

Cytogenetics of *Guizotia* Species and Origin of Niger, A Review

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Cytogenetical relationships among wild and cultivated *Guizotia* species and the origin of niger (*Guizotia abyssinica* (L.f.) cass.) have been reviewed. All species are diploids, with $2n = 30$. Chromosome pairing in the hybrids between wild and cultivated species suggests that *G. abyssinica*, *G. scabra* and *G. schimperi* are closely related and *G. abyssinica* has originated from *G. schimperi*. Translocations have played major role in differentiation of *Guizotia* genomes. *Guizotia bidentoides* Oliver and Hiern (1877) is member of *Bidens* group and should be treated as *Bidens pinnatipartita* (Hoffm.) Wild. as was done in the past. Phytogeographical, morphological and cytogenetic evidences suggest that niger has originated from *G. schimperi*. It is proposed that niger was domesticated in Ethiopian highlands earlier than 3000 B.C. and it entered India through trade routes, well before the christian era.

Key Words : Cytogenetics, *Guizotia*

Introduction

The genus *Guizotia* cass. tribe Heliantheae, family Asteraceae comprises three annual and four perennial species. The genus is of high economic value since one of the speices, *G. abyssinica* (L.f.) cass. (common name : niger), is an oilseed crop, cultivated in Ethiopia, Sudan, Uganda, Tanzania, Malawi and Indian subcontinent. Niger seeds contain about 25-60% edible oil (Seegler 1983) and 12-25% protein. It grows on varied types of soils, including saline soils.

Baagoe (1974) revised the taxonomy of genus *Guizotia* and recognised 6 species, namely cultivated *G. abyssinica* (L.f.) cass.; *G. scabra* (vis.) chiov. ssp *schimperi* (SCH. BIP in WALP) Baagoe; *G. scabra* (vis.) chiov. ssp *scabra*; *G. villosa* SCH. BIP. in WALP; *G. reptans* Hutch; *G. zavattarii* Lanza; and *G. arborescens* I. Friis. In this review *G. scabra* (vis.) chiov.; *G. schimperi* SCH. in WALP. have been treated as independent species, as suggested by Murthy (1987). The review attempts to compile all available information on genomic relationships of various species of *Guizotia*,

and on the origin and domestication of niger.

Genomic Relationship

Chromosomes Morphology-Somatic Chromosomes

Chromosomes of *Guizotia* are medium sized. The karyotypes are either symmetric or asymmetric. In a study of somatic chromosomes Patel et al. (1983) distinguished three types of chromosomes i.e. median, submedian and subterminal in *G. abyssinica*. On the contrary, Dagne and Heneen (1992) classified them into four groups on the basis of centromeric location, chromosome size, satellites and C-bands. Group I includes three pairs of satellited median chromosomes; of these 2 pairs have C-banded satellites and one pair has C-band proximal to the secondary constriction; Group II comprises 7 pairs of median chromosomes; Group III a pair of median or near median chromosomes which have a prominent interstitial C-band in the short arm. Group IV comprises the remaining four pairs of submedian chromosomes. Hiremath and Murthy (1992) undertaken karyology of several African and Indian populations of *G. abyssinica*. karyotypes of these populations consist of median and submedian chromosomes. The range of variation in number of median and submedian types of chromosomes is 18-26 and 2-10 respectively. The interspecific karyotypic variation ranged from perfect symmetric complements with all median chromosomes to increase in number of submedian chromosomes in the complement. In *G. schimperi* the chromosome complement has 15 pairs of median chromosomes of which one pair carries satellite. *G. scabra* complement has

submedian and subterminal chromosomes, which range in number from 16-26 and 2-12 respectively. Chromosomes complement of *G. villosa* consists of only median chromosomes of which one pair has satellite. The endemic species, *G. reptans*, possess a pair of sat. metacentric chromosomes, 7 pairs of metacentric and 7 pairs of submetacentric chromosomes. Another endemic species, *G. zavattarii*, has four types of chromosomes. They are, one pair of satellited median chromosomes, three pairs of median chromosomes, eight pairs submedian chromosomes, and three pairs subterminal chromosomes. These results clearly indicate that *G. abyssinica*, *G. schimperi*, *G. villosa* have symmetric karyotypes and appear to be primitive, whereas *G. scabra*, *G. reptans* and *G. zavattarii* having asymmetric karyotypes are advanced. Further Hiremath and Murthy (1992) propose that *G. abyssinica* may have originated from *G. schimperi* as they are morphologically similar and their karyotypes are identical in several collections.

Nuclear DNA

Hiremath et al. (1992) has compared 2C DNA values of 7 accessions of *G. abyssinica*, 5 each of *G. schimperi* and *G. scabra*, 3 of *G. villosa* and 2 each of *G. reptans* and *G. zavattarii*. No significant variation in nuclear DNA content has been reported among different populations of the same species, but differences exist among the species. The 2C DNA value ranges from 3.61 pg in *G. reptans* to 11.37 pg in *G. zavattarii*. The variation is nearly 3-fold although chromosome count is uniformly $2n = 30$. The cultivated *G. abyssinica* (7.57 pg), has accommodated nearly 78% extra DNA in its chromosome complement as compared

to its wild progenitor *G. schimperi* (4.25 pg). DNA values have also been compared between annuals (5.79 pg) (*G. abyssinica*; *G. schimperi* and *G. villosa*) and perennials, (6.25 pg) (*G. scabra*; *G. reptans* and *G. zavattarii*). Loss of DNA content is indicated during the evolution of annual habit. Genome size variation in *Guizotia* does not follow any set pattern, for both evolutionary loss and gain of DNA is evident.

Interspecific Hybridization and Genomic Interrelations

Interspecific hybridization has been attempted to elucidate genome relations among different species of *Guizotia* (Murthy et al. 1993). Hybrids have been recovered in three combinations, namely, *G. abyssinica* × *G. schimperi*, *G. abyssinica* × *G. scabra*, *G. schimperi* × *G. scabra*. Hybrid meiosis has revealed mean chromosome pairing of 0.26 I + 14.60 II + 0.14 IV in the *G. abyssinica* × *G. schimperi*. Nearly 81% pollen mother cells of the hybrid contain 15 bivalents; 14% of pollen mother cells contained a quadrivalent. In *G. abyssinica* × *G. scabra* hybrids mean chromosomes pairing is 0.05 I + 13.6 II + 0.14 III + 0.58 IV, 43.4% hybrid Pmc's contained 15 bivalents, 10% Pmc's carried two quadrivalents. Mean chromosome pairing was 0.08 I + 12.7 II + 0.08 III + 0.88 IV per cell in *G. schimperi* × *G. scabra* hybrids. About 54% of pollen mother cells carried 15 bivalents and upto two quadrivalents in 38% of the cells. Pollen fertility and seed set for *G. abyssinica* × *G. schimperi* hybrid was 41% and 32% respectively. In *G. abyssinica* × *G. scabra* hybrid, pollen fertility is 11% and seed set is 8%. In *G. schimperi* × *G. scabra* hybrid pollen fertility is 15% and seed set is 10%. In

the *G. abyssinica* × *G. schimperi* hybrid 81% pollen mother cells contained 15 bivalents. Moreover the hybrid exhibits high pollen and seed fertility which suggests that the genomes of *G. abyssinica* and *G. schimperi* are nearly homologous. It has been proposed that *G. abyssinica* may have originated from *G. schimperi* through selection. Based upon these results Murthy et al. (1993) have proposed genomic formula 'GG' for these two taxa. Formation of 15 bivalents in 43% Pmc's of *G. abyssinica* × *G. scabra* and 54% Pmc's of *G. schimperi* × *G. scabra* hybrids reflect partial homology between *G. abyssinica*, *G. schimperi* and *G. scabra*. Genomic formula 'Ge Ge' has therefore been proposed for *G. scabra*. Formation of quadrivalents in *G. abyssinica* × *G. schimperi*; *G. abyssinica* × *G. scabra* and *G. schimperi* × *G. scabra* hybrids suggests that translocations have played role in genome differentiation in genus *Guizotia*.

Status of Guizotia bidentoides Oliver and Hiern

Guizotia bidentoides: Oliver and Hiern is perennial, robust herb which is distributed in East Africa as a common weed. This plant was reported by Oliver and Hiern (1877) in the flora of Tropical Africa. Later Hoffmann (1889-94) transferred this taxon to genus *Bidens* and named it *Bidens pinnatifida* (Hoffm.) Wild. Baagoe (1974), based on morphological analysis, suggested its retention in genus *Bidens*. Murthy (1990) undertook cytological investigation of this taxon to resolve the taxonomic dispute. The species has $2n = 48$ and the complement consists of one pair of satellite metacentric chromosomes, a pair of submetacentric satellited chromosomes, 9 metacentric pairs, 12 submetacentric pairs and one pair of subterminal chromosomes. During meiosis the chromosomes formed 24 bivalents. Based on

these observations Murthy (1990) suggested retention of this taxon in genus *Bidens* as *Bidens pinnatipartita* (Hoffm.) Wild. Thus transfer of *Guizotia bidentoides* from genus *Guizotia* to *Bidens* (Baagoe 1974) on morphological ground is fully supported by cytological evidences.

Origin and Domestication of Niger

Baagoe (1974) undertook taxonomic revision of genus *Guizotia*. She suspected the *G. scabra* (vis.) chiov. ssp. *scabra* or most likely *G. scabra* (vis.) chiov. ssp. *schimperi* (sch.) Baag, as the progenitor of niger. Since the putative progenitor grows in Ethiopia, she proposed Ethiopian origin of niger. History, linguistics, comparative morphology, ecology, phytogeography and cytogenetics comprise important evidences to trace origin and domestication of crop plants. Archaeologic data and historical records of early cultivation of niger are lacking (Vishnu-Mittre 1978, Seegler 1983). Hiremath and Murthy (1988) have used phytogeographic, morphological and cytogenetic evidence to trace the history of origin and domestication of niger.

Phytogeographic Evidence

All the wild species of *Guizotia* occur in East Africa, especially Ethiopia. None of the wild taxa exist in India. *G. reptans* Hutch. is a perennial, prostrate, sparsely branched herb found in moist, swampy, mountain grassland in Mt. Kenya, Aberdares and Mt. Elgon in East Africa. Habitat and distribution of the species suggest that it cannot be the progenitor of niger. *G. arborescens* I. Friis. is a woody perennial shrub upto four meters tall, branching from the very base. The species is endemic to Imantong mountains of Sudan and Southern Ethiopia and is a component of the natural vegetation of

mountainous flora. Morphologically, the species bears no resemblance to niger and is unlikely to be the progenitor of cultivated *G. abyssinica*. *G. zavattarii* Lanza is a rare perennial, endemic to Mt. Mega in Ethiopia and Huri Hills in northern Kenya. In appearance and morphology this species is entirely different from niger. Additionally, none of these species grow anywhere niger cultivation. *G. scabra* and cultivated niger show certain degree of resemblance, yet it can be easily distinguished by its perennial habit, 5 outer involucral leaves exceeding the disk centre and short achenes. This species has wide distribution in East Africa and Nigeria, except in Congoian rain forests. In Ethiopia it is most frequent between 2,500-3,500 metres and is a component of montane vegetation. *G. abyssinica* is a cultivated species and the areas in which it is cultivated in Ethiopia lie between 1,600-2,500 metres. The species does not share habitat with *G. scabra*. It appears therefore, that *G. scabra* is not be a progenitor of niger. *G. villosa* is an annual species, found only in northern part of Ethiopian highlands. The plant is delicate, much branched, with linear outer involucral leaves. Morphological features of the species suggest that it is unlikely to be the ancestor of niger, although the two species co-exists in Ethiopian highlands. *G. schimperi* is a common weed in Ethiopia, especially in the cultivated fields of niger (Riley & Belayneh 1989). These two taxa are morphologically alike. They can be distinguished only by the length of achenes and number of nerves on the paleae; niger has 5 nerved paleae with long achenes, whereas *G. schimperi* has 3 nerved paleae with short achenes. Thus based on morphological, ecological and phytogeographical evidence it appears that *G.*

schimperi might be the ancestral taxon from which niger has originated.

Cytogenetic Evidence

As discussed already, all the species of *Guizotia* including *G. abyssinica* and *G. schimperi* are diploid with $2n = 30$. Karyomorphological data of Hiremath and Murthy (1992) suggest that both *G. abyssinica* and *G. schimperi* have symmetric karyotypes and they resemble in chromosomes size, absolute length, the type and sat. chromosomes and satellite size. Accordingly, they proposed that *G. schimperi* is the possible progenitor of *G. abyssinica*. Moreover, hybrid meiosis has revealed that the genomes of *G. abyssinica* and *G. schimperi* are homologous (Murthy et al. 1993). The fact that the Ethiopian highland has highest concentration of *Guizotia* species, including the possible progenitor of niger, indicates that it is in all probability the centre of origin of niger.

Trade contacts between Africa and India through land and sea routes was extensive. Trading goes back to 3000 B.C. (Hornell 1941). Niger was probably introduced into India by traders early in the history of this crop. There are no archaeological findings of niger in India (Vishnu-Mittre 1978). It is difficult to say when niger was introduced

into India. However, since niger has vernacular names in almost all Indian languages, Hiremath and Murthy (1988) opine it might have come to India along with crops of savanna complex well before the christian era.

Conclusions

Chromosomes of *Guizotia*, as revealed by the studies of Patel et al. (1983), Dagne and Heneen (1992), Hiremath and Murthy (1992) are medium sized, *G. abyssinica*, *G. schimperi* and *G. villosa* have symmetric karyotypes and *G. scabra*, *G. reptans* and *G. zavattarii* have asymmetric karyotypes. Interspecific DNA variation, observed by Hiremath et al. (1992), ranged between 3.61 pg in *G. reptans* to 11.37 pg in *G. zavattarii*. The cultivated oilseed crop, *G. abyssinica* (7.57 pg), has accommodated nearly 78% extra DNA in its chromosome complement during its origin from wild progenitor *G. schimperi* (4.25 pg). Interspecific hybridization between different species of *Guizotia* attempted by Murthy et al. (1993) as revealed close homology among genomes of different species. Based on the degree of genomic homology, it has been proposed that *G. abyssinica* has originated from *G. schimperi* some where in Ethiopian highlands.

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