

## A Review on Maize Hybrid Breeding—Importance of Multiple Crosses in Comparison with Single Crosses in Present Scenario

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**Abstract** In future, world agriculture mainly depends on cultivation of hybrids in almost all crops. In reality, hybrid cultivars will replace homozygous plants in many self pollinated crops and heterogenous populations in most of the cross-pollinated crops in the next few years. The development of hybrid breeding methodology in maize and its successful application to exploit heterosis is considered as significant achievement of plant breeding in the present century. Earlier some reported higher yield of hybrids between open pollinated varieties and advocated the commercial cultivation of inter varietal hybrids even in the absence of knowledge of heterosis concept. The real break through, however, came with the studies who gave the pure line method of maize breeding, production of inbred lines through selfing, crossing inbred lines in pairs to develop single cross and their commercial cultivation. But the non-availability of good inbred lines with accept-

able yield levels and resistance to pests and diseases greatly limited the production of good quality inbred seeds. To overcome the problems in seed production, some suggested the commercial use of double crosses. Thus began the success story of hybrid maize.

**Keywords** Hybrid maize, Multiple crosses, Single crosses.

### Introduction

Initially, double crosses were commercially used because more seed of a desirable size and shape could be produced on a single cross parent than on the inbred lines as a parent. Since 1990's till to date, single crosses are being exploited commercially due to more uniformity and high yielding capacity (Beal 1880, Shull 1908, 1909). But in the recent years, the inbred lines are becoming highly susceptible to biotic and abiotic stresses and the *per se* may cease to be a limiting factor in the production of single crosses for commercial production. Sprague and Federer (1951) reported that double crosses interact with environments less than single crosses and double crosses are superior to single crosses for stability of performance. The hypothesis advanced was that, since each double cross is a mixture of genotypes, whereas each single cross is theoreti-

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cally a single genotype, the double cross would vary less in its performance over a series of environments. Allard and Bradshaw (1964) suggested that heterozygous and heterogeneous populations offer the best opportunity to produce varieties which show small genotype-environment interactions, greater stability of production, broader adaptation to environment and greater protection against disease with population buffering.

#### Why hybrid maize

Self-pollination is the process of taking the pollen from a single plant and applying to the silks of the same plant. This is called inbreeding and after successive generations leads to homozygous low vigor plants called inbred lines. These inbred lines are short in plant height, have small cobs and reduced yields. However, when two inbred lines are crossed, the vigor is restored in the resulting  $F_1$  seed and the yield of the plants grown from the seed is greatly increased. This is called hybrid vigor. It occurs as a result of the interaction between the alleles obtained from the two different inbred lines. The effect of some of the harmful alleles expressed in one of the inbred lines will be masked by more beneficial ones found in the other parent plant. This is called heterosis and has been exploited to develop hybrid cultivars that are widely under cultivation on farmers fields.

The advantages of growing hybrid maize are : (1) Hybrids are generally high yielding than open pollinated varieties, if grown under favorable conditions; (2). Hybrids are uniform in color, maturity, and other plant characteristics, which enables farmer to carry out certain operations such as harvesting at the same time; (3) The uniformity of the grain harvested from hybrid corn also has marketing advantages when sold to buyers with strict quality standards.

The disadvantages of growing hybrid maize are : (1) Hybrid seed is more expensive than open pollinated maize seed. (2) The farmer needs to have more than 1 t/ha in order to justify the cost of the seed. Farmers situated in a low potential environment and who cannot afford extra inputs such as fertilizer, will not recover the cost of the hybrid seed. (3) The crop raised from the harvested grain of hybrid results in

reduction in crop yields upto 30% or more and hence, the farmer needs to purchase fresh hybrid seed for every planting season. (4) Sometimes, the farmer might not be able to obtain hybrid seed in time for the planting season.

#### Single cross hybrid technology

In the 1960s, single crosses began to replace the double crosses as they were more uniform and high yielding. With the cultivation of single crosses not only a sudden increase in yield, but the rate of increase in yield has improved. Before the introduction of hybrids in the 1930's, there was almost no increase in rate of yield. In the double-cross era, the rate of increase was about 1 quintal per acre per year. After single crosses predominated, the annual increase was almost 2 quintals per acre. Current yields are sometimes five times what they were in the pre hybrid days. Furthermore, there appears to be no reduction in the rate of increase, so there is no reason to expect that the yield will plateau in the future ahead.

Single cross hybrid technology has been widely adopted because of its high yield and uniformity. In 1996, the first single cross hybrid Paras was developed and released from Punjab Agricultural University, Ludhiana. Even though the hybrid did not go to farmer's field due to some constraints in single cross hybrid seed production, the hybrids paved the way for single cross hybrid development in the country. The increase in maize production and productivity was possible by bringing only 25% of the total maize area under single cross hybrid. With this fact, we can consider this as a mini revolution and can aptly be considered as landmark in Indian maize scenario. Since 1990's to till to date, single crosses are being exploited commercially due to more uniformity and high yielding capacity (Saikumar et al. 2012). But in the recent years, the inbred lines are becoming highly susceptible to biotic and abiotic stresses and *per se* may cease to be a limiting factor in the production of single crosses for commercial production.

#### Double cross hybrid technology

Double-cross hybrids were the first commercial

maize hybrid cultivars available to farmers. This fact was possible due to work developed by Jones in the early part of 20<sup>th</sup> century. Current studies indicated that roughly 20% of the seed market involves double cross hybrid cultivars (Cruz and Pereira Filho 2008). Various seed companies maintain this kind of cultivars in order to exploit the heterosis that exists among pairs of single-cross hybrids, mainly those with low heterosis *per se* (Jenkins 1934). Double cross maize hybrids are being exploited predominantly in several countries due to the lower seed cost. This is because four lines are involved in obtaining them, which are crossed in pairs to create two single cross hybrids. Later these single cross hybrids are crossed to obtain the F<sub>1</sub> generation of the commercial double cross hybrid. As the single cross hybrids are more productive than the inbred lines, the commercial seed production of the double cross hybrid is much greater than that of a single cross hybrid reducing the costs for farmers. Sprague and Federer (1951) reported that double crosses interact with environments less than single crosses and double crosses are superior to single crosses for stability of performance. Hence, double crosses perform well under adverse conditions compared to single crosses.

Comparative performance of single, three-way and double crosses

Shull's original concept was the production and growing of single cross hybrids, but the cost of seed production limited its usefulness at the farmer level. This limitation was overcome with Jones (1918) suggestion of double cross hybrids. In addition three way cross hybrids and other hybrids have been used because of problems of seed production that are alleviated with the use of single cross as a seed parent.

Arnold and Jenkins (1932) reported that single crosses were most uniform and the double crosses and the top crosses were approximately mid way in variability. Federer and Sprague (1947) observed that the three way crosses are intermediate between single and double crosses. Seed of three way crosses is less expensive to produce than that of single crosses and genotype-environment component of variance was

less for three way hybrids thus they are widely adapted.

Single crosses are highly uniform both genotypically and phenotypically. Field appearance of single cross hybrid is very attractive to the producer because of its uniformity in maturity and higher yields. But the seed production is costly because single crossed seed, is produced on inbred plants which are relatively poor producers of seed and pollen. These single crosses are heterozygous and homogeneous with respect to the genotype. Hence, lack of genetic variability will have a poor adaptability to the external environmental factors viz., weather, soil and pests (Jones 1958).

Double crosses are slightly more variable in plant and ear characters than single crosses and three way crosses, which may be advantageous when crop is grown under adverse climatic conditions and are also more stable and consistent in performance but slightly less yielding than single and three way crosses (Jones 1958).

Jones (1958) stated that the present trend in commercial seed corn industry by replacing double crosses with single cross is a step in the wrong direction because it may lose some of the advantage of genetic homeostasis and it invites disastrous epidemics of new strains of disease to which all plants of a single cross being genetically identical might be susceptible. This situation for a particular maturity zone, existed when the *Helminthosporium maydis* outbreak occurred in the United States in 1970.

Allard and Bradshaw (1964) observed that single crosses may not perform as stable as double and three way crosses because single crosses being uniform they lack population buffering and possess only individual buffering, whereas three way and double crosses have both population as well as individual buffering.

Future strategy and conclusion

In the recent years, climate change resulted in the sudden outbreak of pests and diseases in various

crops and maize crop was no exception. The low yielding maize inbreds susceptible to pests and diseases resulted in hike of seed production costs and further the cost of single cross hybrid. This is overcome by development of three-way and double crosses as the female parent is high yielding single cross with tolerant to pests and diseases and it will certainly benefit seed growers and commercial farmers.

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