Essay

Background and perspectives of seed technology and production at INIFAP†

†*In memoriam*
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in seed technology

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Abstract

In recent years, the National Institute of Forestry, Agricultural and Livestock Research has generated technology for seed production. The objectives of this document are to analyze the achievements of scientific research, identify areas of opportunity and collaborate in improving the seed multiplication process. It was concluded that, except for maize, in the last 30 years production of qualified seed in Mexico declined. The Institute has generated for the main crops, technology to multiply seed of improved genotypes and native species, in both cases, research in post-harvest management is marginal. Despite the institutional link with seed companies of national capital, the adoption of their improved seeds has been low.

Keywords: agronomic management, contributions, evolution, institutional opportunity.

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In the search for higher yield and quality in seed multiplication, information on the areas of adaptation, phenology and agricultural practices is required (Espinosa *et al*., 2003). For the past 35 years the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) has generated technologies in this regard. The objective of this document is to review the achievements of scientific research, identify lines of opportunity, meet current knowledge needs, greater understanding of the topic and thus contribute to the improvement of the seed production process.

Background of seed production in Mexico

In the first Law on Seed Production, Certification and Trade, in 1961, the basis for establishing the National Seed Production, Certification and Trade System was established, formed by the National Institute of Agricultural Research (INIA), which resulted from the merger of the Office of Special Studies (OEE) and the Institute of Agricultural Research (IIA), the National Seed Producer (PRONASE), the National Seed Inspection and Certification Service (SNICS), the Qualifying Committee of Plant Varieties (CCVP) and the National Plant Variety Registry (RNVP); the ordinance mentioned that INIA (today INIFAP) was responsible for developing varieties and hybrids and delivering the original seed to PRONASE, which would multiply, benefit and market it, to make it available to Mexican agricultural producers, replacing the former National Maize Commission (Espinosa *et al*., 2014).

To adapt to the policies of trade globalization, the Mexican government in the 1990s made changes to its legislation that directly affected the agricultural sector, in 1991 a new law of seeds was enacted, which allowed the unrestricted participation of the private sector in agricultural research, particularly in the production and marketing of seeds, and the possibility of other users to multiply and market seed varieties generated by public institutions, such as INIFAP, in addition to PRONASE, was opened. Following the subscription of the North American Free Trade Agreement (NAFTA), Mexico joined the International Union for the Protection of New Varieties of Plants (UPOV) and consistently, in 1996 the Federal Law of Plant Varieties (LFVV) was published, with this ordinance and the Law of Seeds of 1991, the participation of private sector, which joined with public sector investment policies and pressures from international organizations gradually led to the dismantling of PRONASE (Luna *et al*., 2012).

In 2007, the new Federal Law on Seed Production, Certification and Trade is published, which issues the disappearance of PRONASE, which increased control of the seed trade by a few multinational companies. This situation led to a shortage of seeds, such as beans, oats, rice and open-pollinated varieties of maize in large areas (Espinosa *et al*., 2014).

Evolution of seed production in Mexico

In Mexico, just over 18 million ha are cropped annually, 25% under irrigation and 75% under rainfed conditions. The main crops are maize, bean, sorghum, oats, wheat and barley (INEGI, 2019). Worldwide, 60% of the increases observed in the production of the main crops are attributed to genetic improvement (Lee and Tollenaar, 2007). In this sense, seed is the most important input for increasing unit yield (Copeland and McDonald, 2001).

Artisanal seed production (ASP) supplies about 2.7 million production units, usually in rainfed areas and with less than 5 ha, while seed produced by companies supplies just over 0.8 million irrigation units, commonly larger than 5 ha, with machinery and unlimited resources (INEGI, 2019).

In Mexico, over the past 30 years, the production of qualified seed has fluctuated, in the period from 1988 to 1990 about 350 000 t were obtained; however, by 2001 it was just over 100 000 t, while in 2019 it was 243 197 t (SNICS, 2021).

Contributions of INIFAP in seed technology

Genetic effects involved in seed quality

In maize in High Valleys, Gámez (2007), points out that additive effects (*a*) were decisive in the weight and length of plumule (LP); the effects of dominance (*d*) defined the length of radicle (LR), and the epistatic: *aa* manifested in the LP, the *ad* influenced the expression of the LR and the *dd* in the LP. In this regard, Avila (2008) states that, in the manifestation of physiological quality, additive, non-additive and reciprocal genetic effects were important. In the tropics, Manjarrez *et al*. (2008), found that additive gene action predominated in vigor characteristics.

Production environment

Seed production of progenitors and maize hybrids of High Valleys can be carried out in San Luis de la Paz, Guanajuato, as no significant differences in yield, weight, size and physiological quality of the seed were observed between localities (Hernández, 2018). In this regard, Espinosa and Carballo (1988a) mention that the best environment for increasing seed of maize lines and hybrids adapted to the Transition Zone was Francisco I. Madero, Hidalgo; however, Espinosa and Carballo (1988b) indicate that, for H-135, the highest quality certified seed is obtained in localities of El Bajío.

The maize seed production of High Valleys in the autumn-winter cycle in a locality with a warm dry environment, affected the yield and vigor of the seedling (Cruz *et al*., 1985). The single female cross of H-385A, in Tlajomulco, Jal., yielded 50.9% more than in San José de Mojarras, Nay. (Ramírez *et al*., 2017). In wheat of High Valleys, the environment impacted the quality of seed (Fernández *et al*., 2015).

In barley in El Bajío, on the sowing date of December 15 the quality was higher compared to that of January 15 (Pérez *et al*., 2015). In this same region and crop, Arellanes (2018) points out that seed production should be established between November 20 and December 20.

Likewise, Noriega *et al*. (2019) point out that in wheat the planting date of November 15 raised the physical quality and vigor of the seedling. In this same crop, the optimal sowing date to produce seed in Valle de Mexicali, Baja California and San Luis Río Colorado, Sonora, is from December 1 to 20 (Valenzuela, 2011). In High Valleys, the sowing date of early June of maize lines decreased their yield and the percentage of medium-sized seed (Virgen *et al*., 2013). In this aspect, the seed production of H-40 and H-48 in Tlaxcala, should be carried out in the southern and west areas of the state (Rojas *et al*., 2009a; Rojas *et al*., 2009b).

In El Bajío, with the bean seed established on July 5, higher yield was obtained; however, physiological quality was higher in the sowing of March 5 (González *et al*., 2008). In this region, Bobadilla *et al*. (2013) point out that in the oats sowing of December 31, higher seed yield and lower volumetric weight were obtained.

Production technology

Garcia *et al*. (2014) report that, in El Bajío, the seed production of H-135 with the compact planting pattern (CPP) is feasible, in this aspect, García *et al*. (2018) indicate that CPP 4:1 and 8:1 produce seeds of similar quality to those of conventional arrangement 6:2. In barley in El Bajío, seed production in double row grooves and planting density of 100 kg ha^{-1} improved performance and quality (Cobarrubias, 2007). In this crop and region, it was not justified the application of 270 units of nitrogen (UN) ha^{-1}, because it did not increase yield and physical quality (Avila *et al*., 2020).

In the State of Mexico, applying 60 units of potassium ha^{-1} in planting, improved the yield and physical quality of oats (Márquez *et al*., 1991), in this crop, in El Bajío, using 90 kg of seed ha^{-1} increased yield (Bobadilla *et al*., 2013). In the seed multiplication of sorghum lines, Mora *et al*. (1992b) point out that, in unfertilized treatment, the yield of the seed benefited rose between 107 and 132% when applying 100 or 200 kg of nitrogen (N) ha^{-1} in planting, respectively.

In El Bajío, with 75 000 to 90 000 plants ha^{-1} and with the application of 150 kg of N ha^{-1} the highest yield of the female of H-374C was achieved (Cervantes *et al*., 2013). In this region, it is recommended to use the formula 220-60-60, to produce the hybrid seed QPM, whereas in the Humid Tropic, it is advisable to apply 184-69-30 (Espinosa *et al*., 2003). In the increase of seed of tropical maize lines, the highest germination and physical quality were presented with 62 500 plants ha^{-1} and the fertilization dose 184-69-60 (Tosquy *et al*., 1998).

In maize of High Valleys, Espinosa and Tadeo (1992) mention that the population density, that combines high yield and seed quality for both progenitors of H-137, is 60 000 plants ha^{-1}. In this environment, Virgen *et al*. (2010) point out that in Tlaxcala there were no differences between population densities regarding yield, but that with 62 000 plants ha^{-1}, the seed was larger in size and weight. In this regard, Virgen *et al*. (2014), in the evaluation of hybrid progenitor lines, indicate that with 82 500 plants ha^{-1} yield was increased and the weight of one thousand seeds decreased.

In wheat, Valenzuela (2011) recommends the application of 210 UN in Northwestern Mexico. To produce bean under fertigation in San Luis Potosí, it is recommended to apply the fertilization treatment of 100-100-50, dosed in irrigation water (Jasso and Martínez, 2012). In rice, Ortega (2014) recommends the fertilization dose 184-46-30 and the foliar application of phosphorus, potassium and microelements. The largest production of forage pasture seed in northern Mexico was obtained with fertilization 120-60-00 and 60-30-00 plus mycorrhiza (Sáenz *et al*., 2015).

Flowering control

In the production of hybrid maize seed, some practices are recommended to promote a good synchronization of the flowering of the progenitors: 1) sow on two dates the male grooves; 2) sow a male groove to a greater depth to delay flowering; 3) application of foliar fertilizer, phosphorus-based products accelerate flowering and with nitrogen, delay it; and 4) higher population density in male grooves to delay flowering (Virgen and Velásquez, 2006). In this aspect, Torres *et al*. (2006) point out that in High Valleys with a flush cut when the plant had four ligulate leaves, it delayed male flowering, flaming delayed male and female flowering. Espinosa *et al*. (2001) mention that the male flowering of the female and male of H-311 occurred earlier when applying gibberellic acid. In this crop, different doses of fertilization to the soil did not change male and female flowering (Espinosa and Tadeo, 1992); however, in sorghum, this practice did accelerate reproductive development (Mora *et al*., 1992b).

In sorghum, Garza *et al*. (1992) point out that, in the progenitor that is ahead, the frequency and irrigation levels may be modified, since frequent and heavy irrigation may delay flowering, while frequent hoeing on the delayed progenitor can advance it, they also indicate that practices such as the application of 2-4D and gibberellic acid modify flowering. In this same species, the pruning of foliage caused a delay in its phenology, so it would allow to synchronize flowering between progenitors that differ at that stage of development, however, because there was a decreased in seed yield, it would be advisable to apply this practice on the male progenitor (Mora *et al*., 1992a).

In the production of hybrid maize seed, it is essential to remove the head (detasseling) of the female progenitor to maintain the genetic quality, in this aspect, in High Valleys, Espinosa and Tadeo (1998) point out that if three leaves are removed when detasseling, performance and physical quality are not affected, on the other hand Virgen *et al*. (2016a) mention that, in this practice, removing the flag leaf did not decrease yield, size and weight of the seed.

Postharvest management

Barley stored in glass and plastic bottles presented the highest physiological quality after 10 months (Castillo, 2012). The hermetic silo is a technology for the conservation of seeds of maize, beans, pumpkin and many others, allows to avoid losses due to damage of pests, fungi and rodents (García *et al*., 2007). Regarding maize treatment, Rivas *et al*. (2014) in High Valleys recommend that the fungicides Thiram plus Carboxin be applied, while Ramírez *et al*. (2019) in Jalisco, suggest treating the male B-51 and H-391 with Metalaxil.

Artisanal production and seed selection of Creole varieties

ASP is an alternative in low-access regions or where the use of certified seed is not feasible for cultural, economic or other reasons. The goodness of ASP in bean has been demonstrated in Veracruz (Ugalde *et al*., 2014) and Zacatecas (Zandate and Galindo, 2006). Besides, research has been carried out for the training of producers in the seed selection of their Creole varieties, in maize, in Guanajuato (Aguirre and García, 2012) and Tlaxcala (Rojas and Arellano, 2006), as well as in garlic (Reveles *et al*., 2009) and chili (Cabañas *et al*., 2006).

Seed quality assessment

In forage maize, the most important seed quality variables for predicting field establishment were length and weight of a thousand seeds, emergence speed and dry weight of seedling (Pérez *et al*., 2006). Virgen and Vargas (2001) propose a scale of qualification of the index of emergence speed. Gámez *et al*. (2015) indicate that the cold test with 8 °C allows the classifying of low-temperature tolerant maize materials during germination.

INIFAP's linkage with seed companies

The participation of companies, mainly transnational, in the seed industry, did not raise certified seed production as expected, except for maize, where seed supply was concentrated in the regions with the highest productive potential and in farmers with higher economic resources, but the areas of subsistence and traditional agriculture were neglected (Luna *et al*., 2012). INIFAP appeals to strengthen domestic capital firms by providing their improved materials and production technology to reduce costs, benefit local or regional seed companies and grain producers.

In Mexico's High Valleys and Transition Zone, the production of certified seed of INIFAP's improved varieties by domestic companies is a viable alternative to the adoption of technology to produce maize. From 2005 to 2013, 46.71 t of registered category of hybrids progenitors and varieties of maize were sold. With this seed, companies sowed on average 260 ha to obtain certified category, with an estimated production of 1 038 t per year, enough to sow 51 900 ha of maize annually. During this period, 31 applications per year were attended. In 2005 it started with the participation of 12 companies until reaching a maximum of 58 in 2012, located in the State of Mexico, Tlaxcala, Puebla, Morelos, Michoacán, Querétaro, Guanajuato and Jalisco (Virgen *et al*., 2016b). Regarding the H-520, at the Experimental Field Cotaxtla of INIFAP, from 2008 to 2013, 6 106 and 2 630 kg of registered seed of the female and male were sold, respectively, with which the companies established 485.2 ha for the production of the certified category; in this period, 24 companies located in 11 states of Mexico (Sierra *et al*., 2016) were attended.

In the Experimental Field Centro Altos de Jalisco of INIFAP, from 2009 to 2019, 178.7 t of registered seed of progenitors of 14 maize hybrids were sold, thereby companies established 8 932.6 ha and produced more than 40 000 t of certified category, with which 1.9 million ha for commercial production were sown, sales were made to 120 companies located in 16 states of the country, of which 80% are in Jalisco, Michoacán, Nayarit and Guanajuato (Hernández, 2020).

Areas of institutional opportunity

Although INIFAP has the largest supply of improved genotypes for farmers, they have partially adopted only a few, for different reasons including: a) the institution lacks sufficient human, economic and infrastructure resources; b) lacks from adequate regulations and regulations, c) requires a sectoral enterprise to multiply its seed; d) lacks a trans-six-year-period technical accompaniment program that disseminates the use of seed; and e) requires compliance with laws promoting the economic balance of the market, respect for biodiversity as well as the guarantee of the rights of the farmer, researcher, seed producer and consumer. The foregoing would allow them to resume and consolidate their research, multiplication and seed technology programs; in addition to rural development sectors, which promote the economy and well-being of farmers in our country, especially those with limited resources.

It is necessary to develop technology in the post-harvest areas, as well as to strengthen research of agronomic management practices for seed production of species of economic and social importance. Similarly, consolidate research in seed self-supply carried out by small and medium-sized farmers. Also, strengthen the study of the different tests to evaluate physiological quality, seed health and varietal maintenance. As well as consolidating the evaluation of socioeconomic aspects that influence seed multiplication. Finally, INIFAP should have units to define plans and projects on seed multiplication and specific technology generation.

Conclusions

Over the past 30 years, the production of qualified seeds from the country's most important crops has declined, except for maize, where transnational companies market the highest volume. Although INIFAP maintains links with seed companies of national capital with documented success stories, the impact is limited. Even though agronomic practices have been generated to multiply seed from improved genotypes and native varieties of major crops, in both cases post-harvest management research is incipient.

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