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The Chromosome Number of Maize

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HISTORICAL

The wide-spread interest in the genetics of maize, coupled with the uncertainty as to the number of chromosomes occurring in this species prompted the investigation which is here reported.

From a review of the literature it appears that KUWADA (1911, 1915, 1919) is the only worker who has reported extensive counts of maize chromosomes. His results are summarized in table 1. Variations were reported in the number of chromosomes both within and between varieties as well as between different cells of individual plants. He concluded that sweet varieties are usually characterized by having twelve chromosomes, and starchy varieties by having ten, as the haploid number. Several exceptions were recorded, as shown in the table.

With one exception his sweet × starchy hybrids were considered as having a haploid number of ten chromosomes. The pollen mother cells of a single plant of Black Mexican had one univalent and eleven bivalent chromosomes, while cells of the root-tip had twenty-three chromosomes. He considered that this had been caused by non-disjunction. According to KUWADA'S counts the haploid number varied as much as six chromosomes within some varieties.

Since completing the investigation which follows, a brief paper has appeared by LONGLEY (1924) concerning chromosome numbers in maize and related species. Four varieties including Chinese and Tepic maize are reported as each having a haploid number of 10 chromosomes.

[1] Contribution from the Department of Agronomy, NEBRASKA AGRICULTURAL EXPERIMENT STATION as paper No. 6, Journal Series. Published with the approval of the Director.

TABLE 1

Tabulation of KUWADA'S *results showing the frequency of different haploid and diploid chromosome numbers in varieties and hybrids of maize (Zea Mays) and other plants.*[2]

VARIETY OR TYPE	CHROMOSOME NUMBERS PER CELL: Haploid (in pollen mother cells)								Diploid (in cells of root-tips)							Number accepted by KUWADA	
	7	8	9	10	11	12	13	14	19	20	21	22	23	24	25	Haploid	Diploid
A. Maize								Frequency									
Black Starch	1	1	2	46	...	...	...	...	...	25	...	...	...	...	...	10	20
Amber Rice Pop	...	...	...	*	1	...	...	...	...	24	...	...	...	...	...	10	20
Sugar Corn	...	...	2	4	11	69	8	6	...	24	4	13	...	2	...	12	...
Black Mexican	...	...	...	...	...	*	...	...	...	11	19	34	21	27	5	12	...
Black Mexican (1 plant)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11†	23
Red Sugar Corn	...	...	...	...	*	*	...	...	...	...	...	...	...	...	...	10	...
Early Eight Sugar Corn	...	...	*	...	...	*	...	...	...	...	...	...	...	...	...	12	...
Proterogynous Corn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...
Chinese Corn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...
Pod Corn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20
Hybrids	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sugar×Black Starch	...	...	3	44	7	...	...	...	...	18	86	1	...	...	...	10	...
Amber Rice Pop × Sugar	...	...	1	6	8	65	...	...	...	...	...	...	...	...	...	12	...
Amber Rice Pop × Black Mexican	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	10	...
Black Mexican × Black Starch	...	...	...	...	...	...	...	...	...	...	...	39	...	...	...		
Sugar × Black Mexican	...	...	...	...	...	...	...	...	3	107	43	76	3	...	...	...	...
Maize × Teosinte	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...
B. Other species belonging to the tribe Maydeae																	
Teosinte (annual)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20
Coix	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20
C. Species of the tribe Andropogoneae																	
Sorghum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	...
Ischaemum anthephoroides	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	68
Saccharum officinarum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	68
Saccharum spontaneum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	68

* Frequency not stated.

† This plant was reported as having 11 bivalent chromosomes and a univalent chromosome.

[2] This table is summarized by the authors from KUWADA'S tables and text.

EXPLANATION OF PLATE 1

FIGURES 1 to 6 are photomicrographs of the pollen mother cells of maize, showing chromosomes (diakinesis stage).

FIGURE 1.—Dent maize (Pride of Saline). ×400

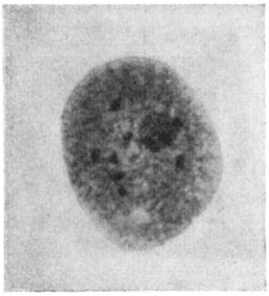
FIGURES 2 and 3.—Dent maize (Hogue Yellow Dent). ×400

FIGURE 4.—Sweet maize (Country Gentleman). ×500

FIGURE 5.—Waxy maize (Chinese). ×400

FIGURE 6.—Teosinte (annual). ×500

FIGURE 7.—Pollen mother cells of teosinte, showing abundance of material often secured in a single mount. ×200



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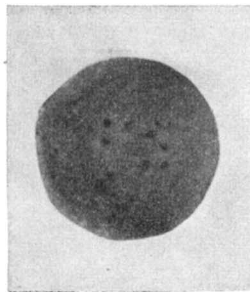

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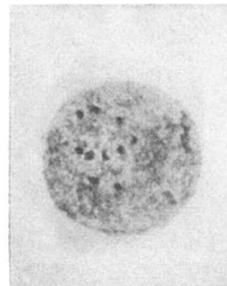

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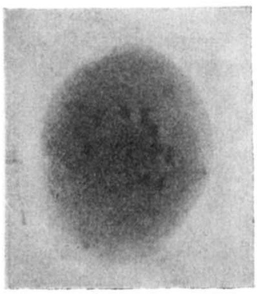

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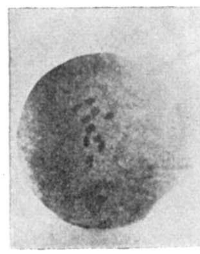

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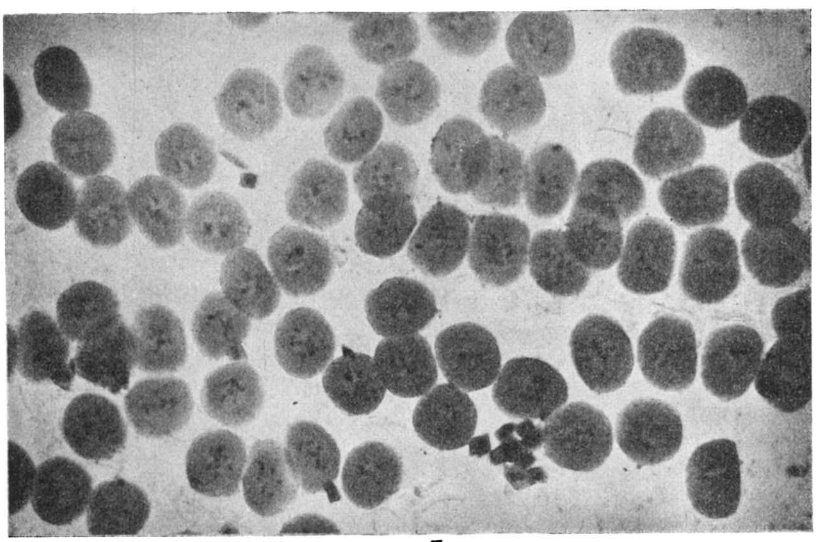

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EXPERIMENTAL METHODS

Under these circumstances it was thought desirable to count the chromosomes in a rather large number of different types of maize. The aim was to have extreme types represented, differing in plant size, earliness, leafiness, endosperm type, heterozygosity, etc. The varieties used were all grown under normal field conditions at the NEBRASKA EXPERIMENT STATION during the season of 1924. The chromosome counts were all made in pollen mother cells stained by BELLING'S (1921) iron-aceto-carmine method. Since the reduction division takes place some time before the tassel is exserted, it was difficult to tell in the field when plants were in the desired condition. Several stalks were taken to the laboratory at a time and kept in water until they could be examined.

The most advanced flowers of the central spike occur a short distance below the tip, and the least developed at its base. For some time a region showing all stages of meiosis may be found between these points. After all the flowers of the central spike are too old, good stages may still be found on the branches of the tassel but are more difficult to locate.

Young anthers not yet showing yellow coloration were placed on a slide in a drop of aceto-carmine solution and cut into two or more pieces. Sufficient iron was dissolved from the razor blades and needles used during the process. A cover glass was applied and tapped until the pollen mother cells were forced out of the anthers. If they appeared to be in the right stage the cover was taken off, the anther fragments removed, the cover replaced and sealed with a mixture of vaseline and paraffin melted with a hot knife. The slides were then left till sufficiently stained when the counts were made. Crushing the pollen mother cells as suggested by BELLING was resorted to only in cases where they showed less than the normal number of chromosomes, to see if such cases were actual variations of number or merely due to inability to see all the chromosomes.

RESULTS

All the forms studied were found to have ten as the haploid number, as is shown in table 2. This does not prove that there may not be forms of maize with different chromosome numbers, but it seems likely that the extreme variability reported by KUWADA was largely due to errors of counting. Various workers, including KUWADA, have called attention to the difficulty of making correct chromosome counts. Among the causes leading to errors, which they have mentioned, are: close contact between chromosomes making them appear as one; obscuring of some chromosomes by others or by the nucleolus; the presence of fragments of the nucleolus or other bodies which may be mistaken for chromosomes; and in sectioned material, parts of chromosomes may be mistaken for whole chromosomes.

TABLE 2

Number of chromosomes found in the pollen mother cells of commercial varieties and pure-line (inbred) strains of maize (Zea Mays). Nebraska Experiment Station, 1924 crop.

VARIETY OR TYPE	DESCRIPTION OF VARIETY					CHROMOSOME	
	Endosperm type	Plant height inches	Leaf area per plant (sq. in.)	Days till tasseling	Days till mature	Number of counts	Chromosome number (haploid)
	A. Varieties and strains of dent maize						
Commercial varieties							
Calico (North Platte)	Dent	98	980	64	97	80	10
Pride of the North	Dent	98	1092	62	103	10	10
Nevada White	Dent	87	1081	67	105	20	10
Substation White	Dent	94	979	64	106	3	10
Reid Yellow Dent	Dent	120	1426	71	112	50	10
Hogue Yellow Dent	Dent	112	1325	79	120	100	10
Ramosa	Dent	108	957	79	114	32	10
Esperanza	Dent	110	1050	80	123	50	10
Pride of Saline	Dent	122	1751	88	124	65	10
Douthit Prolific	Dent	133	2405	79	131	27	10
Mexican June	Dent	133	2493	94	143	50	10
Inbred strains							
Hogue No. 8	Dent	70	631	87	120	4	10
Hogue No. 724	Dent	90	1442	95	138	26	10
Hogue No. 726	Dent	88	631	80	123	12	10
Hogue No. 731	Dent	90	883	82	127	25	10
Hogue No. 742	Dent	75	978	85	138	8	10
Hogue No. 745	Dent	70	1171	88	132	10	10
Nebr. White Prize No. 659	Dent	70	609	77	127	25	10
Nebr. White Prize No. 676	Dent	77	1014	88	127	50	10
B. Endosperm types other than Dent							
Gehu	Flint	48	542	48	84	20	10
White Australian	Flint	83	722	59	99	50	10
King Phillip	Flint	105	1260	69	120	50	10
White Pearl	Pop	88	871	65	99	49	10
Red Flour	Soft	83	702	54	88	10	10
Country Gentleman	Sweet	90	670	56	104	91	10
Chinese maize	Waxy	85	1200	82	132	40	10
C. Plants other than maize							
Teosinte (annual)						25	10
Sorghum						15	10

By the use of BELLING'S method all errors due to cutting are avoided, and the method is so rapid that it is easy to get enough material so that it is not necessary to use any but the best stages.

KUWADA accepted COLLINS'S (1912) theory that maize originated as a cross between teosinte and a member of the Andropogoneae, and thought he could distinguish the larger chromosomes derived from the teosinte from the smaller chromosomes derived from the other parent species. Nothing was found which would tend to confirm this. The chromosomes of teosinte appeared very similar to those of maize, but no measurements were made to see if they were as variable in size as those of maize.

Since such great constancy was found in the number of chromosomes in widely different types of maize, it appears likely that the variability of this species has resulted from factor mutations rather than from irregularity in chromosome behavior during mitosis leading to change of number.

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