Effect of pollen source on seed size of hybrid maize

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Abstract

The yield of maize *(Zea mays* L.) is largely determined by the size, weight and number of kernels produced on each ear. Experiments were conducted in 1993 and 1995 to determine the direct effect (referred to as xenia) of pollen source on kernel size of hybrid maize and correlated responses as consequence of selection for seed size of the male plants. Four versions of Krug yellow dent maize selected for large or small seed size (KC0, KSCI4, KSC30 and KLC30) and Mo17 were used as pollen sources for two hybrids ((N209 × FR1075) and (N209 × 117). Pollen from smaller seeded plants were significantly ($P < 0.05$) smaller (81.728 μm) than pollen from large seeded plants (91.542 μm). Pollen from large seeded population increased seed size up to 1.97 g per 100 kernels whilst pollen from small seeded population decreased kernel size up to 9.88 g per 100 kernels compared to 30.95 g per 100 kernels for the open pollinated hybrid. Seed set was not affected by the pollen source.

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Introduction

Grain size and number of kernels per cob are important traits that determine the yield of maize. Leng (1949) observed that when certain inbred parents were used as pollen parents in hybrids, the weight of the hybrid kernels differed significantly. Similarly, Odhiambo & Compton (1987) reported that the effect of male gametes on seed size was dependent on the source of pollen. Seka, Cross & McClean (1995) reported that kernels from plants pollinated with pollen from large seeded plants accumulated 27 per cent faster dry matter and 36 per cent higher dry matter compared to those pollinated with pollen from small seeded plants. For the same materials, the authors noticed that plants pollinated with pollen from large seeded plants yielded 5.7 per cent more on average across environments than plants pollinated with pollen from small seeded plants. They concluded that exogenous genes from the pollen source influenced development rates of the kernels, hence the yield increase.

The direct effect of pollen on a kernel is termed xenia. Kieselbach (1960) described xenia as an immediate effect of a foreign pollen parent on non-maternal tissue of the kernel. He pointed out that the effect of xenia is due to (1) a change in hybrid vigour of the non-maternal tissues, which may be related to the action of either chromosomal dosage or specific genes, (2) a change from recessive to dominant endosperm type with its accompanying physiological effects, and (3) quantitative (size) inheritance.

Xenia effects have been observed in several crops such as variation in fruit size in *Chamaecrista fasciculate* (Fenster, 1991), production of flowers, ovules fertilization and seed maturation (Waser & Price, 1991), significant differences among maternal (number of seeds that matured, mean seed weight, germinability of seeds and sizes of seeds) *Lobelia* plants (Schilichting & Devlin, 1992), and method of pollination and source of pollen for pollinating male sterile cotton.

Several studies have suggested dominant or partially dominant genes controlling specific phases or processes of kernel development to influence the final weight of the kernel (Kieselbach, 1960; Fenster, 1991; Seka, Cross & McClean, 1995). Selecting maize lines with larger kernels may lead to higher production assuming that the number of kernels per cob will not be affected. For certain crop plants such as sorghum, small seeds confer resistance to insects because they are hard and vitreous.

The objectives of this study were to

investigate the immediate effect of pollen source on kernel size of maize, the effect of pollen size due to selection for kernel size, and the effect of pollen source on kernel formation, grain yield and its correlated traits as a result of selection for kernel size.

Materials and methods

The experiment was conducted in 1993 and 1995. The genetic materials used for the study included four populations of Krug yellow dent, Mo17, N209 × FR1075 and N209 × FR1075. The maize cultivar, Krug yellow dent, was initially developed by selection in three-way cross between a Nebraska-grown cultivar, (Reid yellow dent) with cultivar, Goldmine and an Illinois strain of Reid yellow dent. The four populations of Krug yellow dent were derived from the Krug yellow dent corn divergently mass selected for seed size for many generations at Nebraska. These and Mo 17 were used as male parents (i.e. pollen source). In all, there were five pollen sources including open pollination as a source of pollen. The female plants were selected from a hybrid (N209 × FR1075) derived using N209 as female parent and FR1075 as male parent. The list of materials used in both years is presented in Table 1.

A randomized complete block design with eight replications was used in 1993. The male plants were planted three times to ensure pollen availability throughout the pollination period. To reduce border effect the hybrid maize (female plants) were planted in one large block which was subsequently divided into replications whilst the male plants were planted around them. Each plot comprised four rows of 5 m in length. Plant spacing was 0.8 m by 0.5 m.

Following the preliminary analysis of data of the first year, Krug small seed C30 (KSS), Krug large seed C30 (KLS) and cycle zero (KC0) of the Krug population were used as sources of pollen during the second year. Female plants were selected from a N209 × FR1075, and a second hybrid (N209 × 117). In 1995, several rows of the two hybrids were grown in the nursery along with rows of pollinator Krug population plants. The plots were gridded but not into replications. However, repetitions of each pollination type were used as replications.

The pollination procedure was as follows:

1. Shoots of plants of equal competition selected within the inner two rows of each plot were covered before they produced silk.
2. Tassels of male parents were covered with pollination bags to collect pollen.
3. Collected pollen was transported to the desired female plants when they developed silk.
4. Each cob was pollinated twice. After the second pollination, the pollination bag

TABLE 1:

List of Pollen Sources (male parents) and Hybrids used in 1993 and 1995

Year of development	*Line/Hybrid*		*100 kernel weight (g)*
	1993	*1995*	
-	Krug cycle zero (KC0)	Krug cycle zero (KC0)	28.40
1970	Krug small seed C 14	-	16.5
-	Mo17	-	-
1988	Krug small seed C30	Krug small seed C30	6.5
1988	Krug large seed C30	Krug large seed C30	40.0
1992	N209 × FR1075	N209 × FR1075	24.3
1992	-	N209 × 117	-

was removed and pinned around the stem for easy identification as well as creating the same conditions as the open pollinated cobs.

5. At least five plants were pollinated in each plot.
6. Randomly selected open-pollinated cobs from each replication and the cobs of the crosses of each plot were harvested and treated as samples.
7. The weight of 100 kernels, taken from the mid-section of each cob was determined.
8. Observations were also taken for kernel formation.

In 1995, most of the steps were similar to those used in 1993 except that pollination was done on single plant basis and several plants were pollinated by each pollen source. Each plant was pollinated once and the bag left on the ear until harvesting. In addition to the crosses each plant that contributed pollen was self pollinated and appropriately identified.

All plants were hand harvested, shelled separately and the moisture was measured. The kernels from each cob were weighed and counted. In addition, the weight of 100 kernels per cob was recorded.

Anthers were collected from the mid points of the tassels of five randomly selected plants within each pollen source in 1995. The mature undehised anthers were fixed in 20% ethanol. Two to three anthers were then squashed and stained with potassium iodide. Using low power microscope and Image Scion 1.51 software, the diameters of at least 40 pollen grains per slide for each tassel were measured.

Results and discussion

Seedlings from small seeded plants were smaller, less vigorous and had thinner stems compared to those from large seeds. Three to four out of 20 seedlings from cycle zero were albinos so did not survive to maturity. This was also observed by Odhiambo & Compton (1987) when a similar study was conducted. The mean weight of 100 kernels of the hybrid produced by crossing to different pollen sources in 1993 are presented in Table 2. In 1993, the open pollinated hybrid seed had a mean of 30.95 g per 100 kernels, the seed produced from the cross between the hybrid and Krug small seed size cycle 30 had a mean of 21. 07 g per 100 kernels, while the seed produced by crossing to Krug large seed size cycle 30 had a mean of 32.92 g per 100 kernels. The comparisons showed a decrease of 31.92 per cent in kernel size and an increase of 6.34 per cent in kernel size, respectively. The results for 1995 are presented in Table 3. The trend was similar to those obtained in 1993, except that whereas there was an increase

TABLE 2

Mean Hundred Kernel Weight of Open Pollinated Pollen Source and Cross Pollinated N209 × FR1075 in 1993

Male parent (pollen source)	*100 kernel weight (g)*	
	Open pollinated	*Cross pollinated*
Krug small seed C 14	23.30	25.30d
Mo17	32.86	29.35c
Krug small seed C30	12.94	21.07e
Krug large seed C30	30.64	32.92a
N209 × FR1075	-	30.95b
$LSD_{0.05}$		1.54
CV%		9.63

TABLE 3

Mean 100 Kernel Weight (kwt) Cob Weight (g) and Kernels per Cob of Hybrids Pollinated by the Various Pollen Sources in 1995

Pollen source	*N209 × FRI075*			*N209 × 117*	
	Cob weight	*100 kwt*	*Kernels/cob*	*Cob weight*	*100 kwt*
Krug small seed C30	151.44 c	25.17 c	606	150.79 b	25.64b
Krug C0	198.17 ab	34.59 a	581	180.68 ab	36.98a
Krug large seed C30	218.00 a	36.64 a	612	227.89 a	37.21a
Open pollination	181.39b	29.92 b	607	225.14 a	36.45a
$LSD_{0.05}$	54.44	4.45	ns	54.44	4.45

in seed size (22.42%) there was less reduction in seed size (15.88%). This observation supported that of Odhiambo & Compton (1987) who reported that the effect of male gametes on seed size was dependent on the source of pollen.

The effect of seed size as a result of the male gametes could be due to the quality (Fenster, 1991) and quantity (Waser & Price, 1992) of the pollen. The double fertilization of the embryo sac may also result in gene dosage effects on seed size. Such effects can be large when different embryo types are involved. Since the same type of embryos were used in this study, the effect due to xenia might be the cause of differences in the seed size. Xenia is the result of specific genes transferred through the pollen that influenced the number and/or size of embryo cells and the rate and duration of grain fill, all of which could influence seed size (Seka, Cross & McClean, 1995). Genes occur as multigene family clusters on different chromosomes and are coordinately and specifically transcribed only in endosperm cells. Bianchi & Viotti (1988) investigated the methylation state of a set of storage protein genes of maize coding for zeins and glutelins in different somatic tissues and developing endosperms. They found that the genes occurred as multigene family clusters on different chromosomes and are co-ordinately and specifically transcribed only on endosperm cells. Selecting genotypes for reduced seed size may lead to fewer of these gene clusters. The embryo from the union of such gametes may be small. The result will be the production of comparatively small kernels.

Visual observations of the kernels on each cob showed differences depending on the source of pollen. Open pollinated cobs had both small and large kernels. It was possible to separate kernels that resulted in the fertilization of the various pollens. The grain produced per cob, 100 kernel weight and number of kernels per cob are presented in Tables 2 and 3. Even though there were significant ($P < 0.05$) differences among the pollen sources for grain produced per cob and 100 kernel weight, there were no significant ($P < 0.05$) differences among the pollen sources for the number of kernels per cob. It is obvious that the number of kernels per cob were already set before pollination. Therefore, the yield differences were due to the immediate kernel size that was conferred on the embryo by the type of pollen that fertilized the hybrid.

The pollen diameter measured in micrometers showed significant ($P < 0.05$) differences between

TABLE 4

Pollen Diameter of Krug Population

Population	*Pollen diameter*
Krug small seed C30 (KSS)	81. 728 μm a
Krug cycle zero (KC0)	87.212 μm ab
Krug large seed C30 (KLS)	91.542 μm b
$LSD_{0.05}$	5.965
CV%	5.000

the small seeded pollen source and the large seeded pollen source (Table 4). There was no significant ($P < 0.05$) difference in pollen size between the smaller seeded source and Krug cycle zero nor the large seeded source and Krug cycle zero (Table 4). No reason for the divergence in pollen size due to selection of the male parents is available from this study. However, since kernel size is quantitatively inherited (Bianchi & Viotti, 1988; Seka, Cross & McClean, 1995), it is possible that selection for smaller kernels resulted in some deletions of chromosomal segments, whereas selection for larger kernels resulted in the accumulation or duplication of the same factors responsible for the expression of the trait.

Conclusion

The immediate effect of pollen source on seed size and weight is dependent on the source of pollen. Pollen from large seeded plants increased the seed size up to 6.34 per cent, and pollen from smaller seeded source decreased seed size by up to 31.92 per cent as compared to the open pollinated hybrid. Seed size decreases were more significant than seed size increases. The differences in the seed size might be due to xenia. The pollen from Krug small seed cycle 30 was significantly smaller in diameter than those for Krug large seed cycle 30. However, the source of the pollen did not affect the seed set. In commercial seed production, male fertile genotypes are used to ensure the availability of pollen to every plant, thus maximizing seed set. Therefore, careful selection of genotypes that will ensure both seed set and size of kernel should be the ultimate goal of every seed industry.

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