

**A MODEL OF A SUCCESSFUL UTILISATION OF A HIGH GENETIC  
POTENTIAL OF MAIZE YIELD**

Milovan PAVLOV, Goran SARATLIĆ, Živorad VIDENOVIC  
and Zoran STANIŠIĆ

Maize Research Institute, Zemun Polje, Belgrade, Serbia

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The principle of a system, defined as a ZP system, implying corresponding relationship among research, seed production and seed marketing, is that each segment within the system has its tasks and responsibilities, as well as, a clear interest. This system was established at the Maize Research Institute, Zemun Polje, almost half a century ago. The crucial characteristic is that this system encompasses obtained results of scientific accomplishments (patent - a released hybrid), optimal utilisation of the environmental conditions, facilities for seed drying, processing and packing, staff and transport capacities. The ZP system provides the economic interest of all participants in studies and the maize seed production.

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*Corresponding author:* Živorad Videnović, Maize Research Institute, Zemun Polje, Belgrade, Serbia, S. Bajića 1, 11185 Zemun Polje, Serbia  
email:zvidenović@mrizp.co.yu

The fundamental base of the quality seed production within the ZP system is a multidisciplinary programme on maize breeding, as well as, 535 released hybrids with standard and specific traits. According to regulations in foreign countries, approximately 100 ZP maize hybrids have been released abroad.

Agroecological conditions in Serbia are favourable for the development of the best genotypes and the production of basic and certified maize seed. There 10 processing plants that apply recent technologies in the maize seed processing procedure. Several generations of experts have been trained and gained experience within the maize seed production. Three seed testing laboratories have been accredited by the International Seed Testing Association. According to regulations in Serbia, monitoring of seed production under field conditions, and further on, during the processing practice is done only by designate authorities. This study presents one of successful systems of the seed production organisation applicable in countries with similar conditions.

*Key word:* basic seed, certified seed, genetics and breeding, maize yield, seed processing, seed fractioning, seed fractions, seed packing.

## INTRODUCTION

Maize breeding and the contemporary production of basic and certified seed have been intensively developed during the last 60 years, both abroad and in our country. As a result of this development there are a great number of maize hybrids derived for grain and silage. Modern technical and technological prerequisites for performing a contemporary breeding process and the seed production have been provided (DUVICK 1984, DUVICK 2005, TRIFUNOVIĆ 1986, IVANOVIĆ *et al.* 1995, BERZSENYI and GYÖRFFY 1995)

The first amounts of hybrid maize seeds were introduced from the USA to our country in 1953, when the total areas under maize hybrids encompassed 1% (ROSIĆ 1965). The idea of the maize production system organisation was born at the Maize Research Institute, Zemun Polje in 1954, when the studies were initiated and the maize seed production was begun and the hybrid Wisconsin 641 AA was grown on 100 ha (VIDOJKOVIĆ *et al.*, 1995). During the mid-1960s, our country was one of the first countries to develop single cross hybrids (IVANOVIĆ *et al.*, 2002).

The ZP maize hybrid seed production was initiated in 1964 upon the first ZP maize hybrid ZP 755 had been released. During the last 50 years, the system of production, harvest, drying, processing and seed packing has been improved not only globally but also locally. This system unites more participants and therefore it facilitates the production of the sufficient amount of seeds for both markets, national and international. Furthermore, it provides economic interest of all

participants in the seed production, what is very important for its successful functioning.

Climatic conditions in our country favour the maize seed production. A heat unit sum is about 1650°C, while a precipitation distribution is unfavourable, but it is successfully compensated by irrigation. Soils are of good physical and chemical properties. The above are the most important natural conditions for the successful maize seed production (DOKIĆ *et al.*, 1995). There is a sufficient number of processing plants that are modernised and can process maize seed by contemporary technology.

Several generations of experts have been gaining experience within the maize seed production and they are today a guarantee of a successful, quality and economically justifiable maize seed production.

Regulations provide that monitoring of the seed production in under both, field and processing practice conditions, is done by designate authorities, which is very important for the production of high quality seeds. The Maize Research Institute, Zemun Polje, organises its own system of seed quality control during the production, drying, processing and packing, which prevents non-compliances.

There are three ISTA accredited seed testing laboratories in Serbia that test seeds more than once during drying, processing and packing.

Such a system of a maize seed production unites the use of scientific accomplishments - patents (released hybrids), natural conditions, capacities of drying, processing and packing of seeds, experts, marketing competences and transport capacities. Due to everything stated, this model is very successful in agriculture.

In Serbia, there is an excellent tradition in the production of high quality seed not only of maize but also of other cultivated crops. Since 2000, the greatest world's companies have been having their offices in these regions.

The aim of the present study was to point out to the fact that the Maize Research Institute, Zemun Polje, has developed a contemporary ZP organisation system of maize hybrid breeding, production, harvest, drying, processing and packing of maize seed.

#### A.HIGH-QUALITY BREEDING PROGRAMME - THE BASIS OF A SUCCESSFUL SEED PRODUCTION

A very developed maize breeding programme is a base of the high-quality maize production at the Maize Research Institute, Zemun Polje. This programme includes the development of maize hybrids of high genetic potential of the yield for different traits such as: high and quality yield, grain quality, improved in regard to the content and composition of proteins and oil, tolerance to biotic and abiotic stress. The maize hybrids with stated traits require a specific system of production, drying, processing and packing of seeds (SARATLIĆ *et al.*, 2007).

The maize breeding programme is dependent on a very rich collection of a gene bank, which is used for desirable genetic traits in the development of high-quality maize hybrids (JELOVAC *et al.*, 2000; ANDELKOVIĆ 2000). A comprehensive, extensive and multidisciplinary work within a gene bank programme encompasses the collection classification of different heterozygosis in a narrow- and/or broad-sense and variability of local and synthetic populations. The morphological or biochemical traits are the basis for the classification of materials. The overall programme of characterisation of genotypes is a very important base for the successful maize breeding programme (SARATLIĆ *et al.*, 1996; DUVICK, 2005).

The following factors also significantly affected the improvement of the maize breeding programme: selection for a greater sowing density, greater utilisation of mineral fertilisers, irrigation, mechanised harvest, selection for stress conditions, etc. Out of 535 maize hybrids released in the course of 60 years at the Maize Research Institute, Zemun Polje, 70 hybrids have specific traits. Besides, 100 maize hybrids have been released abroad. The FAO maturity groups of 500, 600 and 700 prevail (52.9%) among the total number of developed hybrids. One segment of the breeding programme related to hybrids with modified grain quality is selection for high oil content. Some of basic results are presented in Table 1, (SARATLIĆ *et al.*, 2007).

Table 1. Comparative value of four high-oil hybrids in comparison with a check

Hybrid	Grain Yield (t/ha)	Oil Content %	Oil Yield (kg/ha)	Protein Content (Nx 6.25)	Protein Yield (kg/ha)	Available Protein (%)	Isocal. seed amount
ZPSC 781	12.8	5.17	660	10.38	1324	6.72*	101.1
ZPSC 727	15.5	5.50	855	11.88	1847	6.89*	98.5
ZPSC 747	12.0	8.19	982	12.50	1498	6.98*	92.7
ZPSC 717	13.8	7.12	981	10.94	1507	6.47*	92.5
M <sup>1)</sup>	13.5	6.50	870	11.43	1544	6.77	97.0
ZPSC 704	14.3	5.11	733	9.63	1381	5.61	100.0

\* Mean value significantly ( $P < 0.05$ ) different from a mean value of a standard grain quality hybrid (ZPSC 704)

M<sup>1)</sup> Average for four high oil hybrids

Genetic yielding potential of maize has been increasing by 100 kg ha<sup>-1</sup> annually for the last 40 years, while a contribution of selection to this increase approximately amounted to 50% (DUVICK 2005). The degree of exploitation of genetic potential depends on climatic conditions and the level of growing practices (VASIĆ and KEREČKI 1988; KRESOVIĆ *et al.*, 2004; VIDENOVIĆ *et al.*, 2005; VIDENOVIĆ *et al.*, 2007).

The production of high-quality hybrid seed is one of very important factors for the successful, high and stable maize production. It is a complex and sensitive process that requires sufficient financial means. However, a necessary genetic yielding potential of maize hybrids can be obtained only in such a system in the process of selection. Simply such seed is a guarantee that a necessary genetic yielding potential will be provided for the mercantile maize. The stated indicates to an importance of a high-quality production system of maize hybrid seed, which is confirmed by obtained results of the long-term studies.

## MAIZE SEED PRODUCTION

The hybrid maize seed production belongs to the group of advanced technologies with a great number of critical points in the course of the production, when even the smallest error at any stage of the process annuls and makes void all previous operations, even if they have been very conscientiously done. Therefore it is necessary to pay full attention to the seed production and to provide optimum conditions and the unconditional support by all participants in the system.

### 1. Basic seed production

The production of seed of genetically pure maize inbred lines is the most important prerequisite for a high-quality production of certified seed of maize. The production of high-quality basic seed is aimed at the conservation of biological purity of inbred lines and the seed multiplication in manual self-pollination by the ear-to-row and pedigree methods in the amounts necessary for the continuance of multiplication. The whole procedure proceeds in two stages: A. the production of elite seed- pre-basic seed and B. the production of basic seed.

A. Elite seed - pre-basic seed is produced in the following way: inbred line seed of satisfactory genetic purity is sown in the spatial isolation of 400 m at the area of 1-2 ha in dependence on the necessary seed amount. Rigorous control and removal of all off-type and doubtful plants are done in the course of the growing season. All doubtful and off-type ears are removed at harvest, while remaining ears are shelled and seeds are mixed and these seeds represent the elite - pre-basic seed.

B. Basic seed is produced from the elite seed in the spatial isolation of 400 m. A part of elite seed is stored as a reserve. Depending on the necessary seed amount, the area of the spatial isolation can be up to 10 ha. If a greater amount of seed is necessary, than several spatial isolations, each of 10 ha, should be sown. Similar to pre-basic seed, strict control and removal of off-type plants are performed during the growing season, while off-type ears are removed at harvest in order to maintain the genetic purity at the required level, so that the produced basic seed would be of good quality.

The basic seed production is exclusively controlled by the Institute's experts. The certified seed, i.e. the certified first generation seed, as it is its official name today, is produced from the basic seed, produced under such strictly controlled conditions.

## 2. The certified seed production - the certified first generation seed

The production of hybrid maize seed is based on the application of the heterotic effect expressed by inbred lines in the first generation after crossing. Today, single-cross (SC) and three-way cross (TS) maize hybrids are developed. Single-cross (SC) hybrids prevail not only in our country but world-wide (SPRAGUE and TATUM, 1942; IVANOVIĆ *et al.*, 2002). They are characterised by a great phenotypic uniformity, but their production is difficult and risky, especially during unfavourable years. In order to obtain higher and more stable hybrid seed yields, the Maize Research Institute, Zemun Polje, has introduced so called "modified two-way cross hybrids". Seed produced from such inbreeds results in more stable and higher yields (URS *et al.*, 2002).

Regions for the production of maize certified seed are selected in such a way that maximum yields are possible and plots are uniform and provided with mineral nutrients. Moreover, these regions should not have any depressions and perennial weeds, and should be supplied with irrigation systems. Legumes are the best preceding crops.

Based on long-term studies and practice it was determined that the best results can be obtained if female and male components are sown in rows at the ratio 4 to 2, and when male component is sown in narrower rows (50cm). In such a way, the female component is spread on approximately 80% of the area, what results in the top yields. Numerous studies show that a sowing density significantly affects maize grain yield. The available literature implies that the number of plants per area unit should be increased by 10-15% under irrigation conditions in comparison to rainfed conditions (NEDIĆ, 1986). Today, however, recent developed maize hybrids require a greater sowing density in relation to other hybrids belonging to the same maturity group, hence it is the question which densities are the most favourable for the maximum yields of certain hybrids under irrigation conditions. The sowing density should range from 50,000 to 80,000 plants ha<sup>-1</sup> depending of a FAO maturity group of a hybrid (SELAKOVIĆ *et al.*, 1999; PAVLOV *et al.*, 2007). Early maturity hybrids are sown in greater densities than the late maturity hybrids. A separate sowing of a female, i.e. male component is applied with some hybrids or sowing of a male component could be delayed on two occasions, which will result in a prolonged pollination and an increased degree of fertilisation of the female component. A spatial isolation should be 200 m.

Control of a correct cross of parental components in the field is the basic and the most important prerequisite for the production of high-quality hybrid maize seed, in order to provide seed vigour heterosis within legally prescribed limits. This is the most critical, sensitive and difficult stage in the production of hybrid maize seed. Properties of inbred, plots and climatic conditions should be

known, otherwise a correct and high-quality removal is not possible. Due to these reasons, it is necessary to monitor crops each day during pollination in order to avoid uncontrolled fertilisation of the female component.

Detasseling can be done by machines, hand and/or both. Hand detasseling is not cheap as it requires expensive labour power. Working conditions are aggravated due to high temperatures, sometimes even above 30°C. Therefore, mechanised detassling has been increasingly introduced. In such case, it is very important not to remove too much of leaf mass as it adversely affects the yield. In order to decrease costs of detasseling, the Maize Research Institute, Zemun Polje, has introduced cytoplasmic male sterility - types c and s. In such a way, genetic purity and quality of seed are increased. Male-sterile inbreeds almost always have greater yields, especially under stress conditions, when the yield can be higher by 5-10% in comparison with their fertile analogues (VIDAKOVIĆ, 1985; URS *et al.*, 2002; VANČETOVIĆ *et al.*, 2006).

## HARVEST, DRYING, PROCESSING AND PACKING OF ZP MAIZE SEED

### *1. Contemporary method of harvest, drying, processing and packing of seed*

Harvest of seed maize begins when grain moisture is 35-38%, i.e. at the moment when seed reaches its physiological maturity (BULANT C. *et al.*, 2000). Kernel shedding is smaller at such moisture, while an adverse effect of different pathogens and pests are decreased, as well as, risks of early autumn frosts. Harvest of seed crop should be done with a maize picker with husk as much as possible. This harvest method lessens damages and injuries of seed. The time from harvest to the beginning of drying has to be as short as possible. Any longer keeping ears in piles results in lower germination. The higher grain moisture at harvest is the greater adverse effect is. Harvest should be done by high-quality pickers while processing plants should be equipped with rubber roll husker shredder and a sufficient numbers of vehicles (NOBLE and RUSSELL, 1963; IVANOVIĆ *et al.*, 2005; MILOŠEVIĆ *et al.*, 2005).

To provide more successful drying of ears it is necessary to rigorously remove off-type, infected and doubtful ears and shelled kernels. Bins should be filled by using shock absorbers for falling kernels, hence damages of kernels when ears drop from the height of 3-4 m could be prevented. In such a way damages of kernel pericarps are mitigated, kernel shedding is reduced and bins are more uniformly filled.

A high and quality yield, as well as, a necessary 1000-kernel weight is essential in the seed production (BOČANSKI *et al.*, 2004; MIRIĆ *et al.*, 2007). ZP seeds are exclusively packed in seed units. The seed unit encompasses 25,000, i.e. 75,000 seeds intended for national, i.e. international market, respectively (SELAKOVIĆ *et al.*, 2006). The 1000-kernel weight is to the greatest extent caused by genetic properties of parental components of hybrids (JOVIN *et al.*, 2006). However, it was demonstrated that growing practices affected the amount of the 1000-kernel weight. A high level of growing practices meaning the fertile plot soil,

timely tillage, legumes as the best preceding crop, (TSAI and TSAI, 1990), a sufficient rate of applied mineral fertilisers, optimum sowing density, irrigation plus favourable climatic conditions, result in seeds of larger sizes. Such seed has satisfactory amount of reserve nutrient substances for the initial development of germs, which is particularly important if conditions in the course of germination are not favourable.

The ZP seed processing system specifies that seeds after shelling are primarily processed using sieves of dimensions ranging from 6.5 to 11.0 mm (ODHIAMBO and COMTON, 1987). Then, seeds are sieved on surfaces with meshes of 8.3 mm and two fractions are separated: smaller (6.5-8.3 mm) and larger (< 8.3-11 mm). Further, it is possible to grade seeds into rounded and flat seed fractions. However, according to gained experience seeds are sufficiently uniform if they are graded only into two fractions. Such a system is important in particular for a correct sowing when sowing machines are used. Also, the growth and yields of such crops are uniform in comparison with better or worse developed plants when seeds of different sizes were used. Different seed fractions carry the equal genetic information and significant differences in yields among them were not established (VIDENOVIC, 1987; STAMP *et al.*, 2000).

The shape and size of the kernel depend on its position on the ear, hence kernels on the tip and bottom of the ear are rounded, while those in the middle are flat (RASSELL, 1991). From a biological point of view, the kernels in the middle of the ear are nourished the best, therefore they are the most developed ones. Rounded kernels occur to a greater degree when pollination is incomplete. The germ of such rounded seeds is damaged in processing to a greater extent because of its position and this is a specific blemish of rounded seeds (WEILAND, 1992; UHART, and ANDRADE, 1995; PAVLOV *et al.*, 2005; PAVLOV *et al.*, 2005).

In order to determine the proportion of seed fractions and 1000-kernel weight, three ZP maize hybrids (ZP 341, ZP 434 and ZP 677) grown by 24 growers were analysed in 2007. These analyses were performed on the basis of the production carried on the area of 1,888 ha. The percentage of two seed fractions - 6.5-8.3 mm and < 8.3-11 mm and the 1000-kernel weight in the total yield differed over observed maize hybrids.

The percentage of the seed fraction 6.5-8.3 mm, i.e. the 1000-seed weight in the total yield of hybrids ZP 341 and ZP 434, amounted to 52.5 % and 48.3 %, i.e. 269.3 g and 268.4 g, respectively. The corresponding values of a larger fraction < 8.3-11 mm amounted to 47.5 % and 51.7 %, i.e. 342.4 g and 344.3 g, respectively. These parameters were different in the hybrid ZP 677. The percentage of the seed fraction of 6.5-8.3 mm amounted to 85.5 %, while the 1000-seed weight was 282.3 g. Moreover, the percentage of a larger seed fraction of < 8.3-11 mm was 14.5 %, while the 1000-seed weight was 333.5 g. Results are presented in Table 2 (PAVLOV *et al.*, 2008).



Table 2. Percentage of seed fractions and 1000-seed weight of ZP maize hybrids in 2007

Hybrid	Fraction 6.5 - 8.3mm		Fraction < 8.3 - 11mm	
	Fraction %	1000-seed weight g	Fraction %	1000-seed weight g
ZP 341	52,5	269,3	47,5	342,0
ZP 434	48,3	268,4	51,7	344,3
ZP 677	85,5	282,3	14,5	333,5
$\bar{x}$	62,1	273,3	37,9	340,0

### 2. One of successful models of seed drying, processing and packing

The seed drying, processing and packing plant of the Maize Research Institute, Zemun Polje, was built up during 1978. The plant is equipped with a Heid Delta 10t seed separator and Carter day graders. The processing plant capacity amounts to 5,000 t, i.e. 3,000 of maize seed, i.e. wheat, barley and soybean seed, respectively. Maize seed is treated with "Maksim HL" and a polymer "VioSpor", which provided high quality of seed. Although the condition of the equipment of the processing plant is uncontested, considering manufacturers, during the years several technological innovations have been contributing to a higher quality and more efficient seed drying, processing and packing, but the following two are the most important:

A shock absorber for falling ears was installed to mitigate kernel damages when bins are filled up.

Rubber roll huskers are created and set in so that they efficiently remove the remaining ear husks and do not injure the grain.

The idea is to introduce the technological innovations into other processing plants, because it will contribute to even more elevate quality of the ZP seed drying, processing and packing system.

### CONCLUSION

According to performed analysis on the ZP system of the development, production, drying, processing and packing of maize seed the following conclusions can be drawn:

The essential base of a high-quality seed production is a good maize breeding programme that is developed at the Maize Research Institute, Zemun Polje, which is confirmed by 535 maize hybrids released in our country and 100 hybrids released abroad.

The stated system is a contemporary model of the organisation of the hybrid maize seed production, drying, processing and packing that provides the optimum exploitation of natural resources and utilisation of the capacity of seed drying and processing plants.

The system encompasses several participants in the seed production, which provides sufficient amounts of seeds that covers not only national but also international needs.

The system provides economic interest of all participants in the maize seed production.

According to its technical and technological properties, the seed drying, processing and packing plant of the Maize Research Institute, Zemun Polje, is one of the very modern plants not only in Serbia but also in the region. It has been planned to organise a modern system of drying, processing and packing of ZP seed of sunflower, soybean and small grains.

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## **PRIMER USPEŠNOG ISKOROŠČAVANJA GENETIČKOG POTENCIJALA RODNOSTI KUKURUZA**

Milovan PAVLOV, Goran SARATLIĆ, Živorad VIDENOVIC  
i Zoran STANIŠIĆ

Institut za kukuruz „Zemun Polje“, Beograd, Srbia

### I z v o d

Ideja o postavljanju sistema proizvodnje semena kukuruza potekla je iz Instituta za kukuruz „Zemun Polje“, pre skoro pola veka. Ovaj sistem objedinjava iskorišćavanje naučnih dostignuća (patenta-priznatog hibrida), prirodnih uslova, kapaciteta za sušenje doradu i pakovanje semena, kadrova i transportnih kapaciteta. ZP sistem obezbeđuje ekonomsku zainteresovanost svih učesnika u istraživanjima i proizvodnji semena kukuruza.

Glavna osnova kvalitetnog semenarstva je veoma razvijen program selekcije kukuruza Instituta za kukuruz „Zemun Polje“, iz koga je dosada priznato 535 hibrida u zemlji i 100 u inostranstvu.

U Srbiji postoje povoljni agroekološki uslovi za stvaranje najboljih genotipova i proizvodnju osnovnog i komercijalnog semena kukuruza. Imaju deset doradnih centara koji doraduju seme kukuruza po savremenoj tehnologiji. Izškolovalo je i steklo iskustva u radu, više generacija kadrova u oblasti semenarstva kukuruza. Akreditovane su tri laboratorije za kontrolu kvaliteta semena, po međunarodnim ISTA standardima. Zakonski propisi Srbije obezbeđuju da se kontrola proizvodnje semena u polju i u toku dorade obavlja od strane ovlašćenih državnih institucija. U radu je prikazan jedan od uspešnih sistema organizacije proizvodnje semena primenjiv u zemljama koje imaju slične uslove.

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