EFFECT OF DIFFERENT HARVESTING METHODS ON THE GERMINATION AND VIGOUR OF HYBRID MAIZE (*ZEA MAYS* L.) SEEDS

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Summary

The germination ability and vigour of the seeds of eight Pioneer hybrid maize varieties were examined in 2009. On the experimental plot the combine shelled the harvested ears, while on the control plot the ears were harvested intact. After preliminary cleaning, the seeds from the shelled and control groups were germinated. Some of the seeds from each group were divided into four fractions and analysed separately. The germination was carried out according to the International Seed Testing Association (ISTA) Rules (2009), in four replications of 100 seeds, between moist filter papers in controlled climate chambers in four seed testing laboratories. The germination percentage satisfied the standard criterion (above 90 percent) in both the shelled and control groups, but the germination rate was lower for the shelled group, while the number of abnormal seedlings was greater than in the control group. The effect of harvesting intact ears on the seed quality was evident for two hybrids (PR35Y65, $LSD_{0.1\%}$; PR39R20, $LSD_{5\%}$). In the case of the various seed fractions, the lowest germination percentage was obtained for the medium-sized round fraction and the highest for the large flat fraction. The superiority of the control (intact ears) group was not manifested in all the fractions and no significant difference was found between the two treatments. The results obtained for the biological value of the seed were surprising. For one hybrid ears harvested intact exhibited the same superiority as recorded for the germination percentage, while for three hybrids the vigour proved to be better in the shelled group. For two hybrids little or no difference in vigour was observed between the shelled and control groups.

Keywords: hybrid maize, harvesting, germination, vigour, seed testing,

Összefoglalás

2009. évben összesen 8 Pioneer fajta hibridkukorica vetőmag csírázóképességét és életerejét vizsgáltunk. A vetőmag szaporító táblákon kísérleti táblarészeket jelöltünk ki. A táblarész egyik felét szemesen, a másik részét pedig csövesen takarítottuk be. A hibridek morzsolt és kontroll csoportjait előtisztítva, frakcionálatlanul csíráztattuk, emellett két, véletlenszerűen kiválasztott hibridet 4 frakcióra bontottunk, és frakciónként is vizsgáltunk. A vizsgálatot 4 vetőmagvizsgáló laboratóriumban, ISTA szabvány szerint, klimatizált kamrákban végeztük. Négyszeri ismétlésben, nedves szűrőpapír között, 100-100 szemet, csíráztattunk. A morzsolt és csöves betakarítású vetőmagok csíráztatása során megállapítottuk, hogy összességében valamennyi csírázóképességi eredmény szabványos (90% feletti) volt. A morzsolt betakarítású vetőmag

csíraeredményei nem érték el a csövesen betakarítottét, az abnormális csíranövényeknek a számában viszont a kísérleti (szemes) csoport meghaladta a kontrollét (csöves). Két hibrid esetében (PR35Y65 SzD 0,1%; PR39R20 SzD 5%) a csöves betakarítás vetőmag-minőségre gyakorolt pozitív hatása statisztikailag igazolható volt. A frakcionált vetőmagtételek csíráztatása során a legkisebb csírázóképességi mutatót a közepes gömbölyű, a legnagyobbat a nagy lapos frakció érte el. A csöves csoport fölénye nem jelent meg minden frakcióban, a két kezelés között nem találtunk szignifikáns különbséget. A vigorvizsgálati értékek között meglepő eredményeket kaptunk. Az egyik hibridnél a csöves betakarítású vetőmag hozta a csíráztatásban tapasztalható fölényét, míg három hibridnél a morzsolt csoport életképessége bizonyult jobbnak a csöves csoporttal szemben. Két hibrid esetében nem, vagy minimális különbséget tapasztaltunk a kísérleti és a kontroll csoport biológiai értéke között.

Introduction

Hybrid maize plants are exposed to numerous stress factors in the course of seed production. The best known of these are the effect of unfavourable soil conditions on germination, drought or heat stress during various phases of the vegetation period, and mechanical damage. In addition to quantitative seed losses, there may also be a deterioration in quality due to human error (e.g. grain moisture content chosen incorrectly at harvest, unsuitable drying temperature).

Many authors have investigated or modelled the effects of chilling stress during germination (Loeffler et al., 1985; Nijenstein, 1985; Bruggink et al., 1991; Hope and Maamari, 1994). Odiemah (1991) studied the effects of various environmental factors on the seed of hybrid maize.

Weather conditions do not always make it possible to harvest whole ears from seed production fields rapidly, on a single occasion. If the ears are harvested at low moisture content, seed shedding may result in losses of 5–25% during processing, according to data from Pioneer Hi-Bred "Zártkörűen működő részvénytársaság (Zrt)" (Nagy, 2009), which could be avoided by shelling the ears during harvesting. Mounsey et al. (2002) also reported higher seed shedding losses when harvesting at low moisture content, and recommended combine (shelled) harvesting as an alternative solution, besides the traditional harvesting of whole ears. If ear harvesting is protracted due to wet weather or the lack of machine capacity, the seeds may germinate on the ear, or *Fusarium* species may cause ear and grain rot.

In order to eliminate these stress factors, maize breeders and variety owners have suggested the application of combine harvesting on seed production fields. Investigations on the feasibility of this proposal are now underway with the support of the Central Agricultural Office and the Hungarian Seed Association, with the cooperation of the variety owners.

The aim of the present research was to determine whether the proposed harvesting method caused a deterioration in the biological value of the seed. Quality deterioration was measured in terms of germination ability and vigour. It should be emphasised that the first year of the investigations involved only six hybrids belonging to a single variety owner. It is planned to expand the research to include a larger number of hybrids with a broader genetic background.

The work was aimed at determining whether the germination ability of combine harvested seed reached the level laid down in the official standards and whether it was poorer than that of seed from traditional ear harvesting. The investigations also covered the response of hybrid maize seed from combine harvesting to various stress factors in the course of germination. The effect of stress factors on seed was previously studied by a large number of scientists (Barla-Szabó and Berzy, 1989; Gáspár, 1980; Van de Venter, 1988).

The biological value of seed harvested in optimum condition in the field may be compromised by an incorrect choice of drying conditions during seed processing (Burris, 1975; Loeffler, 1985), depending on the initial grain moisture content (Gáspár, 1980) and the genotype.

In the course of processing in seed plants, the seed is divided into fractions, depending on the hybrid. The biological value of the seed fractions may vary for each genotype and year (Thielebein, 1958; Pásztor, 1962; Germ, 1966; Fiala, 1973; Eisele, 1981; Berzy et al., 1996).

Based on the data reported by Shieh and McDonald (1982), it was aimed to discover whether there was any significant difference between the two treatments in the biological value of the two randomly selected hybrid seed fractions, especially as regards germination ability, which is considered to be the most significant trait.

When estimating germination ability it is important to ensure satisfactory, uniform water supplies in order to avoid hypoxia, a factor that inhibits germination. During evaluation, it must not be forgotten that the results were obtained under optimum conditions in the laboratory, which means, however, that they can be reproduced at any time (Ertseyné, 2004).

To determine how the seed lot performs under unfavourable environmental conditions, it is also necessary to carry out vigour tests. Sub-optimum environmental conditions were imitated using the complex stressing vigour test, a special technique elaborated for the rapid determination of vigour in maize seeds (Barla-Szabó and Berzy, 1989).

After several years of experimentation it may prove necessary to elaborate a new system of field quality control criteria, allowing combine harvesting as well as ear harvesting in the case of seed production.

Materials and methods

Seed production fields on which half the maize was to be harvested as whole ears and the other half shelled were designated in September 2009. The experiment was set up on a field scale to facilitate the application of the results in practice. All the fields were planted with Pioneer hybrids. The fields were chosen to ensure an approximately equal quantity of seed from both treatments. Within varieties, harvesting was begun at the same time, at the same grain moisture content, which was below 20% in all cases for both whole ear and combine harvesting. The combine harvesting was carried out using a John Deere 98.80 STS axial flow combine, while the whole ears were harvested with OXBO 8430XP and 8420 XP machinery. The shelled seeds were transported straight to the drying chambers, where they were stacked to a height of 80–90 cm. Composite samples of approx. 20–25 kg per variety were taken using an automatic sampler when the lots were removed from the dryers. Samples (approx. 40 kg) of the maize harvested as whole ears were taken from the loading hoppers, dehusked manually and put into jute bags. These were then placed on the conveyor belt taking the dehusked ears into the drying chambers. Drying and processing were carried out in the Pioneer Hi-Bred ZRt seed plant in Szarvas.

The shelled seeds were dried for 2–6 hours and the whole ears for 3–12 hours. In both cases, moisture extraction involved preliminary drying at 38°C, followed by further drying at a maximum of 42°C. After drying, the whole ears were shelled and all the samples were passed through a 6.5–10.5 mm mesh.

The undressed seeds were then germinated in four seed testing laboratories in Szarvas (Pioneer Hi-Bred ZRt; ISO9001:2000 accredited), Budapest (Central Agricultural Office; ISTA, Hungarian Accreditation Board accredited), Székesfehérvár (Regional Agricultural

Office: Hungarian Accreditation Board accredited) and Martonvásár (ARI HAS Seed Testing Laboratory).

It was deemed advisable to divide the seed of two randomly selected hybrids into four fractions (large flat: LF; large round: LR; medium flat: MF; medium round: MR) and to germinate each fraction separately. The germination of the seed fractions was examined in three laboratories (Székesfehérvár, Szarvas, Martonvásár).

All the germination tests were carried out according to the standard, method, with 100 seeds per lot, in four replications, thus ensuring a total of 16 (4 labs) or 12 (3 labs) replications. In all cases the seeds were rolled in three layers of crepe filter paper (Between Paper - Roll), moistened with 1.4–1.7 cm^3/g water. Illumination was provided for at least 8 hours, the temperature was 30-20°C day/night or a constant 25°C (ISTA method), and the relative humidity was 70%. The seedlings were evaluated on the 6^{th}–7^{th} day, depending on their state of development, and classified as normal, abnormal or dead. The germination tests will be repeated after 6 and 12 months on undressed seed samples stored under the conditions normal in the seed plant in Szarvas.

In addition to the germination tests, seed vigour (Complex Stressing Vigour Test) was also analysed at ARI HAS, Martonvásár. The germination medium was the same as that used in the germination tests. In the first step 200 seeds were soaked in 0.15% chlorogen at 25°C for 48 h, followed by a further 48 h at 5°C. Both low temperature and hypoxia cause severe stress. Finally, eight lots of 25 seeds were germinated as described above at 25°C with constant illumination for 96 h. The percentage of normal, abnormal and low vigour seedlings and of dead seeds was then calculated. The shoot and root length of the five most vigorous seedlings from each roll were recorded and averaged, and the shoot and root weight of all the seedlings in each roll were determined.

Results

The germination percentage of both the shelled and whole ear samples exceeded the minimum (90%) laid down in the standard. For the eight hybrids tested, the seed did not suffer any substantial loss of germination ability after the harvesting and drying methods outlined above. It could be seen from the results of laboratory analysis that although the germination percentage of seed from combine harvesting was slightly lower than that for ear harvesting, the difference was not significant (Table 1.). On the basis of biometric analysis, significant differences in germination ability were found for two (PR35Y65, PR39R20) hybrids. The results suggested that some hybrids have better tolerance of combine harvesting than others. The mean germination percentages for 4 × 100 seeds (not divided into fractions) for each laboratory are presented in Table 1. For two of the hybrids (presented in italics) samples from combine harvesting were only germinated in one laboratory, while kernels from ear harvesting were tested in all four.

Table 1. Effect of combine and ear harvesting on the germination ability of seed from Pioneer maize hybrids (Szarvas, Martonvásár, Székesfehérvár, Budapest, 2010)

Hybrid	**Harvesting method**	**Székes-fehérvár**	**Marton-vásár**	**Szar-vas**	**Buda-pest**	**Lab Mean**	**Signifi-cance**
PR39F58	Shelled	95.25	92.00	98.30	94.00	94.89	
PR39F58	Ear	98.00	96.00	97.80	95.50	96.83	NS
PR39R86	Shelled	95.00	94.50	94.90	93.25	94.41	
PR39R86	Ear	98.00	94.00	95.10	98.25	96.34	NS
PR39G83	Shelled	97.25	98.75	97.60	97.00	97.65	
PR39G83	Ear	97.75	97.00	99.50	98.75	98.25	NS
PR38H67	Shelled	93.75	93.00	95.70	93.75	94.05	

PR38H67	Ear	94.50	96.75	97.25	95.00	95.88	NS
PR35Y65	Shelled	95.25	96.25	97.30	92.00	95.20	
PR35Y65	Ear	98.50	100.00	98.75	98.50	98.94	***
PR39R20	Shelled	95.00	96.00	95.80	95.50	95.58	
PR39R20	Ear	97.00	97.25	98.50	97.75	97.63	*
Anasta SV	Shelled			*96.80*		*96.80*	
Anasta SV	Ear	*95.50*	*98.25*	*98.50*	*97.25*	*97.38*	*NS*
PR39H32	Shelled			*96.20*		*96.20*	
PR39H32	Ear	*97.50*	*97.25*	*97.50*	*96.25*	*97.13*	*NS*

Szfv: Székesfehérvár; Mv: Martonvásár; Bp: Budapest; *: $LSD_{5\%}$ = 2.01; ***: $LSD_{0.1\%}$ = 3.56; NS: non-significant.

The results of germination tests on different seed fractions are shown in Table 2. Studies on the seed fractions of two randomly chosen hybrids indicated that the LF fraction had the greatest germination vigour after both combine and ear harvesting. The germination ability of the LR fraction was only slightly poorer. For one hybrid the control gave considerably better results, while for the other, seeds from combine harvesting had slightly better germination. In the case of the MF fraction the difference between the treatments was not significant for the PR39F58 hybrid, while for PR39R86 no difference was observed. Germination was poorest (though still above the minimum laid down in the standard) for the MR fraction, with better results for both hybrids when whole ears were harvested, so if field observations reveal a large proportion of medium round seeds, the wisdom of combine harvesting is questionable.

In the course of biometric calculations, no significant differences were found for any of the fractions. It should be noted that for these two varieties there was no significant difference between the treatments for unfractionated seed.

Table 2. Effect of fractionation on the germination of seeds from Pioneer hybrids harvested using different methods (Szarvas, Martonvásár, Székesfehérvár, 2010)

Hybrid	Fraction	Harvesting method	Székes-fehérvár	Marton-vásár	Szar-vas	Lab Mean	Signif-icance
PR39F58	**MF**	Shelled	90.25	93.50	98.75	94.17	
PR39F58	**MF**	Ear	95.25	95.00	97.00	95.75	NS
PR39F58	**MR**	Shelled	93.75	86.00	96.50	92.08	
PR39F58	**MR**	Ear	93.75	95.00	98.00	95.58	NS
PR39F58	**LR**	Shelled	97.25	93.75	99.00	96.67	
PR39F58	**LR**	Ear	97.25	93.75	98.00	96.33	NS
PR39F58	**LF**	Shelled	97.25	95.00	98.25	96.83	
PR39F58	**LF**	Ear	97.25	94.00	98.00	96.42	NS
PR39R86	**MF**	Shelled	94.00	92.00	96.25	94.25	
PR39R86	**MF**	Ear	95.00	95.25	92.50	94.25	NS
PR39R86	**MR**	Shelled	93.25	87.50	93.75	91.50	
PR39R86	**MR**	Ear	93.50	91.50	96.00	93.67	NS
PR39R86	**LR**	Shelled	94.25	93.00	93.50	93.58	
PR39R86	**LR**	Ear	98.25	98.00	96.25	97.50	NS
PR39R86	**LF**	Shelled	97.25	95.50	93.00	95.25	
PR39R86	**LF**	Ear	99.25	99.00	97.50	98.58	NS

Szfv: Székesfehérvár; Mv: Martonvásár;
$LSD_{5\%}$ = 4.25; NS = non-significant

In all the seedling examinations, a larger number of abnormal seedlings were found in lots from combine harvesting, though the difference was only significant in a few cases. This suggests that a slightly larger number of kernels were damaged during mechanical shelling at harvest. It is also worth noting that the proportion of abnormal seedlings was higher for the round fractions and lower for the flat fractions (Table 3).

Table 3. Effect of combine or ear harvesting on the abnormal seedlings of the seed of Pioneer maize hybrids (Szarvas, Martonvásár, Székesfehérvár, Budapest, 2010)

	Abnormal seedlings (%)	
Hybrid	Shelled Lab mean	Ear Lab mean
PR39F58	2.64	1.34
PR39R86	3.26	2.31
PR39H32	3.00	1.63
PR39G83	1.94	1.44
PR38H67	3.55	2.94
PR35Y65	3.44***	0.75
PR39R20	2.66	1.31
Anasta SV	2.40	1.25
PR39F58 MF	2.00	1.17
PR39F58 MR	4.42**	1.58
PR39F58 LR	2.17	2.00
PR39F58 LF	1.75	1.67
PR39R86 MF	3.00	2.00
PR39R86 MR	4.25	3.25
PR39R86 LR	4.83**	2.33
PR39R86 LF	2.92*	0.92

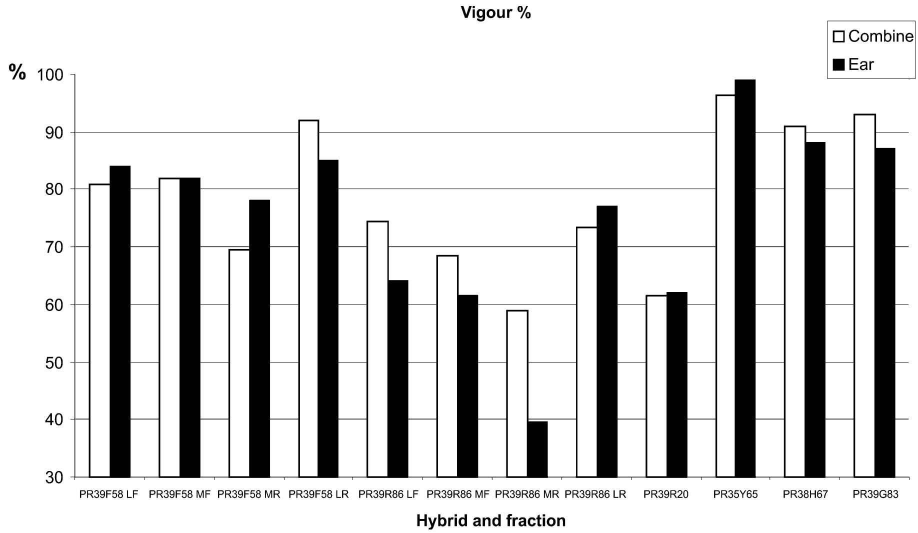
Unfractionated: ***$LSD_{0.1\%}$ = 2.43. Fractionated: ***$LSD_{0.1\%}$ = 2.88; **$LSD_{1\%}$ = 2.2; *$LSD_{5\%}$ = 1.65.

Surprising results were obtained in the vigour tests (Table 4). In the case of the PR39F58 hybrid, the superiority exhibited for germination ability by seed from ear harvesting was confirmed, and for two fractions the vigour was significantly better in terms of both root and shoot weight. For the LR fraction, however, seed from combine harvesting exhibited greater vigour, though the difference was not significant. In the case of the PR39R86 hybrid better vigour and higher root and shoot weights were recorded after combine harvesting for three of the fractions (LF, MF, MR), for two of which the differences were significant. For hybrids where the seed was not fractionated, combine harvesting resulted in seeds with better vigour compared with the whole ear control for PR38H67 and PR39G83, while seed from ear harvesting was slightly more vigorous in the case of PR35Y65. No difference was observed for PR39R20.

Table 4.

Effect of combine or ear harvesting on shoot weight (SW) and root weight (RW) of the seed of Pioneer maize hybrids (Martonvásár, 2010)

Hybrid	Fraction	Harvesting method	SW g/25 plants	RW g/25 plants
PR39F58	**LF**	Shelled	4.38	3.01
PR39F58	**LF**	Ear	6.3**	4.8***
PR39F58	**MF**	Shelled	3.76	2.51
PR39F58	**MF**	Ear	lg	lg
PR39F58	**MR**	Shelled	3.17	2.35
PR39F58	**MR**	Ear	4.82**	4.65***
PR39F58	**LR**	Shelled	6.37	4.5
PR39F58	**LR**	Ear	6.58	5.1
PR39R86	**LF**	Shelled	5.61*	2.9*
PR39R86	**LF**	Ear	4.35	2.28
PR39R86	**MF**	Shelled	3.9	2.25
PR39R86	**MF**	Ear	3.46	1.57
PR39R86	**MR**	Shelled	3.37**	2.31**
PR39R86	**MR**	Ear	2.27	1.34
PR39R86	**LR**	Shelled	5.76	3.06
PR39R86	**LR**	Ear	6.06	4.06**
			*SzD5%=1.21 **SzD1%=1.44 lg= lack of grain in the fraction	**SzD5%=0.62 **SzD1%=0.83 ***SzD0,1%=1,37 lg= lack of grain in the fraction



*SzD5%=8,32 (PR39F58 MR Combine, PR39R86 LF Combine)
***SzD0.1%=13.96 (PR39R86 MR Combine)

Fig. 1. Effect of combine or ear harvesting on the vigour of the seed of Pioneer maize hybrids (Martonvásár, 2010)

These contradictory data suggest that the genotypes may respond differently to harvesting methods and to the artificial stress factors exerted during processing. In the near future the present work will be expanded to include a larger number of hybrids, and the seed lots will be tested in field performance trials.

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