A SURVEY OF CHROMOSOME KNOBS IN MAIZE VARIETIES

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CHROMOSOME knobs are enlarged pycnotic regions on the chromosomes. They stain deeply with acetocarmine and are best studied in the pollen mother cell in the pachytene stage.

McClintock (1930) was the first to report knobs on midprophase chromosomes of maize.

Longley (1938) has demonstrated the presence of these knobs in maize and its related genera, perennial teosinte, annual teosinte and Tripsacum sp.

Chromosome knobs are now considered as structural characters which aid in the identification of many of the ten chromosomes of maize.

MATERIALS AND METHODS

About 150 open pollinated maize varieties were imported from all over the world. Seeds of perennial teosinte (*Euchlaena perennis* Hitchc.) were provided by Dr. R. G. Reeves, at College Station, Texas (delivered by Dr. M. F. El-Obrashy).

These varieties with six local maize varieties and a local annual teosinte (*Euchlaena mexicana* Schrad.), were planted on the farm of the Plant Breeding Section of the Ministry of Agriculture at Giza, Egypt, in the Nile, season of 1956.

Microsporocyte samples were collected from each variety, then killed and fixed in Farmer's fluid (glacial acetic acid, one part; 95 percent alcohol, three parts) for 24 hours. Preservation of the samples was made in 70 percent alcohol at a low temperature.

Belling's acetocarmine smear technique for staining the pollen mother cells was used in studying the chromosome knob number in the pachytene stage.

The enlargement was considered to be a knob if its size was within the measure used by Longley (1941) beginning with the smallest, having a diameter of 0.33 μ and ending with the largest, having a diameter of 3.3μ. Enlargements less than the minimum limit were considered to be chromomeres, and those more than the maximum limit were taken as fused knobs.

EXPERIMENTAL RESULTS

Table 1 shows the varieties used in this study, with their sources, kernel type and size, kernel row number and chromosome knob numbers indicated.

Table 2 shows the geographical position of the sources of the varieties with the range of knob number in the varieties of each source.

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TABLE 1

The varieties, their sources, kernel type (D = dent, F = flint), kernel size (L = Large, M = medium, S = small), kernel row number and chromosome knob number

Variety	Source	Kernel Type	Kernel Size	Kernel Row number	Chromosome knob number
White tuxpan	Arkansas U.S.A.	D	L	14–16	7
White synthetic	Arkansas, U.S.A.	D	M	14–16	3
Hickory king	Georgia, U.S.A.	D	M	8–10	6
Boone County white	Georgia, U.S.A.	D	L	14	3
Cassel	Georgia, U.S.A.	D	L	12–14	4
Alapaha corn	Illinois, U.S.A.	½D	M	12–14	1,2
Southians double	Illinois, U.S.A.	D	M	12–14	2,3
Limber cob	Illinois, U.S.A.	D	S	12	1,2
Garrick	Kentucky, U.S.A.	D	M	12–14	3,4
Gramling	Kentucky, U.S.A.	D	M	14	4
Weekleys prolific	Kentucky, U.S.A.	D	M	10	2,3
Tuxpan	Louisiana, U.S.A.	D	L	14	7
L.W. wadel greanweed Miss.	Louisiana, U.S.A.	D	L	14–16	6
Stiff stalk synthetic	Louisiana, U.S.A.	D	M	14–16	5
Johnson County white	Missouri, U.S.A.	D	L	14–16	6
Champion white pearl	Missouri, U.S.A.	D	L		2,3
Freed	Mississippi, U.S.A.	D	M	14–16	4
Blattel white	Mississippi, U.S.A.	D	L	14	3,4
Knighton little cob	Mississippi, U.S.A.	D	L	8–10	3,4
Long eared synthetic	Mississippi, U.S.A.	½D	M	10	3
Douthit prolific	Tennessee, U.S.A.	D	S	14–16	3
Ellis	Tennessee, U.S.A.	D	M	14–16	3,4
Highland	Tennessee, U.S.A.	D	M		6
Huffman	Tennessee, U.S.A.	D	L	12–14	5
Mexican June white	Tennessee, U.S.A.	D	L	12–14	8
Florident white	Tennessee, U.S.A.	D	L	14–16	5
Pinkney	Tennessee, U.S.A.	½D	S	12–14	3
Biggs two ear	Texas, U.S.A.	D	L	12–14	3
Jellicorse	Virginia, U.S.A.	D	M	14	7
Highland horse tooth	Virginia, U.S.A.	D	S	12–14	2,3
Jones	Virginia, U.S.A.	D	M	14–16	3
Sure cropper white	Virginia, U.S.A.	D	L	12–14	6
Early king	Virginia, U.S.A.	D	L	8–10	2,3
Station wosly	Virginia, U.S.A.	D	M	12–14	3
Fred young	Virginia, U.S.A.	D	M	14	4
Gramling	Virginia, U.S.A.	D	M	14	4
Pride of Saline	Virginia, U.S.A.	½D	M	12–14	3
Thompson prolific	Virginia, U.S.A.	D	L	14–16	5
Wise prolific	Virginia, U.S.A.	D	L	14–16	7
American early	Middle Egypt, U.A.R.	D	L	14–16	5
Nab-El-Gamel	Middle Egypt, U.A.R.	D	L	8–10	4
Giza baladi	North Egypt, U.A.R.	F	S	12–14	2,3
Sabieni white	Faiyum Egypt, U.A.R.	F	S	10–12	2
Sabieni yellow	Faiyum Egypt, U.A.R.	F	S	10–12	0
Sawani white	Faiyum Egypt, U.A.R.	F	S	10–12	3
Maize K. T. 14	Baghdad, Iraq	F	S	12	4

TABLE 1—Continued

The varieties, their sources, kernel type (D = dent, F = flint), kernel size (L = Large, M = medium, S = small), kernel row number and chromosome knob number

Variety	Source	Kernel Type	Kernel Size	Kernel Row number	Chromosome knob number
Yellow maize 35	Baghdad, Iraq	F	M	14	3
Yellow maize 27	Baghdad, Iraq	F	S	14	1
V.C. 31	Montpellier, France	F	L	12	1
V.C. 118	Montpellier, France	F	L	12	0
Burgenlandscher silo	Voldgsen, Germany	D	M	12	3
Gelber Silozahn	Voldgsen, Germany	D	M	12	3
Insubria 521	Rosarno, Italy	D	L	12	5
Bianco perla	Rosarno, Italy	F	S	12	5
Nostrano dell'Isola	Bergamo, Italy	F	S	12	2
P586	Boulaouane, Morocco	D	L	12	6
Dr. Dellile's Neue Kreuzgung	Lunteren, Netherlands	F	M	..	1
Lasspessmeyess silosalin	Lunteren, Netherlands	F	M	..	2
Muratha	Lunteren, Netherlands	F	L	10	2
V.C. 95	Elvas, Portugal	F	S	10	0
Hickory king	Pretoria, South Africa	D	L	8	4
Robyn	Pretoria, South Africa	F	S	12	2
Sahara	Pretoria, South Africa	F	M	10	1
American white flint	Pretoria, South Africa	F	S	12	1
Boesman	Pretoria, South Africa	F	S	12	0
Potchef stroos pearl	Pretoria, South Africa	D	L	10	3
Sennar shami E.C.R./580	Khartoum, Sudan	F	M	12	2
Akaba E.C.R./741	Khartoum, Sudan	D	S	12	3
Shand baladi E.C.R./492	Khartoum, Sudan	F	S	14	1
Hickory king E.C.R./492	Khartoum, Sudan	½D	S	8–10	2
Peruvian yellow E.C.R./320	Khartoum, Sudan	F	S	10	2
Silver king E.C.R./654	Khartoum, Sudan	D	M	..	3
Yellow maize	Beirut, Lebanon	F	M	12	1
Yellow boshar	Beirut, Lebanon	F	S	14–16	2
V.C. 10	Pontevedra, Spain	F	S	..	0
V.C. 11	Pontevedra, Spain	F	S	..	1
V.C. 26	Pontevedra, Spain	F	S	..	2
V.C. 50	Pontevedra, Spain	F	S	8	1
V.C. 59	Pontevedra, Spain	F	S	12	0
V.C. 62	Pontevedra, Spain	½D	L	10	1,2
V.C. 71	Pontevedra, Spain	F	M	8	0
V.C. 77	Pontevedra, Spain	F	M	..	2
Yellow dent O.P.	Samsun, Turkey	D	L	..	3
White dent O.P.	Samsun, Turkey	D	L	..	3
Yellow flint O.P.	Tarsus, Turkey	F	M	10	4
Red flint O.P.	Tarsus, Turkey	F	M	16	5

It will be noted, in Tables 1 and 2, that 39 American open pollinated varieties (imported from the southern states) were tested. All of these varieties were of the dent type. The knob number in them ranged from one to eight. The variety "Mexican June white," which is considered one of the oldest southern dents, has

TABLE 2

The geographical position of the sources of the varieties with the range of knob number in the varieties of each source

Sources of varieties	Latitude	Longitude	Altitude (meters above sea level)	Range of knob number
U. S. A.				
Arkansas	33° 33′ N	91° 11′ W	300	3–7
Georgia	33° .. N	84° 33′ W	180	4–6
Illinois	40° . N	89° W	400	1–3
Kentucky	37° 32′ N	85° 20′ W	350	2–4
Louisiana	31° .. N	92° .. W	50	5–7
Mississippi	33° .. N	90° . W	150	3–4
Missouri	38° 30′ N	29° 30′ W	500	2–6
Tennessee	36° .. N	86° .. W	450	3–8
Texas	32° .. N	100° .. W	300	3
Virginia	37° 30′ N	79° .. W	85	2–7
U. A. R.				
Middle Egypt	30° 2′ N	31° 13′ E	21	4–5
North Egypt	30° 7′ N	31° 7′ E	..	2,3
Faiyum, Egypt	29° 25′ N	30° 45′ E	..	0–3
Iraq				
Baghdad	33° 20′ N	44° 27′ E	25	1–4
France				
Montpellier	43° 36′ N	3° 55′ E	..	0,1
Germany				
Voldgsen	52° 6′ N	9° 36′ E	117	3
Italy				
Bergamo	45° 34′ N	9° 48′ E	146	2
Rosarno	38° 29′ N	16° 12′ E	750	5
Morocco				
Boulaouane	32° 49′ N	8° 6′ W	175	6
Netherlands				
Lunteren	52° .. N	5° .. E	12	1,2
Portugal				
Elvas	38° 53′ N	7° 9′ W	208	0
South Africa				
Pretoria	25° 45′ S	28° 4′ E	480	0–4
Spain				
Pontevedra	42° 34′ N	8° 43′ W	564	0–2
Sudan				
Khartoum	15° 35′ N	32° 35′ E	25	1–3
Lebanon				
Beirut	33° 53′ N	35° 30′ E	98	1,2
Turkey				
Samsun	41° 20′ N	36° 25′ E	1	3
Tarsus	36° 53′ N	30° 42′ E	40	4,5

eight knobs. The varieties imported from the other countries have a narrower range of knob number. In the varieties of these countries, except South Africa, the range did not exceed three knobs.

The wide range of knob number in the varieties of the U.S.A., South Africa and the Egyptian Region may be explained on the basis that the weather in these countries is suitable for varieties, imported from different parts of the world, to be adapted.

Table 2 shows, also, that the varieties in the collection tested (which was imported from regions north to 40° latitude North) do not have more than three chromosome knobs.

The data obtained in the present investigation indicated that high knob number was highly associated with the large kernel size. The correlation coefficient between these two characters was $r = .696$.

There was an indication of positive association between high knob number and each of denting and high kernel row number. The correlation coefficient between high knob number and denting was $r = + .335$, and the five percent level of significance is $r = \pm .349$. The correlation coefficient between high knob number and high kernel row number was $r = .041$, and the five percent level is $r = \pm .232$.

DISCUSSION

Knob number was found to be constant for any individual plant, but it varies from strain to strain. Eighteen knob positions, including knobs on 15 out of the 20 arms of maize chromosomes, have been located.

McClintock (1934) found that, at a certain stage, nucleolar material is associated with all chromosomes, but later this material is drawn to a major organizing center or centers. Further study by Longley (1939) has shown that knob-forming points exist even when no knob is formed, but no single point possesses a knob-forming power that overshadows all other points although there is a marked difference in the different points in their ability to form knobs.

Longley (1938) found very few knobs on the chromosomes of most of the strains from the Northern Indian tribes. A slightly higher number was found in the southern varieties, and many knobs were observed in most of the varieties from New Mexico and Arizona. He reported 4.21 as the average knob number for North American maize strains. Longley (1939) found also that less than one percent of the American varieties were without knobs, and in all of these varieties there was an appreciable piece of each chromosome adjacent to the fiber attachment that was knobless, and the short arms of chromosomes 5, 6, 7 and 8 seemed to be too short to reach a point at which knobs occurred frequently.

Mangelsdorf and Cameron (1942) reported 7.9 and Reeves (1944) 9.25 as the average knob number for maize in Guatemala. Mangelsdorf and Reeves (1939) and Reeves (1944) suggested that maize might have developed as a highly domesticated plant in the Andean region and was spread from there to all parts of South, Central and North America. Its chromosomes were knobless, but during its migration northward it became hybridized with Tripsacum (a related genus with knobby chromosomes) in Central America, and from those hybrids new types of knobby chromosomes were derived.

Brown (1949) in discussing this hypothesis pointed out that one would expect the North flints (which externally exhibit more Tripsacum influence than any other group of varieties he studied) to possess many knobs. Actually they have few if any knobs. He concluded that more data are needed before one can safely regard knobs as a reliable indicator of Tripsacum germ plasm in Zea. He found also that the knob numbers in the Old Southern dents ranged from five to 12 and suggested that some of these varieties which have 11 or 12 knobs might have come directly from Mexico without having undergone much change in plant characters. The knob numbers in corn belt inbreds ranged from two to eight, and their over-all distribution was almost exactly intermediate between that of the Southern dents and Northern flints.

MANGELSDORF and REEVES (1959), in their further studies on the origin of corn, have found conflicting evidence to their hypothesis.

The data of the present investigation confirm the suggestion of LONGLEY (1938) that the number of chromosome knobs might give a clue to the geographical origin of the variety. No varieties having more than three knobs were found in the material tested in a region north to 40° longitude North.

This study shows also that when varieties migrated from one region to another, they were affected with the varieties located in the new region. The example for this is the variety Hickory king. BROWN (1949) found that the original type of this variety which might have come directly from Mexico to Georgia had 11 or 12 knobs. The writer found that the type which was imported from Pretoria, South Africa, had four knobs, and that which was imported from Khartoum, Sudan had only two knobs and had changed from dent type to half dent. The range of knob number in the other varieties imported from the same region in South Africa was zero to three and that in the varieties imported from Sudan was one to two knobs.

LONGLEY (1941) studied knob positions on teosinte chromosomes and found that all knobs on Guatemalan teosinte chromosomes are terminal. In Northern Guatemalan teosinte, 18 of the arms have been seen with a terminal knob, while in the teosinte from Southern Guatemala only 13 have been found terminated by a knob. He also found that the mean knob size for the northern group is 1.35 μ. while that of the southern group is 2.05 μ in diameter.

Perennial teosinte plants (*Euchlaena perennis* Hitchc.) which were tested in the present investigation had seven big knobs (more than 3.3 μ in diameter) and six ordinary knobs (between .33 and 3.3 μ). Eight of these 13 knobs were terminal. The local annual teosinte plants (*Euchlaena mexicana* Schrad.) had nine big knobs, six of which were terminal. The big knobs are considered fused ones.

The relationship between chromosome knob numbers and the agronomic characters has been studied by some investigators. MANGELSDORF (1947) suggested that knobs themselves may have no genetic effect, but that associated with them are segments of Tripsacum chromatin homologous or partially homologous to segments in maize. However, evidence of inheritance of such chromosome segments or blocks of genes which behave like single genes has been reported by him.

BROWN (1947) has found that the high knob number is correlated with high kernel row number, row irregularity, denting, absence of husk leaves, and many seminal roots.

VACHNANI (1950) has made a test for the interrelationship between knob number and nearly all the agronomical and morphological characters of some inbred lines. No significant association was found, though some of the ear characters approached the five percent level of significance.

In the present study, high knob number is highly associated with large kernel size. There is also an indication of association between high knob number and denting and also high kernel row number.

SUMMARY

1. Chromosome knob numbers were determined in a collection of maize varieties from different parts of the world. Knob numbers ranged from zero to eight.

2. Varieties from regions north to 40° latitude North in the collection studied do not have more than three knobs.

3. The same variety names from different sources may have different knob numbers and different agronomic characters.

4. High knob number is highly associated with large kernel size and may be associated with denting and high kernel row number.

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