Indian J. Genet., **54** (4): 409–417 (1994)

CYTOLOGICAL BASIS OF RACIAL DIVERSITY IN INDIAN MAIZE: AN OVERVIEW

M. KUMAR* AND J. K. S. SACHAN

Division of Genetics, Indian Agricultural Research Institute, New Delhi 110012

(Received: January 31, 1994; accepted: November 19, 1994)

ABSTRACT

Cytological characterization of Indian maize races based on knob composition reveals certain well defined knob complexes in northeastern and northwestern regions of the Himalayas. The frequency as well as combination of various knob positions was found to be characteristic of different races and a specific pattern of geographic distribution of these knobs was observed. Two lineages of Himalayan maize could be established on the basis of knob pattern: a) Nal-Tel-Chapalote complex having very high knob number, and b) Confite Morocho with very low knob number. Both pre- and post-Columbian introduction of maize in northeastern Himalayan (NEH) region is postulated.

Key words: Maize, lineages, knobs, Himalayan, races.

RACIAL DIVERSITY IN INDIAN MAIZE

Extensive variability in plant tassel and ear characteristics of various maize germplasms is observed in northeastern Himalayan (NEH) and northwestern Himalayan (NWH) regions of India [1–3]. However, the maize varieties being grown in the Indo-Gangetic plains possess less varietal diversity [4–5]. Broadly speaking, Indian maize varieties can be grouped into two categories: (i) early yellow flint with slender ear, closely resembling those grown in northeastern part of the United States, and (ii) a flint with short compact ears resembling the Cuban yellow flints of the Caribbean region. Remote Asiatic aborigines residing in the erstwhile greater Assam cultivate a number of exceptionally well differentiated maize varieties, having a set of unusual morphological characters which are absent in American maize [6]. Those varieties were categorised as (i) Caribbean, (ii) Early Slender, (iii) Late Upright, (iv) Early Upright, (v) Late Sidewise and (vi) Drooping Waxy.

Landraces with primitive characteristics are known to exist in the entire Himalayan region including Nepal [6–12]. Similarity of the primitive maize strains of NEH with

*Present address: Department of Genetics, Rajendra Agricultural University, Pusa, Bihar 848125.

Caribbean germplasm was refuted on the basis of metroglyph analysis 13. The Himalayan primitives were found to be distinctly different from those being grown in northern plains and peninsular India, which resemble the Mexican and Columbian germplasms.

As many as 15 distinct maize races have been identified in the monograph "Races of Maize in India" [1]. Most of them have been maintained in complete isolation and stringent selection has been practiced for centuries by the aborigines residing in different ecological niches at various altitudes. These races can be broadly grouped into four categories: (a) primitive, (b) advanced or derived, (c) recent introduction, and (d) hybrid races. The details of the various races of Indian maize is given in Table 1.

Table 1. Races of maize in India

Type	Races	Area of cultivation	Altitude
Primitive	Poorvi Botapa	Sikkim & Assam	600–2000 m
	Murli sub race	—Do—	600–1500 m
	Tirap Nag-Sahypung	Tirap Distt. of Arunachal Pradesh	
	Arun Tepi		
	Alop Sapa	Eastern Himalayan region	
Advanced	Manipuri Chujak		
	Mayong Sa-ah		
	Asht Samsung		
	Shyam Nahom		
	Lahar Gomdhan		
	Maidani Makka	Gangetic plains	
	Subrace Ganga		
Recent introductions	Tista Mendi	West Bengal	1500 m
	Silken Tipang	Adjoining regions of Arunachal Pradesh with Burma	600–1500 m
Hybrid races	Khasi Riewhadem	Khasi Hills of	
	Riewhadem	Meghalaya & Lohit areas of Arunachal Pradesh	
	Mikkir Merakku	Mikkir Hills of Assam	Up to 600 m
	Nilip Mekop	Mikkir & Cachar Hills of Assam	600–1500 m

The NEH maize has been assigned to 3 lineages [14] based on morphological similarity: Palomero Tolugueno of Mexico, Confite Morocho and Kuclli of Peru. Two Indian races, i.e. Alok Sapa and Arun Tepi belong to the Palomero Toluqueno lineages, whereas Ashut Samsung and its subrace Tsunghuru belong to the Confite Morocho lineages. The lineages of Shyam Nahom can be traced to another Peruvian race, Kuclli. However, the lineages of two races namely, Poorvi Botapa, its subrace Murli, and Tirap Nag-Sahypung could not be traced to any of the American primitive races.

The northwestern Himalayan (NWH) region also represents a lot of genetic diversity in maize due to variation in ecology, microniches and spatial isolation imparted by different mountain ranges and varying altitudes (500–2000 m.). In contrast to earlier reports [4, 5], both flint and dent types are under cultivation in the NWH region [3]. The significant differences in morphological characters of plant, seed, cob, as well as biochemical characters, viz. isozymes of peroxidase and esterase, have been observed in the maize of this region. Presence of irregular rows in some of the collections of this region comprising the Gull Hills (Udhampur region), Rajouri, Poonch, Bhadarwah and Kistwar region of Jammu and Kashmir suggests primitiveness of these landraces. Such a rich diversity of maize in this region suggests that NWH is a potential centre of landrace diversity [3].

The Sikkim Primitive (SP) maize, a group of 15 primitive strains, found in Sikkim, Meghalaya, Tripura, Nagaland and eastern Nepal was first discovered by Dhawan [9] and later investigated extensively [11]. A large number of primitive characters have been identified in Sikkim Primitive, maize, which make them to be the oldest maize in the world [15] resembling closely the vegetal remains of maize found in the Tehuacan Valley of Mexico [16].

CYTOLOGICAL BASIS OF RACIAL DIVERSITY IN THE HIMALAYAN MAIZE

Heterochromatic knobs located at fixed positions of the maize chromosomes have been used as cytological markers. The position and size of knobs are constant features for a particular plant, but vary from plant to plant and variety to variety. Knob pattern analysis aids in ascertaining their racial and geographical distribution, which is highly nonrandom. It also helps in tracing the migration pathways of various races and race complexes [17, 18]. A knob appears as an electrondense mass consisting of compact fibrillar material, with small electron-leuscent patches [19]. C-bands, Q-bands and knobs have been shown to correspond to each other in a 1 : 1 fashion [20, 21].

KNOB STUDIES IN THE HIMALAYAN MAIZE

The earliest attempt at cytological characterization of Indian maize grown by various ethnic groups of the erstwhile greater Assam was made by Stonor and Anderson [6]. They reported presence of very few but large knobs at positions and in combinations which are either rare or unknown in the New World maize.

Similarity has been observed between the karyotypes of Nepalese, Japanese and American maize [7]. Knob number in the somatic chromosomes of Nepalese maize was in the range of 9–16 with the mean 9.1. It was suggested that the Nepalese maize is closer to the non-Andean type.

The knob composition of two maize collections, one each from Nagaland and Assam has been reported [22]. The Nagaland collection had six knobs, 5 intercalary on chromosomes 2S, 4L, 5L, 7L, 8L and one terminal on 9ST, while the Assam collection had only three knobs on chromosomes, 7L, 8L and 9 ST. Knob constitution of three collections from Sikkim revealed more knobs on the long arms of chromosomes 1, 2, 4, 6, 7, 8, and on the short arms of chromosomes 2, 3 and 9 [23]. Out of these, only one terminal knob on 9ST was present in all the collections and the knob number ranged from 6–9 in above material. Similarly, knob composition of the four maize strains from northeastern frontier agency region has been analysed [24]. The number of knobs ranges from 5–8. The most common knob forming positions were on chromosomes 2L, 4L, 5L, 6L, 7L, 8La, 8Lb and 9 ST. The knob forming pattern in the Himalayan primitives was different from that of cultivars. The presence of knobs on 7L, 8S, 8L and 10La in SP2 and 10L in Sikkim Primitive-1 (SP1) exhibit new positions [25]. However, the C-banded karyotype of stock SP1, revealed mostly terminal and subterminal bands on most of the chromosomes, although some interestital bands on chromosomes 5 and 6 were also observed [26].

Since the early 1980s systematic and extensive cytological characterization of maize germplasm of the NEH region has been carried out which has helped in understanding the racial diversity, its lineages as well as the probable time of its introduction in the region. Possible descent of Himalayan maize from Andean highlands of South America was proposed on the basis of knob-heterochromatin distribution studies in some maize strains from the Sikkim region as well as some Sikkim Primitive strains [21]. Some common knob forming positions, viz. on chromosomes 2L and 4L were observed in Sikkim Primitive maize as well as some established American maize races [21, 27]. Similarities have been observed between C and Q banding patterns in Pira and the two Sikkim Primitives strains, S-18 and S-23 from Sikkim [27]. Further, a negative correlation between knob number and altitude exists in some strains from Sikkim [28]. On the basis of knob number, Sikkim Primitive maize was classified into two groups, suggesting two lineages: one having high knob number of 8–12 distributed in Sikkim and Tripura, and the other with low knob number of 1–4 represented by those of Meghalaya.

Extensive cytological characterization of 66 landraces of the NEH maize cultivated in different ecological niches and varied geographical regions has been carried out [29]. Altogether 26 knob forming positions, including four new knob positions, were identified in the NEH maize (Fig. 1). New knob positions, hitherto unknown in the American maize races were found at 1Lb, 2Lb, 2LT and 9Lb positions which coincided with different geographical locations in the NEH region [30]. The most frequent knob positions in NEH were 6S, 9ST, 8La, 4L, 2La. Less frequent 6Lb, 7L, 3L positions were also observed. Presence of these most frequent knob positions in majority of strains suggests of their common lineages.

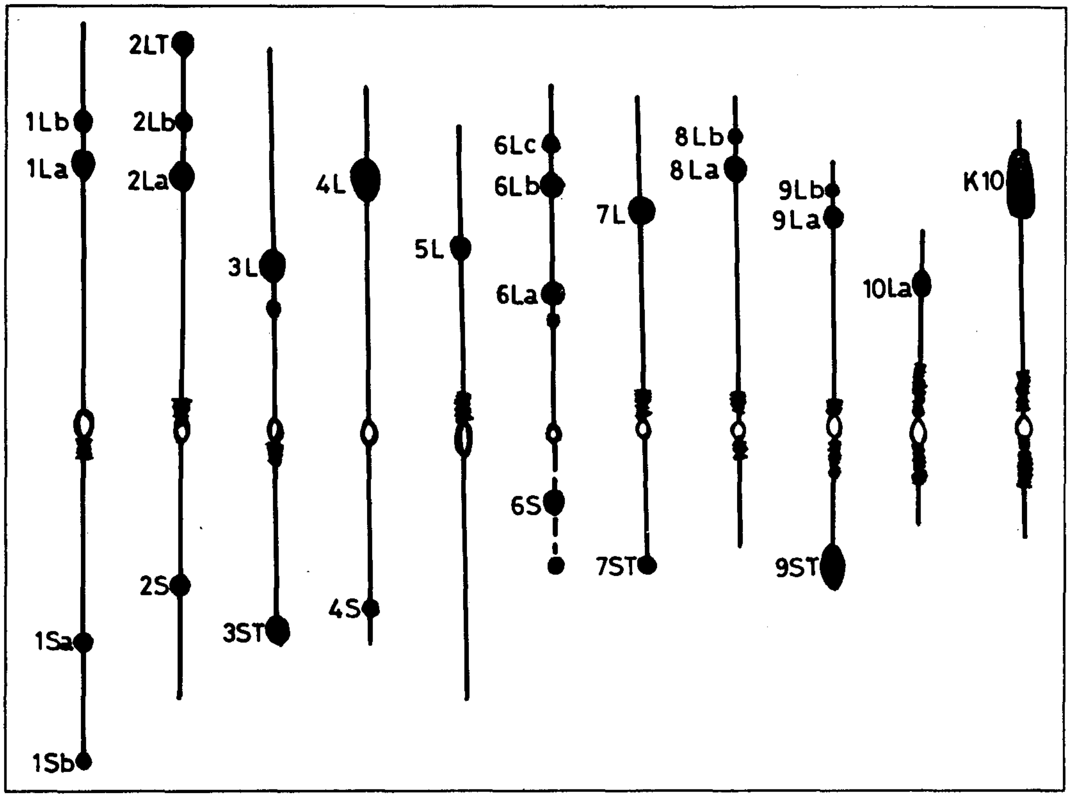

Fig. 1. Knob positions in NEH maize.

The presence of abnormal chromosome 10 in two strains of NEH maize, namely T-17 (Tripura) and N-37 (Nagaland) has been observed for the first time in this region [31]. Similarly, K 10 chromosome was observed with variable frequency in different varieties as well as geographical areas of Kashmir [32]. The frequency of chromosome K10 in the varieties from Phulwama, Anantnag and Baramulla districts of Kashmir was 85.5, 68.7 and 33.1%, respectively. The highest frequency of K10 was observed in the 'Kani' and Badeh varieties, but it was totally absent in the variety Mishri.

More accurate picture about the lineages of NEH maize has been obtained from studies on C and Q banding patterns [27, 33, 34], knob heterochromatin distribution [28, 30, 35] and biochemical characterization [36–38]. These studies have unequivocally established two lineages of the NEH maize: the Nal-Tel–Chapalote and Confite–Morocho complexes [39, 40]. Introduction of wild corn in the NEH region both from Mexico and Andean region in prehistoric time has already been suggested [41].

A lot of interest has been generated in the discovery of Sikkim Primitive maize, which has been found to be the oldest in the world, corresponding to the archaeological race of the Tehuacan Valley. Cytological and biochemical studies including C-banding pattern [34], knob constellation [29, 31, 35, 42] and electrophoretic patterns of soluble proteins and isozymes [36] of Sikkim Primitive maize have established its close relation with Nal-Tel, an ancient indigenous race of Mexico. Presence of the seeds, cobs and other vegetal remains of Nal-Tel in the Bat Cave of Mexico (2500 BC) strengthens our conclusion that Sikkim Primitive maize is the live specimen of prehistoric wild corn. This maize can be divided into the groups on the basis of knob number: one group having large number of knobs varying from six to eleven, and the other group possessing fewer knobs. The lineages of Sikkim Primitive strains having large number of knobs can be traced to the Nal-Tel-Chapalote complex, whereas the Sikkim Primitive strains with small knob number fall in the lineages of Confite Morocho of Peru or to some extent, Palomero Toluqueno of Mexico [31, 42].

Analysis of knob composition in local maize varieties of Kashmir,which are under cultivation in the districts of Anantnag and Baramulla, has revealed 20 knob forming positions, with the mean knob number for all the varieties 7.64. The most frequent knob is the one present on chromosome 5L, followed by those on 6L, 1L, 4L and 8S. The knobs on 2S, 4S and 6S positions were very rare [43].

However, 36 knob positions were reported in 15 local maize varieties of Kashmir [32]. The average knob number of different varieties cultivated in Phulwama, Anantnag and Baramulla was 29, 30 and 31, respectively. The highest knob number of 32 was reported in the Badeh varieties followed by Tripachi, Vozij and Niver group of varieties, which have a knob number of 28, 28 and 18 respectively.

REFERENCES

1. B. Singh. 1977. Races of Maize in India. Indian Council of Agricultural Research, New Delhi: 106.

2. B. Singh. 1989. Diversity of Himalayan Corn. Indian J. Pl. Genet. Resources, **2**(1): 64–65.

3. K. P. S. Chandel and K. V. Bhat. 1989. Northwestern Himalaya a centre of maize diversity. Indian J. Pl. Genet. Resources, **2**(1): 12–17.

4. U. J. Grant and E. J. Wellhausen. 1955. A Study of Corn Breeding and Production in India. Ministry of Food and Agriculture, Govt. of India, New Delhi: 1–27.

5. E. J. Wellhausen. 1965. The origin and breeding of maize. Indian J. Genet., **26A**: 45–59.

6. C. R. Stonor and E. Anderson. 1949. Maize among the hill people of Assam. Ann. Mo. Bot. Gard., **36**: 355–404.

7. T. Suto and Y. Yoshida. 1956. Characteristics of oriental maize. *In*: Land and Crops of Nepal Himalaya, vol. II (ed. H. Kihara). Fauna and flora Res. Soc., Kyoto, Japan: 373–529.

8. T. Ono and H. Suzuki. 1956. Chromosomes of maize. *In*: Land and Crops of Nepal Himalaya, vol. III (ed. H. Kihara). Fauna and Flora Res. Soc., Kyoto, Japan.

9. N. L. Dhawan. 1964. Primitive maize in Sikkim. Maize Genet. Coop. Newsl., **38**: 67–70.

10. J. K. Thapa. 1966. Primitive maize with Lapchas. Bull. Tibetol., **3**: 29–31.

11. J. K. S. Sachan and K. R. Sarkar. 1982. Plant type of Sikkim primitive maize. Maize Genet. Coop. Newsl., **56**: 122–124.

12. C. L. Johannessen and A. Z. Parkar. 1989. Maize ears sculptured in 12tn and 13th century A. D. India as indicators of pre- Columbian diffusion. Econ. Bot., **43**: 164–180.

13. B. K. Mukherjee, N. P. Gupta, S. B. Singh and N. N. Singh. 1971. Metroglyph analysis of Indian and exotic varieties of maize. Euphytica, **20**: 113–118.

14. B. Singh. 1977. Evolution of primitive cultivars from North Eastern Himalayan region in relation to lineage. Indian J. Genet., **37**: 103–113.

15. J. K. S. Sachan and K. R. Sarkar. 1986. Sikkim primitive maize: an overview. Indian J. Genet., **46**: 153–161.

16. P. C. Mangelsdorf. 1974. Corn, Its Origin, Evolution and Improvement. Harvard Univ. Press, Cambridge, Massachussetin: 262.

17. B. McClintock. 1978. Significance of chromosome constitutions in tracing the origin and migration of races in the Americas. *In*: Maize Breeding and Genetics (ed. D.B. Walden). John Wiley and Sons, New York: 159–184.

18. B. McClintock, T. A. Kato Y. and A. Blumenschein. 1981. Chromosome constitution of races of maize. Colegio de Postgraduates, Chapingo, Mexico: 517.

19. A. K. Sharma and J. S. P. Sarma. 1988. Chromosome structure rearrangements and genome relationship in Maydeae. Feddes. Report, **99**(78): 291–337.

20. V. V. Shenoy. 1982. Cytogenetic and Biochemical Studies in Maize (*Zea mays* L.) and Its Wild Relatives. M. Sc. Thesis, IARI, New Delhi.

21. Suchira Pande, J. K. S. Sachan and K. R. Sarkar. 1983. Knob distribution in Himalayan strains of maize. Maize Genet. Coop. Newsl., **57**: 96–98.

22. J. Venkateshwarlu. 1965. Chromosome knobs and B chromosomes in maize types from North-Eastern Frontier Area (NEFA) of India. Maize Genet. Coop. Newsl., **39**: 182–183.

23. P. N. Rao. 1967. Chromosome knobs in maize types from the Sikkim region. Maize Genet. Coop. Newsl., **41**: 5.

24. J. Venkateshwarlu and K. G. R. Rao. 1967. Chromosome knobs in maize types from the North-Eastern Frontier Area (NEFA) of India. Maize Genet. Coop. Newsl., **41**: 4.

25. D. Gupta and H. K. Jain. 1971. Differentiation of evolved varieties and primitive races of maize of Himalayan and Latin American distribution. Maize Genet. Coop. Newsl., **45**: 37.

26. T. S. Mohan and R. N. Raut. 1980. Giemsa C-banded somatic karyotype of maize stock "Sikkim Primitive-I". Turrialba, **30**(1): 111–112.

27. Suchira Pande, J. K. S. Sachan and K. R. Sarkar. 1986. Distribution of constitutive heterochromatin in Sikkim primitive maize. Indian J. Genet., **46**: 366–374.

28. Suchira Pande, J. K. S. Sachan and K. R. Sarkar. 1988. Knob composition in North Eastern Himalayan maize. Indian J. Genet., **48**: 219–224.

29. M. Kumar. 1991. Knob Polymorphism in Northeastern Himalayan Maize. Ph. D. Thesis, IARI, New Delhi.

30. M. Kumar and J. K. S. Sachan. 1992a. Knobs in North Eastern Himalayan maize. Maize Genet. Coop. Newsl., **66**: 84–86.

31. M. Kumar and J. K. S. Sachan. 1992b. B-chromosome and abnormal chromosome 10 (K10) in Northeastern Himalayan maize. Maize Genet. Coop. Newsl., **66**: 82–83.

32. P. N. Jotshi and K. A. Patel. 1983. Knobs in Kashmir maize. Maize Genet. Coop. Newsl., **57**: 134–137.

33. J. K. S. Sachan, K. R. Sarkar and R. Tanaka. 1978. C-banding pattern in some Indian and exotic strains of maize and teosinte. Maize Genet. Coop. Newsl., **52**: 120–121.

34. J. K. S. Sachan, K. R. Sarkar and M. M. Payak. 1992. Studies on constitutive heterochromatin in relation to origin, evolution and diffusion of maize (*Zea mays* L.) *In*: Advances in Cytogenetics and Crop Improvement (eds. R. B. Singh, R. M. Singh and B. D. Singh). Kalyani Publishers, New Delhi: 41–48.

35. S. Dash, J. K. S. Sachan and K. R. Sarkar. 1986. Knob heterochromatin distribution in Sikkim Primitive strains and Nal-Tel. Maize Genet. Coop. Newsl., **60**: 104.

36. A. Pereira, N. D. Sharma, J. K. S. Sachan and K. R. Sarkar. 1983. Genetic distance studies in maize and teosinte based on biochemical assays. Maize Genet. Coop. Newsl., **57**: 103–104.

37. T. M. Shivkumar. 1988. Interrelationship Studies on Maize (*Zea mays* L.) and Its Wild Relatives. M. Sc. Thesis, IARI, New Delhi.

38. S. Katiyar. 1992. Isozyme diversity in *Zea* and related genera. Maize Genet. Coop. Newsl., **66**: 92.

39. J. K. S. Sachan. 1991. Origin and evolution of maize. *In*: Maize Genetics Perspectives (eds. K. R. Sarkar, N. N. Singh and J. K. S. Sachan). Indian Society of Genetics and Plant Breeding, New Delhi: 16–34.

40. M. Kumar. 1991. Knob composition in northeastern Himalayan maize. Abstr. Golden Jubilee Symp. Indian Society of Genetics & Plant Breeding, New Delhi. 12–16 February, 1991, Pt. III: 661–662.

41. J. K. S. Sachan and K. R. Sarkar. 1986. Discovery of Sikkim Primitive precursor in the Americas. Maize Genet. Coop. Newsl., **60**: 104–106.

42. M. Kumar, S. Dash and J. K. S. Sachan. 1995. Characterization of knobs in northeastern Himalayan maize. *In*: Genetic Research and Education: Current Trends and the Next Fifty Years (eds. B. Sharma et al.). Proc. Golden Jubilee Symp., 12–15 February, 1991, New Delhi. Indian Society of Genetics and Plant Breeding, New Delhi, vol. III (in press).

43. P. N. Jotshi. 1982. Knobs in Kashmir maize II. Nucleus, **25**: 152–161.