Past results and future prospects of maize breeding in Hungary

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The climatic conditions in Hungary are favourable for maize production in general, and especially for seed production. In the southern part of the country the heat sum accumulated during the vegetation period makes it possible to grow hybrids in the FAO 500-600 maturity groups, while in the major maize-growing areas in the central part of Hungary hybrids in the FAO 300-400 groups are grown. The annual mean precipitation sum on large areas of the country is around 350 mm during the vegetation period and 200-250 mm during the winter months. The spatial and temporal distribution of rainfall, however, exhibits extremely great variation, causing considerable anomalies in the growth and development of maize, and consequently in the yield. In recent years the temperature has frequently been higher than average, with an increase in the frequency of heatwaves and drought. The frequency of dry years has doubled over the last 100 years.

In Hungary maize has been grown on large areas since the end of the 19th century. The standard of production has always been greatly influenced by the choice of variety. In the late 19th century Italian varieties were mainly grown (Cinquantino, Pignoletto) and the yield average was less than 1 t/ha (*Figure 1*). Without any great change in the technology, the introduction of American varieties increased the national yield average to 1.5 t/ha. From the beginning of the 20th century, breeding began in Hungary for varieties with excellent adaptability, the cultivation of which led to a further increase in the yield average to 2 t/ha. No accurate data are available for the second world war years, but the period following the war was one of the most successful for Hungarian maize production, since the yield average was tripled over the course of 30 years, with yields of over 6 t/ha being produced regularly throughout the 1980s.

The effect of the production factors contributing to this increase in the yield average was estimated by BERZSENYI and GYÖRFFY (1995) on the basis of data from multifactorial experiments. It was found that an increase in fertiliser rates contributed 30 %, a change of variety 29 %, an increase in plant density (from 35,000 to 70,000 plants/ha) 20 % and weed control measures 18 % to the increase in average yields.

In 1985, however, this steady increase in yield, which had continued since the 1950s, suddenly came to an end, and over the last 15-20 years, instead of increasing, yield averages have shown a decline, with extremely great annual and territorial fluctuations (*Figure 2*).

It is highly probably that the same factors were responsible for the decline as were responsible for the previous increase, but the role of individual factors has not yet been clarified.

The contribution of the variety to the increase in yield average should be examined in more detail, however, since the 50th anniversary of the registration of the first Hungarian maize hybrid was celebrated in 2003.

Europe's first maize hybrid

The hybrid Martonvásári 5 (Mv 5) was the first maize hybrid produced by crossing inbred parental lines, not only in Martonvásár, and not only in Hungary, but in the whole of Europe (KOVÁCS, 2003; MARTON, 2003). The development of Mv 5 was due above all to the outstanding efforts of Endre Pap, a highly qualified breeder with wide experience in breeding. He was one of a generation of great Hungarian plant breeders, working with Rudolf Fleischmann, László Baross, Ference Somorjai, László Berzsenyi-Janosits and others on the development of new wheat and maize varieties. The birth of Hungarian hybrid maize was the lifework of Endre Pap and is recognised th-

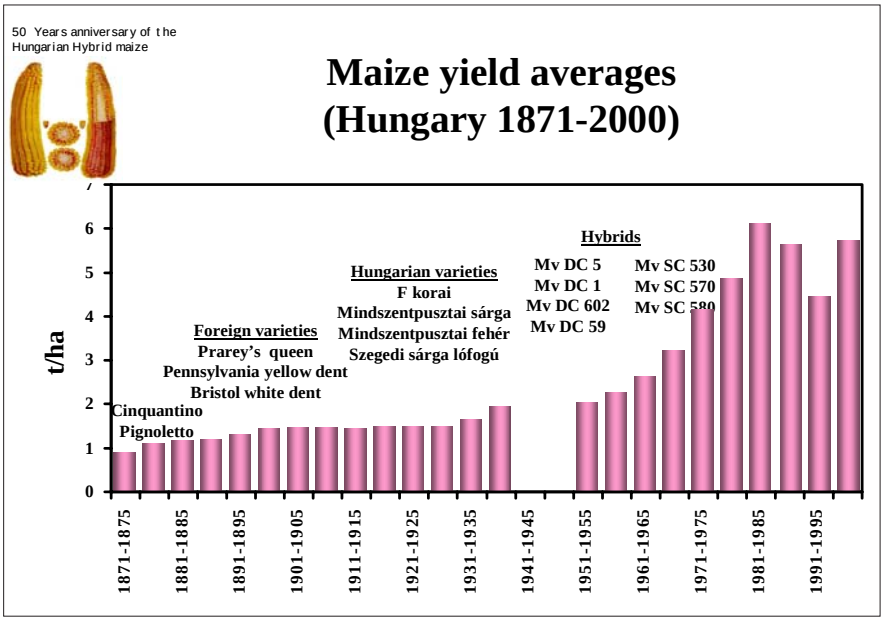

Figure 1: **Maize yield averages (Hungary 1871-2000)**

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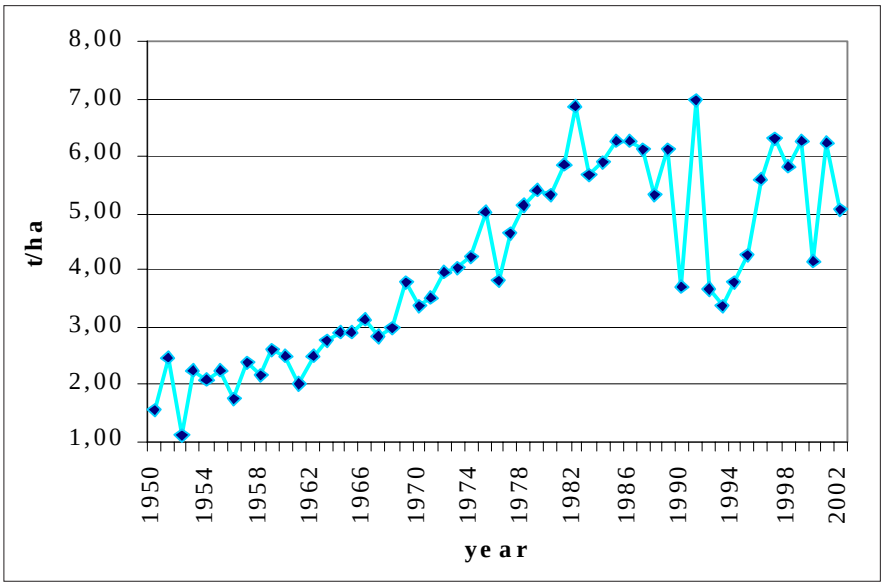

Figure 2: **Maize yield averages (Hungary 1951-2002)**

Table 1: **Martonvásár maize hybrids state registered between 1953 and 1981**

1.	Mv DC 5	1953	22.	Mv SC 660	1971
2.	Mv DC 1	1956	23.	Mv SC 262	1972
3.	Mv 40	1959	24.	Mv SC 380	1972
4.	Mv DC 42	1960	25.	Mv SC 580	1972
5.	Mv 26	1961	26.	Mv TC 635	1974
6.	Mv 48	1961	27.	Mv TC 201	1974
7.	Mv DC 59	1962	28.	BEMA DC 240	1974
8.	Mv DC 602	1964	29.	BEMA DC 250	1974
9.	Mv DC 502	1966	30.	Mv SC 404	1974
10.	Mv DC 520	1968	31.	Mv SC 342	1976
11.	Mv SC 530	1968	32.	Mv SC 429	1976
12.	Mv SC 570	1968	33.	Mv SC 424	1977
13.	Mv SC 620	1968	34.	Mv TC 296	1978
14.	Mv TC 290	1970	35.	Mv SC 484	1978
15.	Mv SC 370	1970	36.	Mv SC 497	1978
16.	Mv TC 431	1970	37.	Mv SC 550	1979
17.	Mv TC 540	1970	38.	Mv SC 550 wx	1980
18.	Mv TC 596	1970	39.	BEMA TC 210	1981
19.	Mv TC 610	1970	40.	BEMA TC 211	1981
20.	Mv TC 281	1971	41.	Mv SC 394	1981
21.	Mv DC 460	1971	42.	Mv SC 434	1981

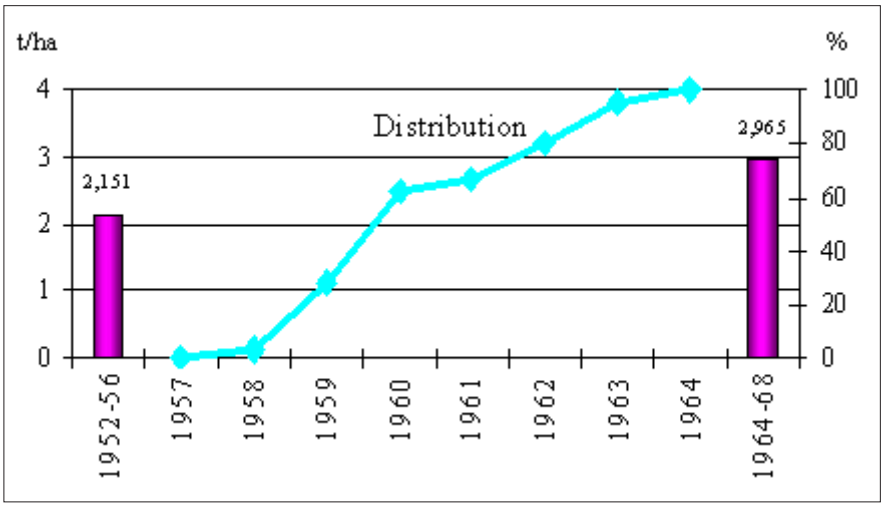

Figure 3: **National maize yield average of 5 years before and after hybrids became widespread in Hungary**

roughout the world as one of the greatest achievements of Hungarian plant breeding.

Endre Pap began his breeding efforts with variety breeding on his father's farm in Mindszentpuszta, where he bred the varieties *Mindszentpusztai White Flint* and *Mindszentpusztai Yellow Dent*, which were grown on wide areas in the fifties. Of these two varieties, *Mindszentpusztai White Flint* played an important role in the breeding of variety hybrids and *Mindszentpusztai Yellow Dent* in that of inbred maize hybrids. It was from this variety that he developed lines 0118b, 156 and 014, which formed the basis of the successful hybrid maize breeding programme in Martonvásár.

Endre Pap left Martonvásár in 1956, but continued to breed maize in Kelvedon, UK. By 1956 a well-trained breeding team had been established in Martonvásár, who continued to produce maize hybrids (*Table 1*) which occupied practically all the maize-growing area in Hungary in the 1960s and a substantial proportion of the area in the 1970s. Thanks to these hybrids, by the late 1970s and early 1980s the national yield average had increased to almost 6 t/ha (*Figure 2*). This success won international acclaim, and is still remembered with respect (the average yield in Hungary over the last ten years has hardly reached 5 t/ha). The 42 Martonvásár maize hybrids developed up till 1982 were grown in Hungary on a total of over 22 million hectares. These hybrids and a number of jointly bred hybrids were also registered abroad, where they were sown on an area of over 5 million hectares.

These important scientific results happily coincided with the desire to modernise Hungarian agriculture, and within a few years practically the whole of Hungary's maize-growing area was sown with Martonvásár hybrids. It took only a fifth the time in Hungary for the hybrids to spread and be exclusively grown as it did in the USA, the "land of opportunity", which is renowned for its innovation and market orientation. The yield-increasing effect of these hybrids could be expressed in millions of tons on a national scale. The average yield over the five years prior to the introduction of the hybrids was 2.15 t/ha, while the average for

the first five years after they were introduced was 2.97 t/ha (*Figure 3*). This increase (38 %) was largely due to the cultivation of hybrids, though the improvements in the technology also contributed to the rise in the yield average.

Competition between Hungarian and foreign maize breeders

Following the success achieved in the Martonvásár research institute, maize breeding programmes were initiated in other parts of the country and are now underway in five places. In order of establishment these are:

- Agricultural Research Institute of the Hungarian Academy of Sciences, Martonvásár
- Cereal Research Non-Profit Company, Szeged
- Agroselect Co. Ltd., Szarvas
- Kiskun Research Centre, Kiskunhalas
- Agricultural Co. Ltd., Debrecen

In addition to Hungarian hybrids, numerous foreign hybrids were also introduced into cultivation in Hungary in the 1980s. The sudden increase in the number of foreign hybrids was accompanied by a similar increase in the number of Hungarian hybrids (*Figure 4*). In 2003 the total number of registered hybrids was over 360, more than 50 % of which were from abroad. There has also been a change in the ratio of areas sown to Hungarian and foreign hybrids. Averaged over the last few years, more than 70 % of the growing area has been sown to foreign hybrids. The difference between the ratios for the number of hybrids and the growing area can be attributed chiefly to the more aggressive marketing activities of the foreign companies, many of whom have set up nurseries in Hungary.

In recent decades Hungarian maize breeding has gained success not only in Hungary, but also in neighbouring countries, as indicated by the total of 136 foreign registrations of Hungarian hybrids. The majority of these were in countries which were previously members of the Council for Mutual Economic Aid (CMEA), and as such were the traditional outlet for Hungarian maize seed. Nineteen hybrids have been registered in Russia (Martonvásár 14, Szeged 4, Szarvas 1), 13 in Ukraine (Martonvásár 6, Kiskun 5, Szeged 2) and 28 in Slovakia (Martonvásár 12, Kiskun 11, Szeged 5). In the days of the CMEA Romania did not typically import seed from Hungary, but recently the situation has changed, and 35 hybrids have now been registered (Kiskun 22, Szeged 10, Martonvásár 3). In recent years the first Hungarian hybrids have also been registered in the EU. Eight are now to be found on the lists of EU countries, 3 from Szeged, 3 from Martonvásár and 2 from Kiskun. Kiskun hybrids have also been successful in African countries (Egypt, Sudan).

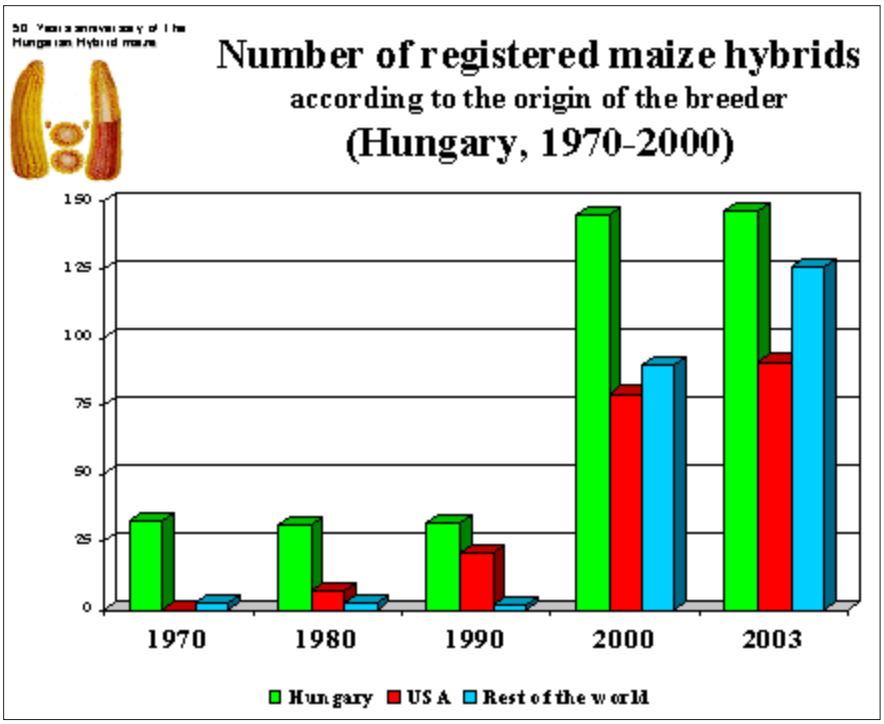

Figure 4: **Number of registered maize hybrids**

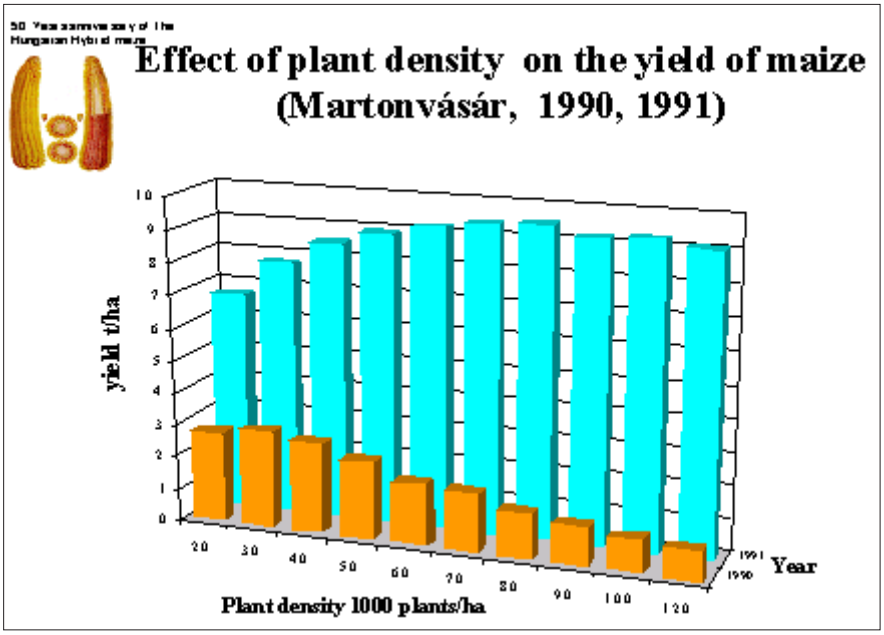

Figure 5: **Effect of plant density on the yield of maize (Martonvasar, 1990, 1991)**

Breeding aims

Improvements in the adaptability and yield stability of the hybrids are essential due to the varied agroecological conditions in export target countries and to the extreme differences in technological standards in Hungarian maize production.

Early sowing (early or mid-April) gave higher yields and lower grain moisture at harvest over the average of many years. Due to the risk of chilling after early sowing, however, improvements are required in chilling tolerance.

Under continental weather conditions drought tolerance is of particular importance. The extremely fluctuating weather experienced in recent years provides every justification for selecting for improved drought tolerance.

In earlier years plant density tolerance was largely thought of as tolerance to dense stands. In recent years, however, a broad optimum range of plant density tolerance is the target, so that a given hybrid is capable of providing a satisfactory yield even at low plant density (30-40 thousand plants/ha), but can also be grown in dense stands (90-100 thousand plants/ha) without any great loss of yield compared to the optimum plant density. The optimum plant density and the maximum yield are greatly influenced by the year and the quantity of rainfall. In favourable years (e.g. 1991) the optimum plant density was around 80,000 plants/ha with a yield of close to 10 t/ha, averaged over 30 hybrids (*Figure 5*), while in dry years (e.g. 1990) the optimum stand density was 30,000 plants/ha with a maximum yield of 3 t/ha, only a third of that achieved in favourable years.

The interpretation of fertiliser response has also been modified since the national level of fertiliser use dropped to 10-20 % of the former level (*Figure 6*). Nowadays hybrids with good nutrient utilisation ability are given preference, rather than those which respond well to high N rates.

The *Fusarium* species rife in Hungary (*F. culmorum, F. moniliforme, F. graminearum*) cause the most serious maize diseases, ear rot and stalk rot. Substantial genetic progress has been achieved in the field of lodging resistance using new breeding stocks and selection in dense stands.

Traditional breeding methods have also proved efficient in improving pest resistance. The damage caused by the European corn borer stems chiefly from secondary infections, since ears and stalks which have suffered moth damage are more easily attacked by *Fusarium* species. A more difficult problem has been raised by the appearance in Hungary a few years ago of *Diabrotica virgifera virgifera*. At present it appears that selection for resistance to this insect is impossible, and crop rotation accompanied by chemical pest control appears to be the only way to protect the crop.

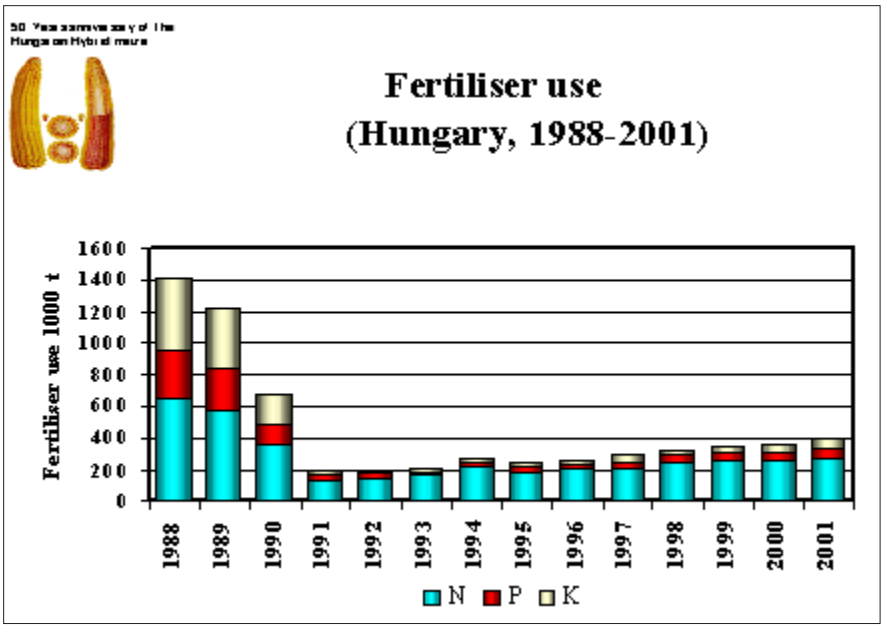

Figure 6: **Fertiliser use (Hungary, 1988-2001)**

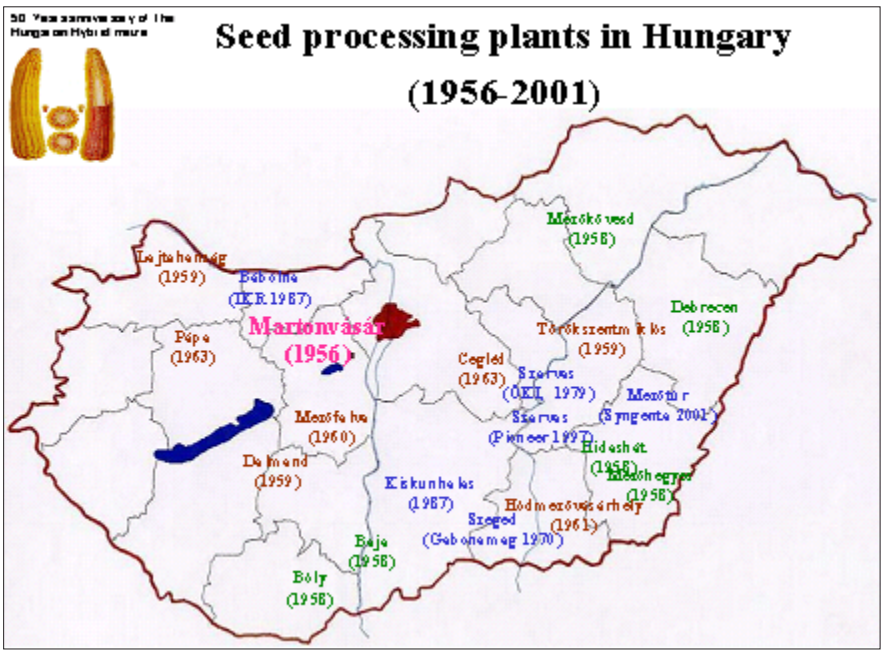

Figure 7: **Seed processing plants in Hungary (1956-2001)**

Seed production

The exploitation of the genetic potential latent in the first hybrids was only possible because of the 12 seed processing plants constructed in Hungary as part of the hybrid programme adopted in 1954. In summer 1956 the Experimental Farm of the Martonvásár institute obtained the first diesel-fired Campbell seed drier, fitted with an automatic thermostat, and in the same year the first six-chambered maize seed drier in Hungary were also built (BERKO and HORVÁTH, 1993; HORVÁTH, 1991). In 1958 a further six seed processing plants were constructed in state farms (in Baja, Bóly, Mezöhegyes, Mezönagymihály, Debrecen and Murony), while the seed processing plants in Mezöfalva, Dalmand, Moson-

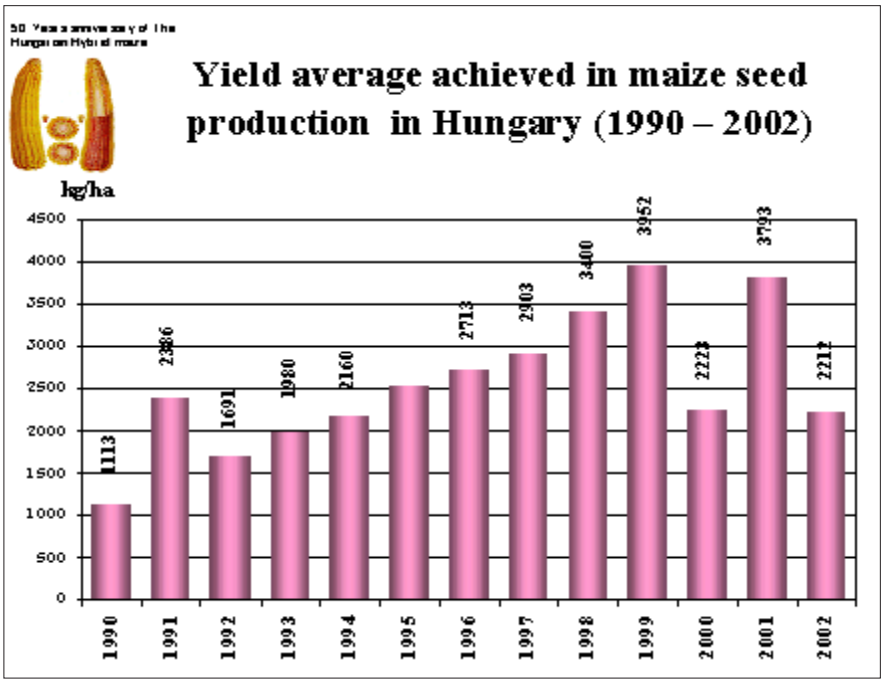

Figure 8: **Yield average achieved in maize seed production in Hungary (1990-2002)**

magyaróvár, Hódmezövásárhely and Cegléd were built between 1959 and 1964 (*Figure 7*). These then formed the backbone of the Hungarian hybrid maize seed industry which, taking into consideration a 65-day season, had an annual capacity of 36,000 tonnes, sufficient to satisfy the seed requirements of the country as regards both quality and quantity.

By the 1980s, following the expansion of the existing plants and the construction of new ones in Szeged, Bábolna, Szarvas and Kiskunhalas, Hungary became one of the world's largest maize seed exporters.

After the change of regime in 1989 export openings to countries in Eastern Europe became very restricted, leading to a reduction in the seed-producing area, which has stabilised at 25-30 thousand hectares in recent years. This has meant that seed-producing areas could be concentrated on irrigated land with good fertility. Due to the better ecological potential and to improvements in the cultivation and processing technologies there has been a considerable rise in the yield average and in the seed quality (*Figure 8*).

Summary

From the beginning of the 20th century Hungarian maize breeding was able to supply the biological material required for maize production for many decades. It was in Martonvásár, Hungary that Endre Pap developed the first maize hybrid in Europe, registered in 1953. Maize breeding is now underway in five research units in Hungary. Since the 1980s there has been an increase both in the number of foreign maize hybrids grown in Hungary and in their sowing area. The 12 seed processing plants constructed between 1956 and 1964 made it possible for hybrid maize production to spread throughout Hungary within a very short time, contributing to an intensive rise in yield averages. By the 1980s Hungary had become one of the world's leading maize seed exporters.

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