TATUS PAPER

Cytogenetics and Crop Improvement of Ginger and Turmeric*

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GINGER

Ginger is the dried rhizome or underground stem of *Zingiber officinale* Rosc. a herbaceous perennial belonging to the family Zingiberaceae. Though the country of origin is not known with certainty, it is presumed to be in the region of India or China (Purseglove, 1972), and Burkill (1966) concluded that the cultivated ginger did not originate in the Malaysian region.

The most authoritative classification of Zingiberaceae is that of Holttum (1950) who followed Schumann's classification of the family into two sub-families, *viz.*, Zingiberoideae and Costoideae and the former sub-family consisting of three tribes *viz.*, Globbeae, Hedychieae and Zingibereae. He transferred the genus *Zingiber* from Zingibereae to Hedychieae renaming the former as Alpinieae which in fact became Zingibereae of Schumann (1904) without the genus *Zingiber*. Tomlinson (1956) also generally concurred with this arrangement.

Cytogenetics

Chromosome number of *Z. officinale* was reported by Morinaga et al., (1929) as 2n=22, followed by Sugiura (1936). Takahashi (1930, cited by Darlington and Janaki Ammal, 1945) reported a chromosome number of 2n=24 for the species. Raghavan and Venkatasubban (1943) reported the cytology of three species of *Zingiber viz., Z. officinale, Z. cassumunar* Roxb. and *Z. zerumbet* Sm. and all of them had chromosome number of 2n=22. They also found differences in the chromosome morphology in these species. Based on the comparative idiogram, Raghavan and Venkatasubban (1943) concluded that the chromosomes of *Zingiber officinale* were different from the other two species in chromosome morphology. Janaki Ammal (Darlington and Janaki Ammal, 1945), reported 2B chromosome in certain types of *Z. officinale* in addition to the normal complement of 2n=22. Chakravorti (1948) also reported a chromosome number of 2n=22 in *Z. officinale*. Based on the investigations,

* Publication No. 18, Central Plantation Crops Research Institute; Regional Station, Calicut.

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he concluded that in view of the normal pairing of 11 bivalents in species like *Z. cassumunar* and *Z. zerumbet*, *Z. mioga* Rosc. with 2n=55 chromosome is to be considered as a pentaploid.

Widespread occurrence of inconsistency in chromosome numbers in several species of Zingiberaceae including *Z. officinale* was reported by Sharma and Bhattacharya (1959). While reporting karyotype of 13 genera including 24 species in Zingiberales, Sato (1960) concluded that *Z. mioga* with 2n=55 is to be considered as a pentaploid with a basic number of x=11.

Cytology of five species of *Zingiber*, including *Z. macrostachyum* Dalz., *Z. roseum* Rosc. and *Z. wightianum* Thw. for the first time, in addition to *Z. officinale* and *Z. zerumbet* was reported by Ramachandran (1969). He found evidence for structural hybridity involving interchanges and inversions in *Z. officinale*.

In an extensive cytological investigation in the Zingiberales, Mahanty (1970) reported chromosome numbers for *Z. spectabile* Griff. and *Z. cylindricum* (both 2n=22) and he concluded that the genus *Zingiber* appears to be much more correctly placed in the tribe Hedychieae than in the Zingibereae.

Karyotypes of 32 cultivars of *Z. officinale* and three species of *Zingiber viz.*, *Z. zerumbet*, *Z. macrostachyum* and *Z. cassumunar* were investigated by Ratnambal (1979). She found considerable differences in gross morphological characteristics of chromosomes. A classification of karyotypes according to the degree of their asymmetry (Stebbins, 1958) showed that karyotype 1B was represented in most of the cultivars of *Z. officinale*, while 1A was found in *Z. zerumbet*, *Z. macrostachyum* and *Z. cassumunar*. The quantitative differences in 32 cultivars of *Z. officinale* and three wild species was estimated by using D^2 statistic of Mahalanobis (1936). Eight groups were recognised based on the generalised distance and it was concluded that it was difficult to classify the cultivars based on the geographical distances (Ratnambal, 1979).

Intraspecific variability for meiotic behaviour was observed in 25 cultivars of *Z. officinale* investigated by Ratnambal (1979). She established significant linear regression between pollen sterility and chromosome aberrations at anaphase II and aberrant quartets. It was concluded that the structural chromosome aberrations had a significant influence in lowering the fertility in cultivars of *Z. officinale*.

Crop improvement

Several commercial types of *Z. officinale* are cultivated. They are generally named after the localities or places from where they are collected. Some of the more prominent indigenous types are Maran, Kuruppampadi, Thodupuzha, Wynad Local, Narasapattom, etc. A high yielding introduction Rio-de-Janeiro has become very popular among the cultivators, compared to local cultivars (Kannan and Nair, 1965). The cultivar Nadia outyielded others in a varietal trial conducted in Assam (Aiyadurai, 1966). According to Thomas (1966), Rio-de-Janeiro produced 32,550 kg of fresh ginger per hectare under Kerala conditions.

Thomas and Kannan (1969) as well as Muralidharan (1973) also reported the high yielding capacity of this cultivar. In a trial of 11 cultivars conducted at Vellayani, Nair, Sasidhar and Sadanandan (1976) observed that Nadia gave the highest yield of 49,335 kg/ha, followed by Himachal Pradesh. Muralidharan and Kamalam (1973) found that Rio-de-Janeiro was superior to other cultivars with respect to yield. However, the percentage of dry ginger was low in Rio-de-Janeiro and maximum dry ginger was obtained in Maran. In a comparative yield trial of 23 cultivars of ginger at Kasaragod, maximum yield was obtained in Rio-de-Janeiro followed by Burdwan and Jamaica (Anonymous, 1978 a).

The crop improvement work carried out so far had been confined to collection of cultivars from different localities and their yield evaluation. Analysis of yield and plant characters like number of tillers, height of plant, and number of leaves, showed that plant height is generally associated with yield (Kannan and Nair, 1965).

Genetic variability and heritability for 14 characters were studied by Mohanty and Sarma (1979) in 28 cultivars of ginger. Their study indicated that straight selection was useful to improve almost all characters except the number of tertiary fingers and straw yield. Significant positive genotypic and phenotypic correlations with the number of tillers, number of leaves, plant height, leaf breadth, total number of fingers, etc. with rhizome yield were observed by them.

Multiple regression analysis using morphological characters, showed that the final yield could be fairly accurately estimated, based on certain morphological characters at 90th and 120th day after planting (Ratnambal, 1979). The improvement in prediction value was noticed with advancement in the age of plants.

Path coefficient analysis revealed that the phenotypic correlation between yield of rhizomes, and height of pseudostem was quite high, and so also the direct effect of height towards the correlation. It was also found that the indirect effect of height in manifestation of the correlation between yield and other characters was also high. The direct effect of number of leaves on yield was found to be low. Eventhough the length of leaf had a negative direct effect, it was compensated by a high positive correlation between plant height and the final yield (Ratnambal, 1979).

Wilk's λ statistics from multivariate analysis showed differences between cultivars of *Z. officinale*, with respect to rhizome characters such as number of nodes, length, breadth and internodal length of mother rhizomes, number of nodes, length and breadth at base, middle and top and internodal distance of fingers (Ratnambal, 1979).

TURMERIC

Turmeric (*Curcuma longa* L. Syn. *C. domestica* Val. and *C. aromatica* Salisb). is best known as a condiment, though the plant has uses in the social and religious life of the people in South-East Asia. The genus *Curcuma* belongs to the family Zingiberaceae and the cultivated species were domesticated in South-East Asian countries from very early times.

Though the country of origin of turmeric is not known with certainty, it is presumed to be South-East Asia and the cultivated species of turmeric became naturalised in some areas of north-eastern parts of India and the island of Java. Watt (1908) believed that several species of *Curcuma* were native to India though there was little positive evidence to justify the claim. Turmeric was supposed to have reached East-Africa in the eighth century and West Africa in thirteenth century (Burkill, 1966). The crop was introduced to Jamaica in 1783. The cultivation of *Curcuma* is largely confined to South Asian countries though the crop is distributed widely throughout the tropical belt.

The genus *Curcuma* is included in the tribe Hedychieae (Rendle, 1904; Hutchinson, 1934: Holttum, 1950), *Zingiber, Hedychium, Camptandra, Scaphochlamys, Boesenbergia, Kaempferia* and *Haniffia* are the other seven genera included in this tribe. In spite of the authoritative works of Valeton (1918), Hooker (1894) and Holttum (1950), the classification of the genus *Curcuma* remains very confused. The genus consists of about 70 species of rhizomatous herbs, out of which 29 species were described by Hooker from India (Hooker, 1894).

Growth characteristics and rhizome development in turmeric were described by Shah and Raju, (1975). Two groups of turmeric were distinguished by Ambekar (1927), one with hard and bright coloured rhizomes and the other with softer, larger and light coloured rhizomes. Some cultivars producing sweet aroma were described by Rajaratnam (1923). Differences in yield and quality in the same cultivar were obtained when grown at different elevations. When the crop was grown at higher elevation the quality improved (Narasimhan, 1931). Valeton (1918) observed that all the cultivars in Java came to flowering, but the seed set was observed in only two cultivars. Patnaik, Patra and Mohapatra (1960) and Pai (1961) described the floral biology and flowering behaviour of *C. longa*.

Cytogenetics

Sugiura (1936) was the first to report the chromosome number in *C. longa*. Chromosome numbers of 24 species in the family Zingiberaceae including that of *C. aromatica* were reported by Raghavan and Venkatasubban (1943). Preliminary survey of chromosome numbers in 38 species of various families of Zingiberaceae including two species of *Curcuma* ie., *C. petiolata* (2n=64), *C. zedoaria* (2n=64) was made by Venkatasubban (1946). An unusual number of 2n=34 was reported in *C. longa* by Sato (1948), which was probably a miscount. Sharma and Bhattacharya (1959) reported the karyotypes of *C. amada* (2n=42) and *C. anguistifolia* (2n=42) in their extensive study on the karyology of Zingiberaceae. A chromosome number of 2n=32 for *C. longa* was reported by Sato (1960) and he concluded based on the karyomorphology, that the species seems to be an allotetraploid with a basic number of x=8. Chakravorti (1948) reported for the first time the somatic chromosomes of *C. amada* (2n=42), *C. zedoaria* (2n=63 and 64), *C. longa* (2n=62, 63 and 64) and *C. anguistifolia* (2n=42).

ytology of six species of *Curcuma* and even cultivars of *C. longa* was reported y Ramachandran (1961). A chromoome number of 2n=86 for *C. aromatica* as also reported by him and he concluded that the species is a tetraploid. He also studied in detail the meiosis of two species, *C. decipiens* (2n=42) and *C. longa* (2n=63) and concluded that the sterility in *C. longa* was probably due to its auto-triploid nature. A further report on the chromosome numbers in Zingiberaceae and genus *Curcuma* was published by Ramachandran (1969), where in he reported the chromosome number for *C. amada* (2n=20, 42), *C. decipiens* (n=21, 2n=42), *C. neilgherrensis* (2n=42), *C. aromatica* (2n = 63, 86), *C. longa* (2n=63) and *C. zedoaria* (2n=63). A high basic number of n=21 was assumed for *Hitchenia* and *Curcuma* and Ramachandran (1969) concluded that the genus *Curcuma* might have been derived either by dibasic amphidiploidy (x=9+12) or by secondary polyploidy.

Microsporogenesis and megasporogenesis in *C. aurantiaea* and *C. lorgengii* were reported by Sastrapradja and Aminah (1970). Fruit set was observed only in *C. aurantiaea* by these workers and they concluded that the absence of fruit set in *C. lorgengii* was due to pollen abortion. Detailed cytological investigations by Nambiar (1979) revealed that all the cultivars of *C. aromatica* had somatic chromosome numbers of 2n=84, and *C. longa* 2n=63. This along with 2n=42 for *C. amada* indicated a polyploid series with multiples of n=21. Nambiar (1979) presumed that the earlier reports of chromosome numbers of 2n=32, 62 and 64 for *C. longa* and 42, 63 and 86 for *C. aromatica* were probably exceptional cases and the correct chromosome numbers for these species are 2n=63 and 84 respectively.

Crop improvement

About 50 commercial cultivars of turmeric belonging to *C. longa* and *C. aromatica* are recognised in this country by the name of localities, where they are cultivated. Some of the popular cultivars are: Armoor, Duggirala, Mydukur, Tekurpetta, Alleppey, Dindigam and Amalapuram (Rao, Reddy and Subbarayadu, 1975). Cultivars of turmeric have been classified as long duration (9 months), medium duration (8 months) and short duration (7 months) based on the time taken for the maturity of rhizomes (Aiyadurai, 1966). Sarma and Krishnamurthy (1960) reported high curing percentage for the early duration *aromatica* types and low value for medium duration *longa* types. Though some of the cultivars mentioned above are capable of yielding 30 to 35 tonnes of raw turmeric per hectare, the actual realised yield is much less and this has been attributed to very little crop improvement work carried out till recently. The research on improvement of turmeric were confined to varietal trials at the agricultural research stations.

Comparative yield evaluation conducted under the All India Co-ordinated Spices and Cashewnut Improvement Project has helped to identify cultivars with high yield potential (Selection No. 15 from Amalapuram type, Selection No. 2 from Mydukur type). Earlier reports indicated that turmeric is a sterile triploid which flowers but fails to set seed (Burkill, 1966;

Purseglove, 1972). However, recently seed set and seedling progenies have been obtained in some cultivars of *C. aromatica* (Anonymous, 1976) which opens new vistas in crop improvement programme of this spice crop.

Based on a critical analysis of morphological and yield data in different cultivars of *C. longa* and of *C. aromatica*, Nambiar (1979) concluded that the final yield was influenced by the weight of the seed material.

An analysis of inter-correlations of coefficients among the morphological characters and yield revealed that number of tillers, plant height and number of fingers had significant correlation with the yield. Number of tillers, number of leaves, plant height and leaf length and breadth had highly significant inter-correlation among themselves. Path coefficient analysis indicated that wherever significant positive correlations between yield and morphological characters were established, it was mainly due to substantial positive contribution by plant height and number of fingers either directly or indirectly. Based on this, Nambiar (1979) concluded that plant height (of pseudostem) in turmeric is a single important morphological character for which selection for yield could be made.

Cultivars of *C. longa* and *C. aromatica* were grouped into four clusters based on generalised distance-D^2 statistic (Nambiar, 1979). The cultivars belonging to *C. aromatica* were keeping separate identity from the cultivars belonging to *C. longa*.

Estimation of oil and curcumin contents in different cultivars of *C. longa* and *C. aromatica* indicated that the variability for oil and curcumin content was high in *C. longa* compared to *C. aromatica* and for identifying cultivars with high curcumin and oil content it may be worthwhile to carry out selection in *C. longa* alone (Nambiar, 1979).

Future line of work suggested

Being vegetatively propagated, both ginger and turmeric have certain inherent advantages than seed propagated crops. Any variability obtained either through the conventional breeding methods or induction is fixed immediately and true to types could be multiplied through vegetative propagation, obviating the necessity for continuous seed production.

An All India survey conducted by the CPCRI in collaboration with National Bureau of Plant Genetic Resources and Himachal Pradesh Agricultural University, has enabled to collect about 230 accessions of ginger and 120 accessions of turmeric. The accessions are being multiplied and the preliminary indications are that wide variability for yield and quality characteristics exists both in ginger and turmeric. So, the immediate future programme should be description and cataloguing of these germplasm collection and identification of types possessing high yield, low fibre content, high oleoresin and resistance to soft rot in ginger; high yield, high quality with respect to oil, oleoresin and curcumin content and resistance to pests and diseases in turmeric. The estimated yield of about 49,000 kg/ha of fresh ginger obtained at the

Horticultural Research Station, Ambalavayal (Anonymous, 1978 b) shows a very high yield potential even in some of the available cultivars. The breeding programme in ginger is handicapped by relatively shy flowering in most of the cultivars and absence of seed set. Hence the only alternative is to induce variability through physical and chemical mutagens.

In the absence of in-built tolerance/resistance to serious diseases like soft rot and bacterial wilt in ginger, it is essential to look for tolerance/resistance in the wild relatives. Reported failure of seed set in ginger limits the use of conventional breeding methods. Hence, when once tolerance/resistance is located we may have to resort to protoplast fusion for combining desirable characteristics. It would be worth attempting to manipulate the physiology of the plant to induce seed setting.

Polyploidy has been successfully induced in ginger recently at this Institute (Ratnambal, 1979) and tetraploids in ginger are being evaluated and multiplied for their yield and quality characteristics. The possibility of inducing flowering and seed set through growth regulators is also worth exploring.

In the case of turmeric, the reported seed set in *C. aromatica* opens out new avenues with respect to plant improvement. The cultivated types belong to two chromosomal groups, probably, triploids with $2n = 63$, *(C. longa)* and tetraploids with $2n = 84$ *(C. aromatica)*. Hybridisation between these two types could be attempted to produce plants with different chromosomal biotypes. In the seedling progenies high variability was observed with respect to growth and rhizome characteristics (Nambiar, 1979). Hence based on conventional method of selection in the seedling progenies, it could be possible to isolate types possessing high yield, curcumin and oil contents.

Ginger and turmeric have been found to be good material for tissue culture at this Institute (Shetty, Padmaja Haridasan and Iyer, 1980). The new types arising out of the breeding programme suggested above, could be easily multiplied by the tissue culture technique and it would be possible to supply large quantities of planting material in the shortest time.

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DISCUSSION

T. A. Sriram (ICAR): Whether Thomas and Nambiar have collected *Zingiber elatum* and *Z. chrysanthum* during their expeditions?

T. A. Thomas (NBPGR): We haven't come across these species. But from NBPGR we will be going to the Himalayan regions for collection and we will certainly look for them.

V. S. Govindarajan (CFTRI): Could you tell me the chromosome number of *Curcuma xanthorrhiza?*

M. K. Nair (CPCRI): The chromosome number for that species has not been reported so far.

V. S. Govindarajan: I would like to caution the research workers against mixing up *longa* and *aromatica* types in their studies. *Aromatica* cannot be used for any culinary purposes, but is useful only as a cosmetic. So there is no need for incorporating *aromatica* types in comparative yield trials. In fact, except for academic interest, even crossing programmes involving these two species are unnecessary, as *aromatica* will only reduce the quality of *longa* types.

V. K. Muralidharan (NBPGR): Can any one give a set of characters by which *longa* and *aromatica* be differentiated?

M. K. Nair: *C. longa* and *C. aromatica* differ by a series of morphological, cytological and biochemical characters. The root stock in *C. longa* is ovoid, with sessile, thick cylindric tubers, while in *C. aromatica* the root stock is tuberous, with elongated thin tubers. *C. longa* has a somatic chromosome number of 2n=63 and considered as a triploid, while *C. aromatica* is a tetraploid with 2n=84. In *C. longa* the curcumin content is sometimes as high as 12–14% where as in *C. aromatica* curcumin content is generally low.

S. K. Iyer (NAFED): The turmeric types grown in Orissa are darkish in colour and do not have the bright yellow colour of other turmeric types. What is it due to?

V. S. Govindarajan: The colour of turmeric is due to various components in addition to curcumin. In *curcuma* types grown under certain conditions some other colouring components also are present which changes the colour to a darkish shade.