POLLEN MORPHOLOGICAL STUDIES OF SOME PRIMITIVE VARIETIES OF MAIZE (*ZEA MAYS* L.) WITH REMARKS ON THE HISTORY OF MAIZE IN INDIA

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ABSTRACT

The paper describes the pollen statistics of ten primitive varieties of maize from Assam and Mexico. The pollen statistical data are used to recognize subfossil maize pollen from amongst the pollen of Cerealia recovered from the Postglacial deposits of Kashmir Valley.

The evidences of subfossil pollen, the archaeobotanical material and the occurrence of most primitive types of maize in Assam seem to suggest the occurrence of maize in India during the Pre-Columbian times.

INTRODUCTION

POLLEN morphology and statistical evaluation of the dimensions of pollen in several varieties of maize have earlier been carried out by Barghoorn, Wulfe & Clisby (1954) and very lately Nair (1962) investigated the pollen morphology of nineteen varieties of maize cultivated in India and America. The studies by Barghoorn *et al.* were especially taken up with a view to identify the pollen of maize and the other allied genera in the Quaternary sediments of Mexico and they were amply rewarded through the identification of subfossil pollen of maize in sediments as old as 10,000 years, thus lending considerable support to the Mangelsdorf's theory of the origin of maize in the New World (MANGELSDORF & REEVES, 1939, 1959).

The present study of the pollen morphology is based upon the polliniferous material from ten varieties of maize of which there are some extremely primitive varieties recently discovered in Assam by Dr. N. L. Dhawan of Indian Agricultural Research Institute, New Delhi. The primitive varieties are the first factual primitive plants which have been visualized and hypothetically constructed by Mangelsdorf in one of his papers. Dhawan, who has bred these varieties successfully at the I.A.R.I., New Delhi, will deal with them separately. We are indeed grateful to Dr. Dhawan for kindly placing at our disposal the polliniferous material of these varieties for study.

The chief object of the pollen investigation of these varieties has been primarily to discover if the pollen of these varieties, being extremely primitive, is in any way different from those of the advanced varieties and secondarily to acquaint ourselves with the pollen morphology of these varieties, so as to make use of it in recognizing the subfossil pollen of maize in the Indian Quaternary sediments.

The occurrence of extremely primitive maize in Assam is indeed enigmatic as discovered recently by Dhawan although the origin of maize has now been proven beyond doubt in the New World by Barghoorn *et al.* (*l.c.*). The new Assam finds are likely to reopen the long held controversy, now laid to rest, of the origin of maize in the old world (ANDERSEN 1943, 1945, STONOR & ANDERSON, 1949) or in the New World (MANGELSDORF & REEVES, *l.c.*). In that context it is all the more important now to look for any historic and prehistoric more especially pre-Columbian evidences of maize in India. The paper, therefore, discusses some archaeobotanical records and the pollen evidence for the past occurrence of maize in India.

POLLEN STATISTICS OF THE PRIMITIVE VARIETIES OF MAIZE

Of the ten varieties of maize, two are from Assam and the rest from the new world. They differ in their degree of primitiveness, but the varieties from Assam are the most primitive. Pollen preparations have all been made by the method of Acetolysis and the bleached and unbleached pollen of each variety has been mixed in the same slide and their observations have been taken separately. This was particularly done to discover any unusual or extraordinary effect of bleaching on the size and the characters of pollen as compared to the unbleached ones. The dimensions in both the bleached and unbleached pollen are based upon one hundred pollen each. Besides the diameter

TABLE 1 — AXIS LENGTH, PORE DIAMETER, PORE-AXIS AND PORE-ANNULUS RATIOS IN PRIMITIVE VARIETIES OF MAIZE

Name of the Varieties		No. of Grains Measured	Pore/Axis Ratio 3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0	8·2	8·4	Pore/Annulus Ratio 0·20	0·22	0·24	0·26	0·28	0·30	0·32	0·34	0·36	0·38	0·40	0·42	0·44	0·46	0·48	0·50	Averages: Length of the Pollen Grains (μ)	Diam. of the Pore (μ)	Pore/Axis Ratio	Pore/Annulus Ratio	Difference between BL & UNBL Pollen (μ)	Remarks
Pira NPS$_4$K 3164	BL	100									1		5	6	10	17	10	19	9	4	6	2	5	2	2			1		1				1	1	14	14	10	26	4	13	12		1	2	2	124·8	21·6	1: 6·1 (5·7)	1: 0·36	18·4	one grain bears bulgings on the surface
	UNBL	100								2	3	1	4	3	10	10	13	14	8	9	4	7	4	4	1	2		1							15	6	20	17	13	9	9	8	1			2	106·8	17·8	1: 6·0 (6·0)	1: 0·35		one grain diporate
Imbricado 3165	BL	100			1		1	3	3	4	13	6	20	19	8	5	3	8	1	3	1				1						3	10	14	24	9	12	16	7	4		1						117·0	23·2	1: 5·1 (5·0)	1: 0·28	16·5	11 grains have bulging on the surface
	UNBL	100				1		6	8	14	10	8	14	12	7	4	1	8	2	2	1	1	1								2	2	21	16	27	13	6	6	5		2						100·5	18·9	1: 5·0 (5·3)	1: 0·28		24 grains have bulgings
Palomero Toluqueno	BL	100	1				3	3	12	10	17	13	18	12	4	2	2	2				1									1	1	4	10	3	31	31	7	8	3	1						123·0	25·3	1: 4·8 (4·8)	1: 0·31	29·7	
3167	UNBL	100				4	2	10	9	15	12	11	17	5	5	3	2	3		2											4	2	11	7	23	14	13	9	6	2	3	5		1			93·3	20·5	1: 5·3 (4·5)	1: 0·30		3 grains have bulgings 2 grains diporate
Chapalote 3168	BL	100						3	3	6	7	13	22	11	12	10	7	2	1		3										1	2	9	8	11	23	22	11	12	1							122·8	23·2	1: 5·1 (5·1)	1: 0·30	34·4	one grain bears faintly granulated pattern
	UNBL	100					2	5	5	4	12	14	13	10	14	3	2	7	6	1			1	1							3	4	13	5	24	14	17	6	6	2	6						88·4	17·8	1: 5·1 (4·9)	1: 0·30		2 grains faintly granulated and one grain diporate
Sikkim Primitive I SP$_1$	BL	100						1	1	3	12	9	17	16	8	10	8	6	4	2	2		1									8	14	13	7	24	17	5	7	1	3	1					124·8	23·0	1: 5·2 (5·3)	1: 0·29	33·3	
	UNBL	100						4	9	16	7	12	12	8	10	6	8	7		1											5	3	10	3	35	7	21	9	1	1	2			1		2	91·5	17·8	1: 5·0 (5·1)	1: 0·30		one grain diporate
Palomero Toluqueno	BL	100						1	5	9	16	14	24	9	5	11		4	1	1												8	12	8	8	24	18	11	8	1		1	1				114·0	23·0	1: 5·0 (4·9)	1: 0·29	28·9	23 grains having bulgings one grain diporate
3167	UNBL	100				1		2	4	9	6	7	24	8	14	11	3	8	1	1	1											4	2	4	14	14	37	4	9	1	10			1			85·1	16·5	1: 5·1 (5·1)	1: 0·32		31 grains having bulgings
Sikkim Primitive II SP$_2$	BL	100								1	1	3	4	7	16	15	14	14	13	6	5	1											2	14	4	32	34	6	8								150·5	25·3	1: 5·7 (5·5)	1: 0·34	50·0	1 grain granulate
	UNBL	100				1			3	6	5	7	20	8	14	7	11	8	3	1	4	2										3	9	6	23	17	23	9	5	2	3						100·5	18·1	1: 5·3 (5·5)	1: 0·30		11 grains having bulgings
Pollo Segregaciones	BL	100										1	1	2	5	5	19	19	24	11	9	2	2											11	3	16	47	12	10	1							152·0	24·3	1: 6·1 (6·2)	1: 0·32	54·2	
3174	UNBL	100						1	3	4	10	12	26	6	9	8	2	7	2	5	3	1	1								3	1	5	13	39	8	19	7	1		4						97·8	18·9	1: 5·4 (5·1)	1: 0·29		
Pollo Blanco 3172	BL	100						3	3		8	5	12	16	8	10	10	9	4	2	5	3	1	1							1		10	10	9	23	24	7	7	7	2						125·6	24·6	1: 5·5 (5·1)	1: 0·30	36·5	
	UNBL	100						2	2	8	10	8	24	8	11	7	5	10	1	1	3										1	1	13	3	22	15	34	1	2		8						89·1	17·8	1: 5·2 (5·0)	1: 0·30		4 grains have obscure pattern and one grain is diporate
Francisco Flint × SP$_2$	BL	100						3	1	4	11	14	20	21	12	6	4	2			2											1		6	1	18	40	20	3	3	6	2					130·3	25·9	1: 5·0 (5·0)	1: 0·33	41·9	
	UNBL	100						2	11	26	24	13	21	1	1			1													2		3	3	50	15	19	5	1		1	1					89·4	18·6	1: 4·7 (4·8)	1: 0·29		

(the longest axis), the pore-axis ratio (as determined by Barghoorn *et al.* also) and the pore-annulus ratio (longest diameter of annulus including pore divided by the diameter of the pore) are also determined. The values so determined are not only entered in Table 1 but also graphically represented (TEXT-FIG. 1, 2).

MORPHOLOGICAL OBSERVATIONS

Normally the exine of the maize pollen in these varieties is devoid of any structural features but occasional grains have been found to show some sort of protrusions from the exine. Such grains have usually been found to be rare but in some varieties they are up to 30 per cent as in *Palomero Toluqueno*. About 4 per cent pollen with obscure pattern has been seen in *Pollo Blanco* whereas only a single pollen with granulate exine is found in *Sikkim Primitive* II.

The number of apertures is normally one but 1-2 per cent pollen grains with two apertures have been observed in some varieties, viz., *Pira*, *Palomero Toluqueno*, *Chapalote*, *Sikkim Primitive* I and *Pollo Blanco*.

THE SIZE-RANGE

The size in the bleached pollen ranges from 114 to 152·8 μ whereas in the unbleached pollen it is from 85·1 to 106·8 μ. In the two extremes (the minimum and the maximum) the difference of 28·9 μ and 45·2 μ has been discovered in the unbleached and the bleached pollen grains respectively. In the individual varieties the *Pira* and the *Imbricado* show the lowest difference between the bleached and unbleached pollen and it is 18 and 16·5 μ respectively. Two specimens of *Palomero Toluqueno* show ± the same difference whereas *Chapalote*, *Sikkim Primitive* I and *Pollo Blanco* have ± similar difference and size ranging between 33·3 and 36·5 μ. The hybrid variety *Franscisco Flint* × SP_2 shows a difference of 40·9 μ in size. *Sikkim Primitive* II and *Pollo segregaciones*, the later having the largest size difference of 54·2 μ, have ± similar difference in increase of size.

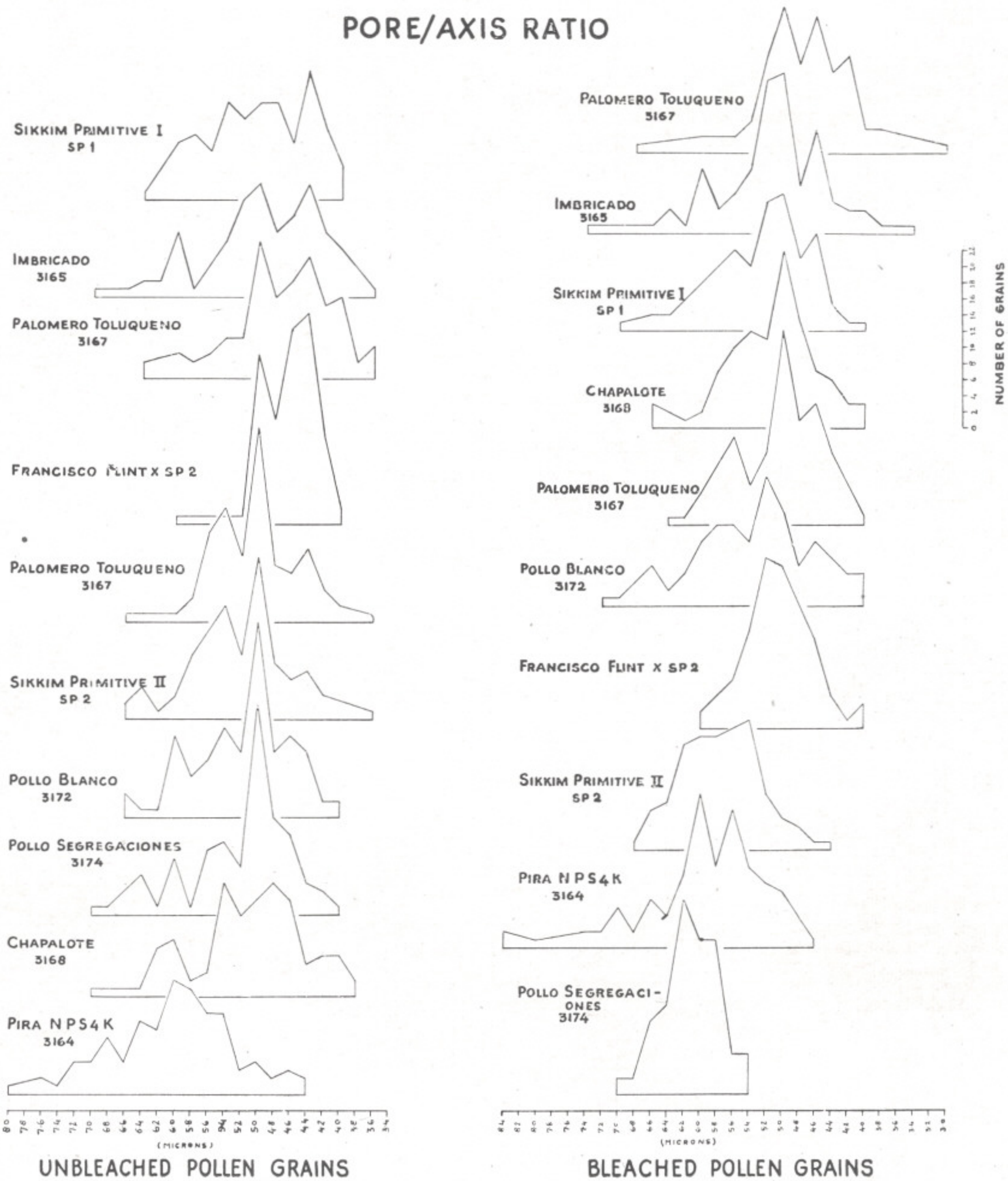
As compared to the dimensions of pollen of several maize varieties investigated by Barghoorn *et al.* (1954), a vast difference in the size range is discovered, although in both the cases the method of Acetolysis has been used. The range in size as found by Barghoorn *et al.* is 87·2-122·8 μ, whereas the one found by us is 114-152·8 μ. From this it would appear that the size of pollen in most of the primitive varieties was larger than the modern varieties but surprisingly enough the size range of the subfossil pollen from the Archaeological materials and sediments as described by Barghoorn *et al.* is in the range of 88·7-95·6 μ. And this approaches the size range of the unbleached pollen of the varieties investigated by us.

PORE/AXIS RATIO

The pore diameter in the acetolysed pollen of ten varieties investigated by us ranges from 3·0 to 8·4 μ, whereas of varieties investigated by Barghoorn *et al.* it is from 5-9 μ. It may, however, be pointed out that the range below 5·0 μ in our specimens overlaps the range found in *Tripsacum* and *Euchlaena*. There are certain differences in the range of pore diameter in the bleached and unbleached pollen of these varieties the range in the bleached pollen being 3·0-8·4 μ and that in the unbleached one is 3·6-8·0 μ. Of the ten varieties investigated by us the unbleached pollen in the variety *Pira* has a comparatively higher range between 4·4-8·0 μ with a maximum between 5·0-6·6 μ. While *Chapalote*, *Pollo segregaciones*, *Pollo Blanco*, *Sikkim Primitive* II, and *Palomero Toluqueno* show range between 3·6-7·0 μ with a maximum between 4·4-5·2 μ. The varieties such as *Francisco Flint* × SP_2, *Palomero Toluqueno*, *Imbricado* and *Sikkim Primitive* I show a tendency of maximum slightly lower than in the previous group.

The results obtained from the measurements of the bleached pollen are very much different from those mentioned above. The pore diameter for bleached pollen reveals that the varieties *Pollo Segregaciones*, *Pira*, and *Sikkim Primitive* II have more or less the same range in the maxima whereas all the other varieties show a slightly lower range in the maxima.

The computed pore-annulus ratio is more consistent since it ranges between 0·28 and 0·36 μ. The difference in the pore-axis ratio (simple or computed) remains between 0·1 and 0·3 μ but in *Pollo segregaciones* the simple pore-axis ratio differs in the bleached and unbleached pollen by 1·1 and in the computed ratio the difference is 0·7 μ.



TEXT-FIG. 1 — Showing pore/axis ratio in bleached and unbleached pollen.

As compared to the results obtained by Barghoorn *et al.* (*l.c.*), the computed pore-axis ratio of all except *Pira* NPS_4K and *Pollo segregaciones* falls within the range of *Euchlaena* although in size the pollen grains are much larger than those of Teosinte. The pore diameter in many of them is also larger than that of the varieties of maize, Teosinte and *Tripsacum* investigated by Barghoorn *et al.* (*l.c.*).

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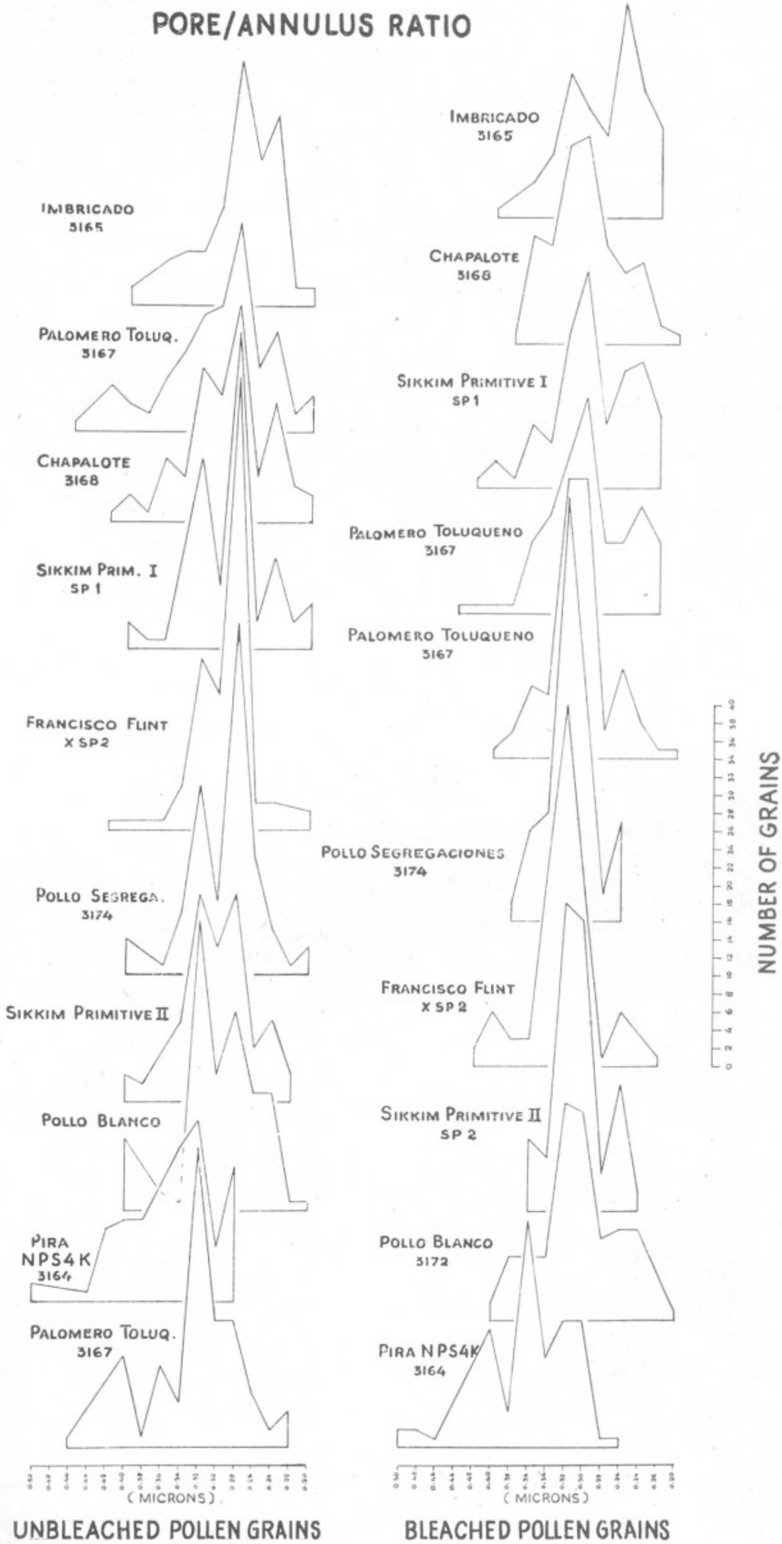
TEXT-FIG. 2 — Showing pore/annulus ratio in bleached and unbleached pollen.


PORE/ANNULUS RATIO
IMBRICADO 3165
PALOMERO TOLUQ. 3167
CHAPALOTE 3168
SIKKIM PRIM. I SP 1
FRANCISCO FLINT X SP2
POLLO SEGREGA. 3174
SIKKIM PRIMITIVE II
POLLO BLANCO
PIRA NPS4K 3164
PALOMERO TOLUQ. 3167
IMBRICADO 3165
CHAPALOTE 3168
SIKKIM PRIMITIVE I SP 1
PALOMERO TOLUQUENO 3167
PALOMERO TOLUQUENO 3167
POLLO SEGREGACIONES 3174
FRANCISCO FLINT X SP 2
SIKKIM PRIMITIVE II SP 2
POLLO BLANCO 3172
PIRA NPS4K 3164
NUMBER OF GRAINS
(MICRONS)
(MICRONS)
UNBLEACHED POLLEN GRAINS
BLEACHED POLLEN GRAINS

PORE/ANNULUS RATIO

The pore/annulus ratio shows a range from 0·20-0·50 μ in both the bleached and the unbleached pollen grains. The pore/annulus ratio seems to be more consistent than the pore-axis ratio with the exception of *Pira* which in both bleached and unbleached pollen shows a comparatively higher range than the others. Amongst the others *Imbricado* consistently shows a comparatively lower range.

The pollen morphology and statistics of ten primitive varieties of maize as investigated by us tend to reveal that in size the pollen grains of the primitive varieties are larger than those of the advanced ones. It also establishes that the pore/annulus ratio gives more consistent results than the pore/axis ratio. Further differences in the bleached and unbleached pollen grains as regards size and pore/axis ratio are far greater than in the pore/annulus ratio.

CONCLUSION

Comments on the History of Maize in India

It is largely believed that maize was introduced into India by the Portugese after Columbus had discovered America. This post-Columbian introduction of maize into India is supported by the historical records mentioned in Indian literature. According to Gode (1950) the earliest reference to maize is found in 1540 A.D. after the advent into India of the Spanish or Portugese travellers in about 1498 A.D.

The absence of any indigenous name for maize in Sanskrit or other old languages and the uniform use of Makka, Makki, or Bhuta in modern languages further reveals that maize in India may be of recent introduction. Roxburgh's comments (ROXBURGH, 1832, p. 568) that it is " cultivated in different parts of India especially in the gardens, and only as an ornament, but no where on the continent of India as an object of cultivation on a large scale " is also suggestive of its recent cultivation into India.

In the absence of any pre-Columbian evidence of maize in India from literature, it would be worthwhile to look for any factual evidences which archaeobotany or pollen evidence may furnish. The historical evidence could have been taken seriously if the most primitive varieties of maize had not been found in Assam. Their existence is a mystery but perhaps not without much significance unless it could be proven that they too are somehow introduced either by man or through some other agency. Andersen (1943) dwelt at length on the occurrence of primitive maize in Assam to support his theory of the origin of maize in India. But eventually he has reconciled himself with Mangelsdorf's viewpoint (from personal communication) regarding the origin of maize in the New World, since the archaeobotanical records and the pollen evidence from the New World have finally established the origin of maize from there.

In the light of occurrence of the most primitive maize in Assam, it may seem possible to once again put life into the dead theory of Andersen (*l.c.*) that maize originated in the old world, but the chances seem to be remote until undoubted factual evidences far older than those obtained in the new world, could be discovered. Even if the factual evidences could show the occurrence of Pre-Columbian maize in India, we ought to feel very much rewarded.

Archaeobotanical record of Maize in India

The factual knowledge of the history of our cultivated plants is still very meagre, although we have by now some information regarding the major crops of cereals such as wheat, rice, barley and millets (*Sorghum*) and of Legumes like lentil, black and green gram etc. (VISHNU-MITTRE 1961, 1964). Chronologically speaking we now know something about the food habits of ancient Indians from about 4500 years down to our historial period. Rice and wheat have repeatedly occurred during the Harappan, the Neolithic and the Chalcolithic periods, but any evidence of maize has been wanting.

A recent discovery (VISHSNU-MITTRE, 1966) from Kaundinyapur (M. P.) ranging in age from the Late Chalcolithic to the Historic period may, however, be pressed to present such wanting evidence of maize. The specimen comprises a fragment of a potsherd bearing three impressions—one of a blade and two of what appear to be those of cobs of maize probably made by rolling a cob on the wet unbaked surface of the potsherd.

The identity of the impressions on the potsherd to a cob of maize is perhaps of prior importance before the age of the specimen is considered. The plasticine casts of modern cobs of maize produced by rolling them on the plasticine mould of a potsherd produced identical prints, although the alternation of rows of grains was prominently marked on the plasticine casts rather than on the actual specimen.

For confirmation of its identity to cobs of maize photographs of the specimen were sent to Dr. Mangelsdorf for his opinion. Disagreeing that the impressions could be of maize, he suggested the following possibilities after consulting some of his colleagues — Dr Richard McNeash of the National Museum of Canada and Dr. James Griffin of the University of Michigan —

1. that it could be the impression of a piece of basketry
2. or of a coarse textile or fabric.

The impression in the central part of the sherd interpreted by one of us (V.M.) as that of a leaf of maize is believed by Dr. Griffin to have probably been made by two fingers rubbed across the surface of the vessel. The opinions of these experts refer to what they see in the photograph of the specimen sent to them and they have also expressed in their letters that they cannot be certain about the impression without seeing the actual specimen.

For expert opinion a photogaph of the specimen was also referred to Dr. Dhawan of I.A.R.I. who (personal communication) gives the following three reasons in support of his view that the impressions could not be of maize —

1. There are six rows of depressions, corresponding to the rows in a maize ear. The imprint should make a concave depressions if it were made by a maize ear. The photograph does not show this.
2. In an ear of maize the grains in adjacent rows alternate with one another. In the photograph this alternating pattern is absent.
3. In the actual size photograph, there appear to be six rows. The imprint indicates that if it was a maize ear, it must have been very small. It is difficult to visualize how such a small ear of maize could make an imprint of six rows from one face.

Prof. M. E. D. Jeffreys, on the other hand, to whom also a photograph of the specimen was sent, comments the discovery and finds in it support to his views of the pre-Columbian introduction of maize into India by the Arabs. His view is largely derived from the commonness of names of maize in Hindustani, Arabic and African languages (personal communication).

From a comparative study of pottery the specimen dates to the 6th to 9th century A.D. Should the specimen be proven to be of maize, this pre-Columbian occurrence of maize in India would suggest the pre-Columbian contacts between South America and India, supporting the views of Andersen and Jeffreys (personal communication).

POLLEN EVIDENCE

Recent pollen-analytical investigations of the Postglacial lake deposits carried out in the Kashmir valley proper by Sharma (1964) have brought out evidences of the origin and progressive development of Agriculture. We have recently attempted to recognize the pollen of maize from amongst the cereal subfossil pollen recovered by Dr. Sharma. In earlier analyses from shallow swamps in the valley Singh (1963) had recovered the subfossil pollen of maize and the pollen diagram from Walanwar was dated to Stage 'h' representing the topmost part of the pollen sequence and which on conservative estimate could not be older than 200 to 300 years.

The pollen of *Zea mays* stands out unique amongst the pollen grains of other cereals, because of its large size amongst the wild and cultivated grasses. Pollen morphological studies of 38 genera and 56 spp. of Gramineae distributed in the Kashmir Valley reveal that some occasional pollen grains in *Dendrocalamus strictus* may be as large as the smallest Teosinte pollen. But there are quite a few wild and cultivated grasses distributed in the Jammu & Kashmir State of which the pollen approaches the size of pollen in *Tripsacum* and these include *Phacelurus speciosus* (45 μ), *Dendrocalamus strictus* (51 μ), *Bromus patulus* (42 μ), *Hordeum murinum* (44 μ), *Deveuxia scabrescens* (45 μ), *Pennesitum glaucum* (51 μ), *Setaria glauca* (51 μ) and *S. viridis* (45 μ). From this it appears that apart from the other characters the size of the pollen can alone be used to separate pollen of maize from that of other grass pollen. It may be stated that pollen grains above 90 μ could be safely referred to maize. This statement applies to the acetolysed pollen both the bleached and the unbleached ones but not to the unacetolysed pollen.

As a result of the recognition of pollen of maize amongst the subfossil cereal pollen in the pollen diagram from the Haigam Lake, Srinagar, it has been discovered that (based on size statistics) none of the cereal subfossil pollen, until during the upper part of Stages 'e' & 'f' can by any means be referred to *Zea mays*. Some pollen grains ranging between 70 and 83·7 μ in these two Stages, however, call for immediate explanation. Pollen of maize has rarely been recorded in the lowest size range between 70-84 μ. The lowest extreme referred to by Barghoorn *et al*. is 72 μ in *Zea mays* (BARGHOORN *et al*., 1954, p. 231). This smaller range, however, corresponds well with the size range of *Euchlaena* (Teonsinte). The subfossil pollen between the size range 40-70 μ may be referred to any of the wild and cultivated species of grasses including *Tripsacum*. It may, however, be pointed out that both the genera *Tripsacum* and *Euchlaena* supposed to be the nearest relatives of maize are not indigenous to India. According to Bor (1960) *E. mexicana* is cultivated in Bihar, Orissa, U.P. and in other parts of India for fodder. *T. dactyloides* is introduced into India as an excellent fodder plant. Some subfossil pollen as small as 69 to 80 μ is referred to maize by Barghoorn *et al*. (*l.c.* TABLE 2) since the pore-axis ratio in such cases is greater than in either, *Tripsacum* or *Euchlaena*. The pore-axis ratio of the subfossil grains in this size range from Kashmir is far above the maximum of 8·8 as noted by Barghoorn *et al*. (*l.c.*), thus pointing to the possibility of their reference to maize.

So far as the evidence of the introduction and cultivation of maize in the Kashmir Valley is concerned, the pollen-analytical investigations hitherto available do not establish beyond doubt that maize is an indigenous crop so far as the valley of Kashmir is concerned. Taking into consideration the lowest extreme size and high pore-axis ratio of subfossil pollen in Stages 'e' and 'f' approaching that of maize it may be said that the maize cultivation in Kashmir began in the thirteenth-fourteenth century. Since the dating of the sediments is indirect, we cannot be pretty sure of its exact date of introduction and cultivation there. Much will, however, depend upon the future pollen analyses to state definitely about the history of maize in Kashmir and in India.

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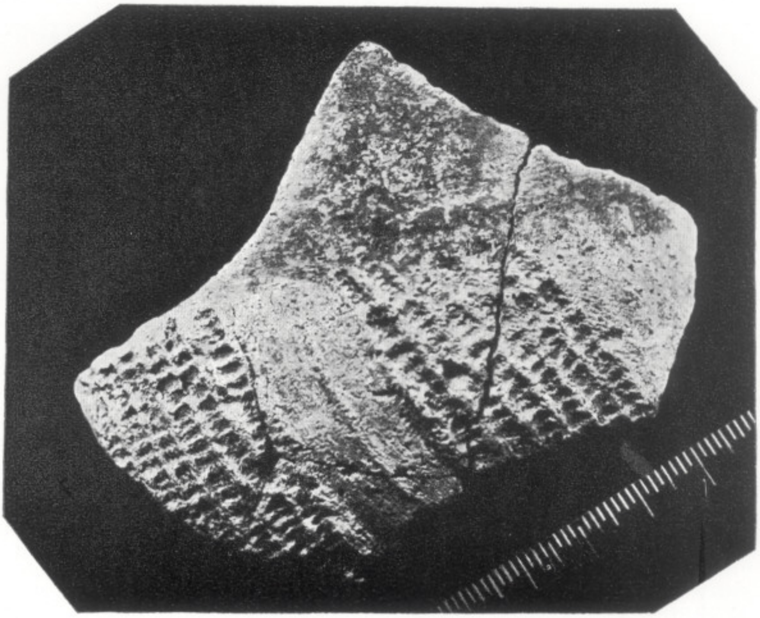
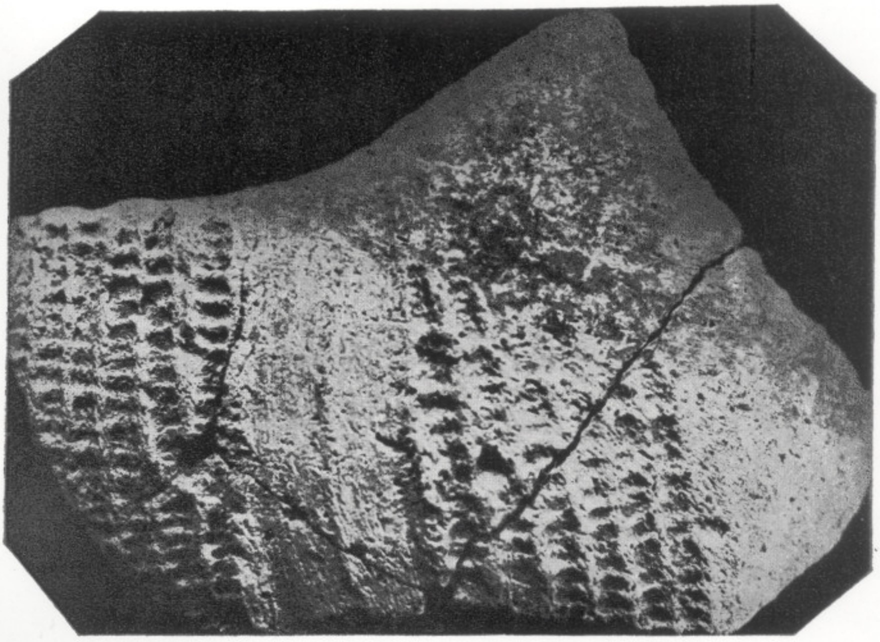
EXPLANATION OF PLATE

1. Photograph of the potsherd from Kaundinyapur (M.P.) showing impressions looking like those of cob of maize. Fig. 1. Nat. size.

2. Photograph of the potsherd from Kaundinyapur (M.P.) showing impressions looking like those of cob of maize. Fig. 2. × 2.



1



2