pp. 549-557.
9. Marton L.Cs., Berzsenyi Z., Szundy T., Árendás T., Bónis P., 1999, Különböző tenyészidejű kukoricahibridek termőképességének és szemnedvességének összehasonlító értékelése. http://www.date.hu/kiadvany/tessedik/4/marton.pdf 2005.07.12.
10. Marton L.Cs., Árendás T., Berzsenyi Z., Szundy T., Bónis P., 2004, A kukorica vízleadásának és vízfelvételének vizsgálata Martonvásáron, Gyakorlati Agrofórum, 15, évf. 11, szám., pp. 24-26.
11. Molnár Zs., Sárvári M., 2002, A vetésidő hatása a kukorica termésére és betakarításkori szemnedvesség tartalmára. Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában, pp. 360-364.
12. Nagy J., 1989, A műtrágyázás és az öntözés hatása a kukoricahibridek termésére. DATE Tudományos Közlemények XXVIII, pp. 437-452.
13. Németh T., 2006, Nitrogen int he soil-plant system, nitrogen balances, Cereal Research Communications, 34, 1, pp. 61-65.
14. Pethe F., 1817, A kukorica termésének igen hasznos módja. Nemzeti Gazda, 4, pp. 229-230.
15. Rácz F., Marton L.Cs., 2005, Vetésidő – avagy az eredményesség fokozása költségek nélkül, Gyakorlati Agrofórum Extra 9, pp. 37-38.
16. Sárvári M., 1995a, Monokultúrás termesztés hatása a kukorica termésére réti talajon, műtrágyázási tartamkísérletekben, Növénytermelés, 44, 4, pp. 359-374.
17. Sárvári M., 1995b, A tőszám szerepe a fajtaspecifikus kukoricatermesztési technológiában, Növénytermelés, 44, 3, pp. 261-270.
18. Sárvári M., 1999, Ökológiai tényezők hatása az eltérő genetikai adottságú kukoricahibridek termésére és minőségére. Tiszántúli Mezőgazdasági Tudományos Napok DATE, Szerk.: Ruzsányi L., Lesznyák M-né, Jávor A., pp. 97-103.

19. Sárvári M., Futó Z., 2001, A vetésidő hatása a különböző genetikai adottságú kukoricahibridek termésére, In: Növénytermelés, 50, 1, pp. 43-60.
20. Szél S., 2005, Kukoricahibridek és a változó kukoricatermesztési körülmények, Gyakorlati Agrofórum Extra 9, 2005, február, pp. 8-10.