

among the progeny in varying numbers, sometimes as high as in self pollinations of variegated individuals.

In crosses of colorless or variegated females with red (Bz) males, the colorless and mosaic phenotypes appear but at much lower frequencies than in self pollinations or outcrosses to bronze. One example (4316-1 x 3991s) is included in Table 1. In some cases, no colorless kernels and only a few variegated ones are observed.

In reciprocal crosses using the colorless or variegated individuals as pollen donors, the appearance of colorless or variegated progeny does in fact occur but is dependent upon the stock used as the ear parent. Of three different bronze families used as females in these crosses, one exhibited the colorless character but the other two produced only full color progeny. The one red stock employed as a female parent yielded only the full color phenotype in the offspring.

When transmission of the character through the pollen is observed, it occurs in unpredictable ratios as in the reciprocal crosses. These inheritance patterns indicate that a cytoplasmic factor is apparently not responsible for the colorless trait.

When the mutant phenotype first appeared, it was thought that bz-x3m was somehow involved because of the color/colorless mosaics. Such kernels indicate an instability of some sort. This relationship, however, does not exist since ears have been recovered which segregate for the colorless and variegated phenotypes but which cannot contain bz-x3m or an element derived from it. The same results indicate that transmission of the colorless phenotype does not necessarily involve sexual reproduction. These observations are described below. Among the offspring of plants which were not related to the colorless individuals but which were in the same field, colorless and variegated kernels appeared. These progeny were from self or sib pollinations of several C sh bz wx lines and from crosses of these lines to other full color stocks. The colorless and variegated frequencies were generally not as high as in progeny of mutant individuals and varied substantially from one ear to another. There appeared to be no relationship between the location of a plant in the field with respect to the colorless types and the frequency of colorless or variegated kernels on the ear. In many cases, fertilization by mutant pollen could be thoroughly ruled out since some of these lines flowered after the colorless stocks and their relatives had completely shed their pollen.

It was also noted that colorless kernels were appearing in a number of open pollinated plants which were homozygous for full color genes. Since there were no stocks in the field carrying C-I, it was concluded that the same factor responsible for the colorless trait in the controlled pollinations was producing white kernels in the open pollinated individuals.

The transmission patterns of the colorless trait suggest that a virus may be responsible. If this proves to be the case, there are two mechanisms which could explain the colorless phenotype. Either the virus has the ability to somehow block the metabolic pathway leading to anthocyanin production in the aleurone; or it carries genetic information for pigment inhibition which is becoming incorporated into the maize genome.

Identification of a virus as the agent and distinction between the two possibilities await further data.

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A preliminary study on chiasmata frequency in two races and two single hybrids of maize

Variability in a maize population is known to be due to many factors, one of the most important of which is the recombination which is basically determined by

chiasmata. There are many studies on chiasmata frequencies in maize, but they are limited to the effects of systems of breeding and the effect of environment (V. Grant, Cold Spring Harbor Symp. Quant. Biol. 23:337, 1958; W. F. Bodmer and P. A. Parsons, Adv. Genet. 11:40, 1962; S. K. Sinha and A. P. Rao, Cytologia 32:343, 1967).

Seeds of two races and two single crosses of maize were planted in December, 1974, at the Instituto de Genética, ESA "LQ". They were Entrelaçado, an indigenous race; Canario de Ocho, an ancient commercial race; IAC-HS-7.777, a single cross from the Tuxpeño race; and IAC-HS-1.227, a single cross from the Cateto race. Anthers from these plants were collected in February, 1975, fixed in acetic alcohol 1:3 and smeared in propionic-carmin; permanent slides were made, and chiasmata were counted in the permanent preparations. Five plants of Entrelaçado, six plants of Canario de Ocho, seven plants of IAC-HS-1.227 and five plants of IAC-HS-7.777 were studied. Fifty cells at diakinesis and twenty cells at metaphase from each plant were examined. Analysis of variance was made according to G. S. Snedecor and W. G. Cochran (Statistical Methods, 6th ed., Ames: Iowa St. Coll. Press, 1967), with the data transformed in square roots.

Races of maize in the area of the Brazilian Germplasm Bank have been studied by F. G. Brieger et al. (Nat. Acad. Sci. Nat. Res. Council Pub. 593, 1958) and classified by Paterniani (Races of Maize in Brazil, unpublished paper, 1975) into four categories: indigenous, ancient commercial, recent commercial and exotic races. He defined indigenous races as corn which has been cultivated only by Indians; presumably, these races have been maintained in approximately the same state as in pre-Columbian times and have not been greatly disturbed by the influence of people who arrived after 1492. To this category belongs one of the races studied, Entrelaçado. Paterniani's second category, ancient commercial, was defined by Paterniani as races of corn that existed in pre-Columbian times but were adopted from the Indians by the early European immigrant farmers; these races are indigenous in their region but presumably have been changed somewhat by their recent large scale cultivation and probably do not represent precisely the population present in pre-Columbian times. To this category belongs the race Canario de Ocho and the single cross IAC-HS-1.227, which was developed at the Instituto Agronômico de Campinas from Cateto germ plasm. Races of maize in Mexico have been classified by E. J. Wellhausen et al. (Razas de maiz en Mexico. Folleto Técnico nº 5, Secretaria de Agricultura y Ganaderia. Mexico, 1951) in five categories: ancient indigenous, pre-Columbian exotic "Mestice", pre-historic, incipient modern and not well defined races. It has been suggested that the ancient indigenous races originated in Mexico from primitive popcorn and that they developed independently in different places and different environments. The representatives of these races did not hybridize since they came from a common ancestor. Pre-Columbian exotic races were introduced in Mexico from Central and South America in pre-historic times. The pre-historic "Mestizas" race originated from hybridization between ancient indigenous races and pre-Columbian exotic races. The Tuxpeño race belongs to this category, and IAC-HS-7.77 is a single cross from Tuxpeño which was developed at the Instituto Agronômico de Campinas.

The mean of the frequency of chiasmata, standard deviation, mean standard error and coefficient of variability in these different germplasms at diakinesis (50 cells) and metaphase (20 cells) are presented in Table 1; the analysis of variance is shown in Table 2. It can be seen that the differences between the germ plasms and also among the plants within races are significant. These results are in accord with other reports, which show also that the frequency of chiasmata in maize is highly affected by environment as well as by gene factors (Grant, 1958; Sinha and Rao, 1967). The general mean of the frequency of chiasmata in different germplasms at diakinesis and metaphase can be seen in Table 3. A Tukey test was performed at the 5% level; its significance can be noted in Table 4. Entrelaçado differs from IAC-HC-1.227 at both diakinesis and metaphase. What is worthy of mention here is that the two races showed lower frequencies than the single

Table 1. Number of cells counted at diakinesis and metaphase (N), mean ( $\bar{x}$ ), standard error (s), mean standard error ( $s_{\bar{x}}$ ) and coefficient of variability (CV).

Plant		N	$\bar{x}$	s	$s_{\bar{x}}$	CV
IAC-HC-7.777						
1	Diak	50	16.53	0.97	0.14	5.88
	Meta	20	13.82	0.82	0.17	6.02
2	Diak	50	17.20	0.87	0.12	5.07
	Meta	20	13.15	0.37	0.08	2.84
3	Diak	50	17.22	0.69	0.09	4.03
	Meta	20	13.85	0.36	0.08	2.64
4	Diak	50	17.28	0.44	0.06	2.58
	Meta	20	13.65	0.49	0.11	3.58
5	Diak	50	17.14	0.89	0.12	5.14
	Meta	20	13.50	0.51	0.11	3.79
IAC-HS-1.227						
1	Diak	50	18.24	0.79	0.11	4.36
	Meta	20	15.15	0.36	0.08	2.58
2	Diak	50	18.44	0.86	0.12	4.69
	Meta	20	14.35	0.48	0.10	3.40
3	Diak	50	18.92	0.72	0.10	3.82
	Meta	20	14.15	0.36	0.08	2.58
4	Diak	50	19.08	0.90	0.13	4.72
	Meta	20	14.15	0.37	0.08	2.59
5	Diak	50	19.50	0.73	0.10	3.77
	Meta	20	12.40	0.50	0.11	4.05
6	Diak	50	17.32	0.76	0.11	4.49
	Meta	20	14.10	0.30	0.04	2.18
7	Diak	50	18.60	0.63	0.09	3.41
	Meta	20	14.15	0.36	0.08	2.58
ENTRELACADO						
1	Diak	50	13.12	1.10	0.15	8.38
	Meta	20	10.83	0.62	0.14	5.88
2	Diak	50	15.54	0.50	0.07	5.32
	Meta	20	11.89	0.56	0.11	4.76
3	Diak	50	17.42	0.92	0.13	5.32
	Meta	20	12.70	0.47	0.11	3.70
4	Diak	50	17.74	0.66	0.09	3.74
	Meta	20	11.90	0.31	0.07	2.58
5	Diak	50	19.22	0.81	0.11	4.20
	Meta	20	11.95	0.05	0.25	1.87

Table 1.—continued.

Plant		N	$\bar{x}$	s	$s_{\bar{x}}$	CV
CANARIO DE OCHO						
1	Diak	50	14.25	0.59	0.08	4.17
	Meta	20	13.76	0.43	0.10	3.17
2	Diak	50	15.89	0.77	0.11	4.89
	Meta	20	13.20	0.41	0.09	3.10
3	Diak	50	16.32	0.62	0.09	3.82
	Meta	20	13.15	0.37	0.08	2.84
4	Diak	50	16.45	0.50	0.07	3.03
	Meta	20	13.10	0.30	0.04	2.34
5	Diak	50	16.77	0.42	0.06	2.51
	Meta	20	13.80	0.41	0.09	2.91
6	Diak	50	17.88	1.08	0.15	6.05
	Meta	20	12.05	0.22	0.05	1.85

Table 2. Analysis of variance.

Sources of variation	d.f.	S.S.	M.S.
Diakinesis			
Among races	3	20.95	6.99**
Among plants/races	19	25.17	1.32**
Among cells/plants/races	1.127	155.27	0.14
Total	1.149	20.39	
Metaphase			
Among races	3	5.39	1.79**
Among plants/races	19	2.68	0.14**
Among cells/plants/races	437	1.74	0.004
Total	459	9.81	

Table 3. General mean in both phases.

	Number of plants	Diakinesis	Metaphase
(1) IAC-HS-7.777	5	17.13	13.59
(2) IAC-HS-1.277	7	18.56	13.92
(3) Entrelaçado	5	16.61	11.85
(4) Canario de Ocho	6	16.27	13.18

Table 4. A Tukey test among the four germplasms.

	Diakinesis			Metaphase		
	2	3	4	2	3	4
1	NS	NS	NS	NS	NS	NS
2		*	*		*	NS
3			NS			NS

crosses — the mean was 16.61 in Entrelaçado and 16.27 in Canario de Ocho, whereas the means of the two single crosses were 17.13 and 18.56. This fact may be interpreted to mean that evolution has brought together in these primitive races gene combinations that have a particularly high adaptive value in a given situation (G. L. Stebbins, *Chromosomal Evolution in Higher Plants*, Reading, Massachusetts: Addison Wesley, 1971). Paterniani reported that Entrelaçado has some primitive characteristics which date back to the very early days of domestication, and he considers this race a stable one. Indeed, he states that plantings made in Piracicaba from this race with seeds collected from the Indians have always resulted in plants showing definite signs of lack of adaptation.

In Entrelaçado there is seen also a phenomenon that may support the above mentioned proposal: it is the only race which exhibits a notable difference between the maximum and minimum chiasmata frequencies at diakinesis (19.22/cell in one plant and 13.12/cell in another). Such a wide difference is not seen in other races, and it may be that a buffering system has evolved which maintains adaptability to the environment through the mechanism of chiasmata formation; such a system could persist for a long time, given the genetic isolation of this race. That is, that race has a kind of polymorphism enabling the population to always have individuals with a low or a high frequency of chiasmata formation.

Table 5. Terminalization index.\*

Race	Number of cells observed	Index
IAC-HS-7.777	250	1.35
IAC-HS-1.227	250	1.38
Canario de Ocho	250	1.31
Entrelaçado	250	0.98

\*According to Darlington, C. D., *Recent Advances in Cytology*, 2nd ed., Philadelphia: Blakiston, 1937.

Table 5 shows the terminalization index of the germplasms, calculated on data from the first five plants from each source listed in Table 1. The notably low level (0.98) of terminalization in the Entrelaçado race contrasts with a figure of 1.3 in other races and reveals a high level of homozygosity, a fact that may be explained by the isolation of this race. It is believed that this race exists today with a genetic constitution similar to that which it displayed in pre-Columbian times.

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