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Pollen production of maize inbred lines sown at different dates

Main points of the PhD thesis

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1. BACKGROUND AND AIMS

The hybrid maize seed requirements in Hungary amount to 22–26 thousand tonnes a year, which can be produced on an area of 15–20 thousand hectares a year. Yield averages fluctuate widely, ranging from 2.2–3.9 t/ha. The climate in Hungary is excellent for hybrid maize seed production, so considerable quantities are also produced for export. The number of hybrids to be multiplied is increasing from year to year. Due to the large number of hybrids, which are regularly replaced, and the fact that many of the hybrids produced for export are unknown in Hungary and unadapted to local conditions, there is a constant need to study the environmental responses of the parental lines of new hybrids. Previous knowledge on production technologies frequently becomes outdated, and must be regularly revised.

Apart from information on the flowering time, very few other data are available to provide a guideline for achieving flowering synchrony, and in general little attention is paid to the male parent. No studies are made in most cases on the pollen production of the inbred lines, on the length of the pollen shedding period, on the dynamics of pollen shedding or on the duration of tasselling.

The size of the tassel has decreased considerably over the last thirty years, as there was thought to be a negative correlation between tassel size and grain yield (Hunter et al., 1969, Lambert and Johnson, 1978, Ramirez-Diaz, 1993). This may lead to unsatisfactory pollen production, yet breeders have given little attention to the genetics of pollen production or even to pollen production itself (Vidal-Martinez et al., 2001). This can be attributed to the fact that pollen production is not regarded as a limiting factor for crop yields. For certain modern hybrids, however, the smaller tassel size, the use of male sterile mixtures and the application of the top-cross technology may lead to an insufficient supply of pollen. Similar problems may arise due to reductions in pollen viability and in the number of pollen grains as the result of environmental factors (Westgate et al., 2003).

Very few data have been published on maize pollen production. The old local varieties may have produced as much as 20–42 million pollen grains, while for modern hybrids this figure is only 2.2–3.3 million (Sadras et al., 1985, Uribelarrea et al., 2002, Fonseca et al., 2002, Hall et al., 1982). This decline is clearly a consequence of the reduction in tassel size (Duvick, 1997, Galinat, 1992). One reason for the decrease in pollen quantity is inbreeding depression, which has an unfavourable influence on tassel traits (Sari-Gorla et al., 1975, Pfahler, 1967).

The quantity of pollen is influenced by both genetic and environmental factors. The latter may affect the available pollen quantity by causing changes in flowering synchrony or by altering the amount of pollen produced per tassel (Bolańos and Edmeades, 1993, Hall et al., 1982).

The purpose of the present work can be summarised as follows:

In order to achieve flowering synchrony, the following factors were studied in various environments:

- the emergence percentage and the heat sum required for 50% emergence
- the heat sum accumulated from sowing to 50% tasselling, 50% male flowering and 50% silking
- the length of time for each genotype between 50% tasselling and 50% male flowering, and the existence of proterandry.

To assist in the selection of female and male parents, the genotypes were investigated in terms of:

- pollen production, and the duration and dynamics of pollen shedding
- tassel morphological traits
- grain yield and grain moisture content.

To obtain better knowledge on the parental lines and SLCs used in Martonvásár:

- it was hoped to refine the technology currently used for seed production
- data and information were collected for the seed production of new hybrids.

2. MATERIALS AND METHODS

2.1. Genotypes examined

A total of 19 inbred lines and 2 sister line crosses (SLC) were examined in the experiment. The lines chosen were the male components of Martonvásár hybrids currently in general cultivation, the aim being to obtain information that would help improve the seed production technology.

2.2. Traits investigated

1. Heat sum required for emergence (°C)
2. Emergence percentage
3. Flowering:
    - a) heat sum required from sowing to 50% tasselling (°C)
    - b) heat sum required from sowing to 50% anthesis (°C)
    - c) period from tasselling/tassel emergence to anthesis (days)
    - d) heat sum required from sowing to 50% silking (°C)
    - e) proterandry (anthesis to silking period, days)
    - f) pollen quantity (no. of grains)
    - g) dynamics of pollen shedding
    - h) duration of pollen shedding (days)
4. Tassel morphology
    - a) tassel length (cm)
    - b) length from the lowest branch to the tip of the main tassel branch (cm)
    - c) number of lateral branches
    - d) number of spikelets on the main tassel branch
5. Grain yield (t/ha)

6) Grain moisture content (%)

2.3. Determination of pollen quantity and viability

Pollen production was investigated in two experiments. Experiment I (2002 and 2003) examined the effect of four sowing dates on the pollen production and pollen shedding period, while Experiment II (2002–2005) studied the effect of the year when sowing was carried out at a single date (the first of the four applied in Experiment I).

During the tasselling period five characteristic plants were labelled in each row for the measurement of pollen production. White parchment bags measuring 20×38 cm were used to cover the tassels of the selected plants. The pollen was collected each day and passed through a fine sieve to remove contamination. It was then weighed using a SCALTEC SBA 32 analytical balance. The measurements were begun when the first anthers appeared and continued until there was no longer any measurable quantity of pollen in the bags.

Pollen viability was determined using the method of Widholm (1972). A quantity of 25 mg was taken from the pollen of each line and placed in fluorescein diacetate solution. The suspension was homogenised, after which 10 μl aliquots were pipetted onto slides. The number of pollen grains was counted under a Zeiss Stemi 2000C stereomicroscope (0.8× magnification) and the viability was examined under an Olympus BX51 fluorescence microscope. Digital images were taken of the pollen grains and these were analysed using ImageTool 3.0 software.

3. RESULTS

3.1. Emergence percentage and the heat sum required for emergence

The emergence traits of the genotypes varied when averaged over both sowing dates and years, but the genotype MS value was lower than the year and sowing date MS values. Analysis of variance revealed that the year had a greater effect on the given traits than the sowing date, indicating that the year was responsible for greater environmental variance in emergence than different sowing dates within a given year.

Among the treatment interactions, the sowing date × year effect was the greatest, but the genotype × year interaction was also significant at the 0.1% level of significance.

The sowing dates had a similar influence on the emergence traits of all the genotypes; no specific genotype × sowing date interactions were observed.

3.2. Flowering data

Averaged over the four sowing dates and three years, significantly different heat sums were required by the various genotypes from sowing to 50% tasselling, 50% anthesis and 50% silking. This was not surprising, as the lines included early, mid-season and late lines.

The sowing date averaged over the three years and the year averaged over the four sowing dates caused significant differences in the heat sum of 50% tasselling, 50% anthesis and 50% silking.

In all cases the treatment interactions also resulted in significant differences in the heat unit accumulation required for the flowering of the inbred lines and SLCs.

The MS values for the year were several orders of magnitude greater than those of the sowing date and genotype. The year thus exerted the greatest effect on the heat sums required for 50% tasselling, 50% anthesis and 50% silking.

Among the treatment interactions the sowing date × year had the highest MS value.

Averaged over the sowing dates and years significant differences were observed between the genotypes for the period between 50% tasselling and 50% anthesis. The sowing date, averaged over three years, also had a significant effect on the duration of tasselling, while the effect of the year was not significant.

In all cases the treatment interactions indicated significant differences in the length of the tasselling period. Among the interactions the highest MS value was recorded for the sowing date × year interaction.

As the year effect was not significant for the period between 50% tasselling and 50% anthesis and the genotype × year interaction was only significant at the $LSD_{5\%}$ level, this trait appears to depend to the greatest extent on differences between the genotypes.

3.3. Pollen production and pollen shedding period

3.3.1. Pollen production

Averaged over sowing dates and years, the pollen production of the genotypes differed significantly. Among the treatment MS values the genotype MS values were the highest, suggesting that the trait is under strong genetic control.

The mean pollen production of the genotypes in the four sowing date treatments was similar, averaged over the two years. Nevertheless, the year caused significant differences in the mean pollen production of the genotypes. The treatment interactions were significant, i.e. the pollen production of the genotypes differed both with the year and with the sowing date.

Averaged over the years and sowing dates, there were significant differences between the pollen shedding periods of the genotypes. The genotype MS values were again the greatest in the case of the duration of pollen shedding. The mean pollen shedding period of the genotypes was significantly influenced by the sowing date, averaged over the years, and by the year.

The pollen production of the genotypes varied both with the sowing date and with the year. The highest MS values were obtained for the sowing date × year interaction.

The mean pollen production of the 21 genotypes examined in the experiment was determined in four sowing date treatments over two years. Averaged over the four sowing dates in 2002 and 2003, the genotypes differed significantly in terms of pollen production.

The grand mean of the experiment was 2.24 million pollen grains. The lowest quantity of pollen, 0.48 million grains, was produced by HMv5408. Less than a million pollen grains was also produced by HMv5327 (0.81 million), HMv5141 and HMv5496 (both 0.9 million).

Considerably more pollen than average was produced by HMv5062 (5.62 million grains), HMv651 (4.43 million), F564×F564-12 SLC (4.15 million) and HMv5414 (3.76 million). The SLCs produced more pollen than their parental components. The sister effect compared to the mean for the parental lines was 189.93% for the F564×F564-12 SLC and 223.12% for HMv5327×HMv5328.

The pollen production of the 21 genotypes was examined for four sowing dates in 2002 and 2003. The weather in the two years differed considerably during most of the vegetation period, but no significant differences were observed for the pollen production of the genotypes in the four sowing date treatments, with 2.17 million grains for the first sowing date, 2.3 million for the second, 2.17 million for the third and 2.32 million for the latest sowing date. These similarities could be attributed to the daily mean temperature and rainfall quantity during the tassel differentiation period, which, according to data in the literature, takes place in the 4–5-leaf stage. This phenophase occurred in May, with the exception of the fourth sowing date. Correlation coefficients of r = 0.77 and r = –0.90 were observed between the pollen production and the May rainfall and mean temperature data, respectively.

This indicates that late sowing does not represent a risk for pollen production provided the temperature and rainfall conditions are favourable for plant development during the tassel differentiation stage. The temperature cannot be influenced, but a lack of rainfall can be remedied by irrigation.

The effect of the year on pollen production, averaged over the genotypes, was examined over a period of four years (2002–2005) in Experiment II. An analysis of the main (first) sowing date in the four years revealed that the mean pollen production of the genotypes differed significantly in the individual years. The grand mean of the experiment was 2.58 million pollen grains, with values ranging from 2.00 million (in 2002) to 3.19 million (in 2004). The mean annual pollen production of the genotypes was found to correlate with the temperature and rainfall data for May. As reported in the analysis of the sowing dates, the rainfall sum in May had a strongly positive effect on the pollen quantity, which was in negative correlation with the mean temperature in May.

3.3.2. Duration of pollen shedding

Based on the data for four sowing dates in two years, the pollen shedding period differed for the individual genotypes. The grand mean of the experiment was 6.65 days.

Genotype HMv5062, already shown to have high pollen production, was found to have the longest pollen shedding period, while the SLC F564×F564-12 also combined plentiful pollen production with a favourable pollen shedding period of 8.4 days.

In the case of line HMv5408 the pollen shedding period was only 4.7 days, and this was associated with a low quantity of pollen, thus increasing the risk of using it as male parent. Other lines with low pollen production (HMv5141, HMv5327, HMv5406) had average pollen shedding periods.

The “sister effect” had a favourable influence on the pollen shedding period, which was 30.63% longer than the parental mean for F564×F564-12 and 18.48% longer for HMv5327×HMv5328.

Based on the mean value of the two years in Experiment I (2002, 2003) the sowing date had a significant effect on the average pollen shedding period of the genotypes examined, though only the data recorded for the latest sowing date differed significantly from those of the three earlier dates. The grand mean of the experiment was 6.65 days, with the longest flowering period (6.9 days) for the second sowing date (late April, early May). The pollen shedding period was 6.67 days for the first sowing date, 6.68 for the third and 6.35 for the fourth.

An analysis of the four years of data in Experiment II demonstrated that the genotypes had different mean pollen shedding periods. The grand mean of the experiment was 6.38 days, with the longest duration in 2005 (7.06 days) and the shortest in 2004 (6.11 days). This difference was significant, but was of little importance from the agronomic point of view, as the difference between the years was less than one day.

Among the treatment interactions, the length of the pollen shedding period was influenced to the greatest extent by the sowing date × year interaction, based on MS values.

3.3.3. Dynamics of pollen shedding

There was no great difference in pollen shedding dynamics between the two inbred lines, despite differences in pollen production and pollen shedding period. For both lines pollen shedding began with a steeply rising trend, which lasted for a different length of time for each line, but made up a similar proportion of the total pollen shedding period. The peak pollen shedding period was followed by a short phase when the quantity of pollen declined greatly, after which the quantity decreased slowly for a relatively long period. The first half of the pollen shedding period was thus decisive in terms of the total pollen quantity.

3.4. Tassel morphological traits

The length of the tassel differed significantly for the various genotypes, averaged over the years and sowing dates. The longest tassels were recorded for the SLC HMv5327×HMv5328 (32.96 cm) and the shortest for the line HMv5226 (24.41 cm).

The length of the main tassel branch also differed for the genotypes, averaged over years and sowing dates, with a mean value of 19.99 cm. In absolute terms HMv5327×HMv5328 had the longest main tassel branch (24.35 cm), while among the lines the longest was recorded for HMv5406 (23.69 cm) and the shortest for HMv124-2 (16.55 cm).

Averaged over years and sowing dates, the genotypes also differed for the number of spikelets on the main tassel branch. The average number was 180.63, ranging from 252.03 for HMv651 and 241.28 for HMv5414 to only 129.95 for HMv124-2.

The "sister effect" had a positive influence on all the tassel traits examined.

The number of primary branches exhibited a very wide range for the individual genotypes, averaged over sowing dates and years. The differences were significant. The grand mean for the experiment was 7.5, with the lowest number for HMv5408 (2.92) and the highest for F564×F564-12 (14.82).

The sowing date had a significant influence on tassel morphological traits, averaged over genotypes and years, the longest tassels being produced after sowing in late April or early May.

The length of the main tassel branch exhibited the highest values for the 2nd and 3rd sowing dates, while the number of primary branches was greatest for the 4th sowing date.

There was a significant difference in the number of spikelets on the main tassel branch for the sowing dates, averaged over genotypes and years, with the greatest decline in the spikelet number in the case of the latest sowing date.

The mean tassel length of the genotypes differed significantly with the year, averaged over the sowing dates, the greatest mean tassel length being recorded in 2004 and the shortest in 2003. The same order was observed for the length of the main tassel branch. The number of primary branches was significantly greater in 2003 (7.75) than in 2002 (7.46) or 2004 (7.3).

The number of spikelets on the main tassel branch exhibited a similar tendency to the tassel length and the length of the main tassel branch. The highest number was recorded in 2004 (194.32) and the lowest in 2003 (168.85).

With the exception of the spikelet number, the tassel morphological traits examined were stable over the years and sowing dates, exhibiting only slight deviation. Judging from the MS values in the variance table, the treatment interactions were significant, but the absolute differences between the data were small.

3.5. Grain yield and grain moisture content at harvest

The grain yield of the genotypes differed significantly, averaged over sowing dates and years. The sowing date, averaged over genotypes and years, and the year, averaged over genotypes and sowing dates, also had a significant effect on the grain yield, and the treatment interactions were also significant. The sowing date × year interaction had the greatest MS value.

The highest yield was recorded for the SLCs, with values of 5.98 t/ha for F564×F564-12 and 4.84 t/ha for HMv5327×HMv5328. Genotypes with outstanding yield potential were also found among the inbred lines, with a yield of 3.99 t/ha for HMv5408. The lowest yield potential was determined for F564-12 (1.48 t/ha).

Sowing date had a significant influence on the grain yield, averaged over genotypes and years. The earlier the crop was sown, the greater the yield. The yield was also significantly affected by the year, with the highest yields in 2002 and the lowest in 2003.

The grain moisture content at harvest differed for the genotypes, averaged over years and sowing dates. The effects of the sowing date and year were also significant. The genotype MS values were an order of magnitude smaller than those of sowing date and year, indicating that the grain moisture content differed with the genotype, but depended primarily on the sowing date and the year.

The highest grain moisture content was measured for HMv5062 (28.17%) and the lowest for HMv09 (17.00%), which is related to CO109.

The sowing date caused significant differences in grain moisture content, averaged over genotypes and years, resulting in gradually increasing moisture contents as sowing became later.

The year also had a significant effect on the grain moisture content, with the lowest value in 2003 (18.92%).

3.6. Correlation analysis

The data indicated that pollen production was significantly correlated with the duration of pollen shedding, the length of the tassel and the main tassel branch, and the number of spikelets and primary branches. Close linear correlations were not observed in any case. The closest correlations were observed between the pollen production and the pollen shedding period (0.390**), the number of primary branches (9.437**) and the number of spikelets on the main tassel branch (0.436**), but these were only moderate, suggesting that pollen production is jointly influenced by the traits examined, thus ensuring a high level of protection against environmental effects.

The duration of pollen shedding exhibited a significant correlation with the pollen production, the number of spikelets and the number of primary branches, but in all cases the strength of the correlation was only moderate.

The length of the main tassel branch was closely correlated with the tassel length (0.844**), since it makes up a high proportion of the total tassel length. The number of spikelets on the main tassel branch was also in significant correlation with the length of the main tassel branch (0.578**).

An analysis was also made of how the tassel traits and pollen quantity were correlated with the grain yield. The data showed that the length of the main tassel branch, the number of spikelets on the main branch and the pollen quantity exhibited a significant but only weakly positive correlation with the grain yield. No significant correlation was revealed between the number of primary branches and the grain yield.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Emergence

The emergence date is generally expressed as the number of days from sowing to 50% emergence, but experience has shown that the emergence of individual genotypes can be described more accurately by means of the heat sum required for 50% emergence.

Differences were observed between the individual inbred lines and SLCs both for the heat sum required for emergence and for the emergence percentage, averaged over sowing dates and years. Emergence traits were substantially influenced by the year and the sowing date, and by the interaction of these two factors. The heat sum required for emergence depended on the rainfall and temperature conditions during the period between sowing and emergence. Late sowing results in a lower plant density than planned, because of the soil moisture deficit, so in the case of late sowing it is advisable to increase the seed norm for the male parent. Averaged over the years and sowing dates, HMv09, HMv5141, HMv651, HMv5778 and HMv5414 had low emergence percentages, so they are not recommended as female parent, as the low plant density may influence the seed yield.

4.2. Tasselling, anthesis and silking

Flowering synchrony can only be ensured if information is available for the parental lines on the period from sowing to 50% anthesis and silking. The results indicated that the flowering of individual genotypes can be more precisely characterised by the heat units accumulated from sowing to 50% flowering than by the number of days. The sowing date and the year had a significant effect on the heat sum required for flowering, but the deviation between the absolute values was not as great as when this phenophase was expressed in terms of days. The year had a greater effect on tasselling, anthesis and silking than the sowing date. Among the interactions, the sowing date × year was the strongest. The strong environmental effect means that it is extremely difficult to ensure flowering synchrony under diverse conditions. The results suggest that the precision of the technology can be improved if the lines are previously examined in a variety of environments.

The period between 50% tasselling and 50% anthesis gives an indication of the time available for detasselling, which is of importance for work planning purposes.

Genotypes which have a relatively long period between 50% tasselling and 50% anthesis should be chosen as female parents, so that more time is available for detasselling. In the present experiment, lines that satisfied this criterion were F564, F564-12, HMv124-2 and

HMv5332. By contrast, there was less than 2 days between tasselling and anthesis for lines HMv8431 and HMv5406, where the tassels virtually flowered before they emerged, leaving very little time for detasselling and increasing the risk of accidental self-fertilisation. The period between 50% tasselling and 50% silking was shorter for the SLCs than for their component lines, so if the parental components have a short tasselling period, it is not advisable to use SLCs as female parents.

The sowing date had a significant influence on the tasselling period of the genotypes, but the difference between the sowing dates in this respect was less than a day, which is not of great importance from the agronomic point of view. However, the effect of the sowing date varied with the year. Under unfavourable conditions the tassel development period was protracted, which could influence flowering synchrony. This effect was experienced in the case of long-term drought and very hot days. If this danger arises, the risk can be reduced by irrigation prior to tasselling.

4.3. Pollen production, and the duration and dynamics of pollen shedding

Considerable differences were observed in the pollen production of the individual lines, suggesting the advisability of obtaining information on the pollen production of the lines before elaborating seed production technologies. Among the genotypes investigated, outstanding pollen production was recorded for HMv5062 (5.62 million pollen grains/plant), HMv651 (4.43 million pollen grains/plant), F564×F564-12 (4.15 million pollen grains/plant) and HMv5414 (3.76 million pollen grains/plant), while that of HMv5408 was only 0.48 million pollen grains/plant. Less than a million pollen grains/plant was also produced by HMv5327, HMv5406 and HMv5141. This quantity of pollen may still be sufficient for satisfactory fertilisation, but if consideration is given to the settling velocity of maize pollen, the quantity of pollen washed off by rainfall and the effect of sunshine on pollen viability, the use of these lines as male parent can only be recommended if the plant density is increased.

The pollen production of the SLCs was significantly greater than the mean pollen production of their parental components. SLCs can thus be used to increase the pollen production of lines with poor pollen-producing ability, thus improving the quality of pollination. In addition SLCs have a longer pollen shedding period than their parental components. The extent of heterosis was 189.9–223.1% for pollen quantity and 118.48–130.63% for the duration of pollen shedding.

As the pollen production of the genotypes varied with the year, it is advisable to test the pollen production of the lines in several environments before selecting pollinators.

In addition to the absolute quantity of pollen, fertilisation may also be affected by the pollen shedding period, which was significantly influenced by all the treatments. A long pollen shedding period is particularly important for fertilisation in the case of flowering asynchrony.

Some genotypes, such as HMv5062 and F564×F564-12, produced large quantities of pollen over a long period, while HMv5141, HMv5327 and HMv5406 only shed pollen for a short period. From the pollen shedding point of view, the use of HMv5408 as male parent is not recommended, as it had the lowest pollen production and shortest pollen shedding period of all the genotypes examined. If sister line crosses are used, a longer pollen shedding period can be expected, thus improving the reliability of seed production.

The dynamics of pollen shedding was studied on the data for HMv5062 and HMv5328. For the line with a short pollen producing period, the pollen shedding peak occurred on the 1^{st}–2^{nd} day, while the line that produced pollen for a longer period peaked on the 3^{rd}–4^{th} day. This date must be synchronised with the entire silking period. The pollen shedding peak is generally short (1–3 days), but in most cases a longer pollen shedding period is required. The reliability of seed production can be improved if some of the male rows are sown earlier than the optimum sowing date.

4.4. Tassel morphological traits

The experiment included an analysis of the tassel length, the length of the main tassel branch, the number of primary branches and the number of spikelets on the main tassel branch. All the main effects were found to be significant for these traits. In the case of tassel length, the length of the main tassel branch and the number of spikelets on the main tassel branch, the first- and second-order interactions were also significant, with the exception of the genotype × sowing date interaction. This could probably be attributed to the fact that the spring weather during the tassel differentiation period was similar in 2002 and 2003. A further reason could be that these traits have strong genetic determination.

It was found that if a line was unsatisfactory for some aspect of tassel development, this could be improved by using sister line crosses.

Among the genotypes, HMv5062 proved to be an ideal male parent, as all its tassel morphological traits developed harmoniously. This line produced a large quantity of pollen and had a long pollen shedding period.

4.5. Grain yield and grain moisture content

All the treatments had a significant effect on the grain yield and on the grain moisture content. For both traits the MS values were lower for genotype × sowing date than for genotype × year, suggesting that the years investigated differed from each other to a greater extent than the diverse environments caused by differences in sowing date.

The grain yield and grain moisture content of the individual genotypes exhibited differences for the various sowing dates. The yields of F564, HMv5141, HMv651, HMv5414 and HMv5062 declined in the later sowing date treatments, while HMv5139, HMv09, F564-12, HMv124-2, HMv5328 and Mo17/Mv were not sensitive to late sowing.

Later sowing resulted in lower yields with a higher moisture content.

The yields of HMv09, HMv5141, HMv5407, F564×F564-12 and HMv5327×HMv5328 were very stable over the years, while those of HMv651, HMv5327 and HMv5414 fluctuated from one year to the next.

No close correlation was found between the grain yield and the grain moisture content, indicating the existence of high-yielding, late-maturing lines that can be harvested with relatively low grain moisture content.

The pollen quantity and pollen shedding period of HMv5408 and HMv8431 were below average, but their yield potential was above average, so they make excellent female parents. Based on the pollen quantity and pollen shedding period, HMv5062 proved to be an ideal male parent. Despite its high grain yield, it cannot be recommended as a female parent due to the long vegetation period and the high grain moisture content.

The coefficient of correlation between pollen quantity and grain yield was $r = 0.143$, so no correlation could be proved between the grain yield and tassel traits.

5. NEW SCIENTIFIC RESULTS

1. A method was elaborated for the measurement of pollen production under field conditions, including the pollen production of individual plants.
2. The pollen production and pollen shedding period were determined for 19 Martonvásár-bred lines and two SLCs. A considerable extent of heterosis was detected for pollen production compared with the parents, based on the two SLC combinations.
3. Pollen production appears to be subject to strong genetic regulation. The correlations between tassel morphological traits suggest that under diverse environmental conditions the tassel traits combine to ensure a balanced pollen quantity.
4. It was found that the quantity of pollen entering the atmosphere was correlated with the rainfall sum and mean temperature in May. The correlation coefficients were –0.9 for the mean May temperature and pollen production, and 0.77 for the May rainfall sum and the pollen production.
5. Significant differences were observed for the duration of pollen production in individual genotypes, and this was not influenced to any great extent by the year or the sowing date.
6. The length of time between 50% tasselling and 50% anthesis was found to differ significantly for the genotypes, averaged over years and sowing dates. The period between 50% tasselling and 50% anthesis proved to be 3–37% shorter for the SLCs than for their parental components. This information could be used to select female parents where there is sufficient time available for reliable detasselling.
7. The level of proterandry was 7.4–35.5% lower for the sister lines than for their parents, suggesting that the SLCs had better stress tolerance. Under non-irrigated conditions, seed can be produced with greater reliability on sister line crosses than on their parents.
8. Close correlations were not revealed between the tassel traits and the pollen production. This means that it is possible to breed higher yielding hybrids even using parental lines with good pollen production.
9. The genotypes were separated into those primarily suitable for use as female or male parents, or which can be profitably used for both purposes. Genotypes were also designated that were only suitable for seed production if the male or female plant density was increased, and/or if irrigation was applied during the tassel differentiation period, or with other limitations.

10. The knowledge acquired was used to elaborate seed production technologies for 10 or more grain and silage maize hybrids registered between 2006 and 2010.

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