COIX: AN UNIQUE AND REMARKABLE GENUS

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The grass genus *Coix* of the monoecious tribe Maydeae is unique in having its pistillate spikelet enclosed in an indurated leaf sheath, which becomes stony-hard on seed formation called fruit case, false fruit, shell etc., and used as a bead in tropical Asia in tribal jewellery. *Coix* has a myriad uses as food, fodder, medicine etc.

Of the three conventionally recognized species of *Coix*, *C. aquatica* (2n=10) has large chromosomes and *C. gigantea* and *C. lacrymajobi* (job's tears) have small chromosomes (2n=20 and 2n:4x=40 in the former and 2n=20 in the latter). They occur throughout South and South-East Asia, and *C. lacrymajobi* in all warmer parts of the world. The rest of the six species are endemic to restricted areas, and could be endangered (except *C. puellarum*). All species and varieties have hard fruit cases, except var. *Ma-Yuen* of *C. lacrymajobi* (adlay) which has soft shells, and is cultivated as a cereal in sub-himalayan slopes of India. Conventional species occur in aquatic (*C. aquatica*), mountainous terrain (*C. gigantea*) and dry (*C. lacrymajobi*) habitats, but they thrive well in any of these habitats by changing the reproductive process and altering the plant structure to be compatible with the habitat as adaptive measures. They are potentially perennial and occurrence of semigamy in *C. aquatica* is the first report in Poaceae.

Pachytene chromosomes are differentiated in *Coix*, exceptionally in a race of *C. lacrymajobi*, they are completely euchromatic, and in *C. aquatica*, they are the longest in the tribe. Intra- and interplant chromosome numerical mosaicism in *C. aquatica* and *C. gigantea* and translocation heterozygosity in *C. aquatica* have adaptive significance and help to maintain and enlarge cytogenetic diversity.

Genetically controlled bivalent pairing in aneuploids and polyploids results in racial differentiation and stabilization. Races with 2n=12 in *C. aquatica* and 2n = 2x=18, 22 and 2n=4x=40 in *C. gigantea* are well established.

2x = Two ancestral n=5 small chromosome forms by allopolyploidy yielded *C. lacrymajobi* and *C. gigantea*, the former has a stable genome, differentiated into six morphological varieties through accumulation of gene mutations. One of the two ancestors also gave rise to *C. aquatica* by accumulation of duplicate segments and heterochromatin resulting in its having longer chromosomes, which could be recognized at meiosis from the small chromosomes of the other two species in their interspecific hybrids, facilitating the study of inter- and intragenomic pairing in the haploid state. The two aneuploid species (2n=32) from Madhya Pradesh and West Bengal forming six large and 10 small bivalents at meiosis arose as allopolyploids with *C. aquatica* (n=6 race) as one parent, and *C. lacrymajobi* as the other parent in the former and *C. gigantea* in the latter.

C. ouwehandii, *C. poilanei* and *C. puellarum* arose as ecogeographic species from *C. gigantea*, *C. aquatica* and *C. lacrymajobi* var. monilifer in Northern Sumatra, Indonesia, in Laos, and in Myanmar, Malaysia and Indochina respectively. *C. gasteenii* originated as an alloploid of *C. lacrymajobi* (2n) and *C. gigantea* (2n) and flourished in Cape York Peninsula, Australia.

Coix is distinct from both American and Asiatic Maydeae and occupies an intermediate position between the two groups. *Coix* species serve as good class work material for teaching cytogenetics.

Key Words: adaptation, chromosomes, *Coix,* morphology, speciation.

The grass genus *Coix*, belonging to the monoecious tribe Maydeae, to which maize also belongs, has few racemose inflorescences arising in leaf axils, usually the basal spikelet in each is pistillate and uniquely surrounded by an indurated leaf sheath called capsular spathe, involucre etc., leaving an opening at the apex through which the feathery bifid style protrudes, the upper portion of the raceme which also emerges through the same opening is staminate with a few to many spikelets. At seed formation the involucre becomes silicified and turns stony-hard and shiny, called fruit case, false fruit, shell etc. and bead in colloquial

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parlance. *Coix* yields the nature's most perfect bead used in tribal jewellery and probably the most worn plant bead.

Coix was implicated in the origin of maize (Anderson 1945), but the idea was promptly rejected on various grounds. However, *Coix*, attracted considerable attention, not only because of its alleged role in maize phylogeny, but also in its own right, itself being cultivated as a minor cereal of importance in tropical Asia. From the morphological and cytogenetic perspective, many extraordinary features, like (i) exciting qualities for survival, adaptation and evolution, (ii) usefulness as food, fodder, medicine and ornament, (iii) potential for the future as a cereal, (iv) reproductive flexibility, (v) survival strategies in changed habitats, (vi) resourcefulness to compensate for reduction in population size, (vii) genetically and cytoplasmically inherited traits, (viii) chromosome numerical (mosaics) and structural variations, tolerance to addition or loss, and deficiency-duplication of chromosomes, (ix) gene control of bivalent pairing and race formation, (x) genetic mutations and varietal differentiation, (xi) chromosome size and number differences in species, (xii) aneuploidy, alloploidy and ecogeographic speciation, (xiii) endangered species, (xiv) position in Maydeae, (xv) utility as classwork material etc., some of which that made *Coix* an unique and interesting genus, have been highlighted in this presentation, based on personal research (published and unpublished), scientific articles, and some facts shared from the experiences and observations of other researchers, and some found in informal writings.

MATERIALS AND METHODS

Studies made on several populations and accessions of *C. aquatica*, *C. gigantea* and *C. lacrymajobi* collected from various sources in India and abroad, and maintained in the Experimental Field Station of the Botany Department for cytogenetic work (Rao and Nirmala 2010a) and on natural populations were included.

RESULTS AND DISCUSSION

Species, Distribution, Distinction and Utilization

Coix comprises nine species with a host of synonyms and intergrade forms. Only the three conventionally recognized species (*C. aquatica* Roxb., *C. gigantea* Koen. and *C. lacrymajobi* L.), on which considerable knowledge is currently available, are widely distributed in South and South-East Asia, Polynesia and to some extent in Australia, but *C. lacrymajobi,* known as job's tears, has become pan-global. The rest of the species (67%) are endemic to different highly restricted regions (*C. ouwehandii* Koord. in Northern Sumatra, Indonesia, *C. poilanei* Mimeur in Laos, *C. gasteenii* Simon in South-Eastern part of Cape York Peninsula, Queensland, Australia, two unnamed aneuploid species, one in Madhya Pradesh (M.P. form) and another in West Bengal (W.B. form) in India, and *C. puellarum* Balansa in Myanmar, Malaysia and Indochina); barring *C. puellarum*, the rest of these may be considered as truly endangered (Watt 1904, Mimeur 1951, Bor 1960, Simon 1989, Fox 2000, Thomson and Burnham 2004, Rao and Nirmala 2010a).

C. lacrymajobi occurs in dry habitats, *C. gigantea* in terrestrial regions and mountainous terrains and *C. aquatica* in swamps, ponds, lakes etc. as a floating weed growing upto 30 Mts in length and stoloniferous. *C. poilanei*, *C. ouwehandii* and *C. gasteenii* are semiaquatic; *C. gasteenii* is rhizomatous and perennial, the others nonrhizomatous but potentially perennial, through basal suckers or stolons, and ecologically annual (Watt 1904, Mimeur 1951, Simon 1989).

The fruit case varies in shape, colour, size9 and texture, *C. aquatica, C. gigantea C. poilanei, C. ouwehandii* and *Coix* aneuploid species W.B. form have pyriform fruit cases, the rest have nonpyriform fruit cases. In *C. lacrymajobi*, six varieties, originating through accumulation of gene mutations, are recognized on the basis of morphology of fruit case. Varieties *lacrymajobi* Bor, *major* Mimeur, *minor* Mimeur, *C. gasteenii*, and *Coix* aneuploid species M.P. form have hard ovoid fruit cases, var. *monilifer* Watt and *C. puellarum* have hard, globose fruit cases, var. *stenocarpa* Stapf has hard cylindrical fruit cases. Var. *lacrymajobi* has bluish-white fruit cases, in the remaining varieties the colour ranges from chalkywhite, grey, brown to black, and in the rest of the species they are hard and range in colour from white, greenish-brown, marbled, brown or black. Only in var. *Ma-Yuen* (Romanet) Stapf, the fruit cases are soft (easily breakable), of various shapes and colours (white, straw, pink or brown and striate).

In *C. lacrymajobi* the fruit cases do not shatter on maturity. The other species are of shattering type. In the hard shelled varieties, which are perennial, germination of seeds is staggered, and starts in 10 days after sowing and completed in about two months, whereas in var. *Ma-Yuen* and the wild species which also behave like annuals when cultivated, germination begins in a week's time and completed simultaneously (present study).

In var. *major*, *C. gigantea* and *Coix* aueuploid W.B. form, the fruit cases are comparatively larger, in *C. poilanei*, var. *minor* and *C. puellarum* they are smaller. In *C. ouwehandii* and *C. gasteenii* the fruit cases are subtended by a reduced leaf blade which is much smaller in the former. The fruit cases occur sequentially in twos in var. *minor* and in twos and threes in *C. gasteenii*, the rachis between them is much longer in the latter.

Job's tears, the edible forms of which are also called adlay, is cultivated as a cereal since ancient times (3000-4000 years) by the vedic Aryans on the hill slopes of Himalayas and is an important food grain of some of the aboriginal tribes of India; from the fact that so much was mentioned about *Coix* in early botanical writings, it is inferred that formerly it was more extensively cultivated (Watt 1904). It is grown presently in several countries in Asia, Africa, South and Central America, parts of Europe and U.S.A. for various other uses as beads in necklaces, baskets etc., and also as a curiosity in European gardens and greenhouses. Hard shelled varieties are said to be known in Europe since the first century A.D., but soft shelled forms are known to Europeans only in the 17th Century. In China, beads of job's tears were found in the Sampula Cemetery (nearly 2000 years old) signifying that they were in use since early times (Jiang *et al*. 2008). Job's tears probably was the first plant to be used for ornamental purposes. Its domestication occurred long before the species became a cereal in the tropics.

It is possible that Job's tears was independently domesticated in India and Philippines (see Wester 1920, de Wet 1981). As a crop it has many uses (see Watt 1904, Vallaeys 1948, Schaaffhausen 1952). Grain ground into flour is used in many ways as rice flour, has same amount of protein as wheat and much more than rice, it is brewed into a drink, roasted grain used as coffee beans and grain as cattle and poultry feed. Medicinally it is a blood purifier, diuretic and vermifuge. Plants are used as forage and fodder, and for thatching. The crop is tolerant to drought, comes up even in low fertile soils, and cost of production less. Despite these, it did not succeed much as a cereal crop because of long growing season, nonavailability of suitable machinery for deshelling (hard shelled forms), low keeping quality of shelled grain, lack of assured market for the farmers, damage by birds, lack of uniformity and stability of crop due to cross-fertilization, erratic yields and competition from more popular and productive cereals like rice, wheat, maize etc. in the tropics. It is therefore cultivated as an emergency crop in times of scarcity, though it holds great promise for the future.

The rest of the species are all wild, even from these (*C. aquatica* and *C. gigantea*) fruit cases are collected by hill tribes for ornamental purposes.

Considering the long recorded history of *Coix* as a plant useful to both man and beast, and its unique occurrence in both wild and cultivated states (in many crop plants, the wild species from which the cultivated forms have arisen are no longer extant) with populations exhibiting vast genetic variability, *Coix* truly offers many exciting opportunities for ardent and devoted students of biology interested in understanding the interrelationships, origin and evolution of the cultivated plants from wild species, and in augmenting food and fodder resources by crop improvement circumventing its present deficiencies. Rao and Nirmala (2010b) laid out a presumed blueprint for the origin and evolution of species in the genus *Coix.* Schaaffhausen (1952) reported in Brazil a dwarf variety of adlay with brown elongated seeds (fruit cases) obtained through selection with higher productivity (3,500 kg/hectare), early maturing, eliminating bird damage etc. Murakami and associates (see Murakami *et al.* 1963) bred and assessed different varieties, their hybrids and induced polyploids for efficiency in forage production in Japan. The above were only beginnings, and persistent efforts might ultimately yield satisfactory and desired results.

Population disruption, Genetic traits, Chromosomal variations, Mosaics and Races

Successful invasion of a species into any area depends on its seed dissemination. Dispersal of seeds (fruit cases) in *Coix* occurs during floods by water flowing downstream, domesticated forms in agriculture by man, and to far and near places by birds and animals. *Coix* species are robust, growing nearly 2m tall and occur mostly as clumps and patches. However, it appears the species are struggling to hold ground in some regions, as evidenced by their virtual disappearance (germplasm plunging abruptly) in parts of Eastern and North-Eastern India (the latter considered the place of origin of *Coix,* and cradle of flowering plants) from where a large number of samples were collected earlier. This dwindle is partly related to human intervention, by way of expansion of civilization, habitat destruction, agriculture, construction activity etc. In other areas also, in similar circumstances, even if a species (like *Coix* sps.) has no risk of disappearing, it can still lose much of its potential through the loss of genetic material by reduction in range, numbers and varieties (Tandon *et al.* 2009).

Inheritance pattern of several Mendelian traits like seedling base and style colour, leaf hairiness, lazy habit, male sterility etc., and also a case of uniparental maternal transmission of yellow striped leaf condition were studied in the species of *Coix*. They involved complementary, inhibitory, duplicate, incomplete dominance and other types of gene action (Rao 1974 a, c, Rao 1975, Venkateswarlu and Rao 1974, Rao and Nirmala 1991, 1994).

In chromosome number and size, *Coix* species have unique differences. *C. aquatica* has 2n=2x=10 large chromosomes, *C. lacrymajobi* and *C. gigantea* have small chromosomes, the former with 2n=4x=20, and the latter with 2n=4x=20 and 2n=8x=40 chromosomes (see Rao and Nirmala 2010b). Both the aueuploid species, W.B. form and M.P. form have

2n=6x+2=32 with 12 large and 20 small chromosomes (Koul and Paliwal 1964, Christopher and Mini 1988).

Pachytene chromosomes in *Coix* are differentiated and have knobs and macrochromomeres also. But in *C. lacrymajobi* a race with exclusively euchromatic chromosomes was found under aquatic conditions in Anantagiri, North of Andhra Pradesh, India (see Rao and Nirmala 2010b). Further, pachytene chromosomes in *C. aquatica* are the longest in the tribe Maydeae (see Rao and Nirmala 1999).

Chromosomal translocations are rampant in *C. aquatica* involving one or more of all chromosomes. Translocation complexes mostly show nondisjunctional orientation at meiosis, the resulting gametes with deficiencies and duplications of chromosomal segments are to some extent functional even on the male side, such that the individuals in the offspring also carry deficiency-duplication chromosomes which are tolerated. Significant increase in frequency of plants with translocations in the population after a few generations, compared to the situation in the original populationa, indicates the chromosomal translocations have an adaptive advantage (Venkateswarlu 1958, Venkateswarlu and Chaganti 1966, 1973, Rao and Nirmala 2010b).

Intraplant variation in chromosome number (mosaicism) is found in *C. aquatica* and *C. gigantea* due to mitotic nondisjunction and genome reduplication, 2n=10-13, 3x=14-16 and 4x=20 in the former, and 2n=18-22 and 4x=40-44 in the latter (Nirodi 1955, Venkateswarlu *et al.* 1968, Venkateswarlu and Rao 1976, Nirmala and Rao 1984, Rao and Nirmala 1990, Sapre and Naik 1990, present study). In addition, somatic chromosome elimination during ontogeny leading to trisomic-disomic mosaics (Rao 1976), and semigamy forming diploid-haploid and diploid-aueuploid mosaics were also found in *C. aquatica* which is the first report in Poaceae (Rao and Narayana 1980).

Euploid and aueuploid variation of chromosome numbers was found in different individuals in the same population in *C. aquatica* and *C. gigantea* (Venkateswarlu and Chaganti 1966, 1973, Venkateswarlu and Krishnarao 1966, Venkateswarlu *et al.* 1976, Sapre and Barve 1984, 1985a, present study). Gametes with excess or less than haploid numbers resulting from meiotic nondisjunction, and gametes with unreduced chromosome number also are fertile producing progeny with interplant variation. Individuals tolerate the excess or loss of whole chromosomes or chromosome segments as evidenced by their normal development (Rao and Nirmala 2010b).

In the aneuploids and polyploids there is a clear tendency of genetically controlled meiotic bivalent pairing so that chromosomal racial formation and stabilization will ensue, but the newly formed races are also unstable, like their parents, and variation in chromosome number will result in the next generation also. The genome is plastic and it is likely that the composition of each of the emergent genomes is tested and the most stable ones presumably become settled as distinct races. In *C. aquatica* 2n=12 (Christopher and Jacob 1991, Jacob and Christopher 1992) and *C. gigantea* 2n=18, 22 and 2n:4x=40 (Christopher *et al.* 1989, Rao and Nirmala 2010b) stable races are established. In *C. gigantea,* only the longest chromosome in the complement is involved in aneuploidy (Sapre and Barve 1985b, Rao and Nirmala 2010b). In *C. aquatica*, however, any one of the five haploid chromosomes may be included in tetrasomy (Rao and Nirmala 2010b).

In *C. aquatica*, occurrence of univalents with interarm pairing, and intragenomic pairing in its haploid state in F_1 interspecific hybrids are indicative of the presence of duplicate segments both within and between chromosomes (Rao and Nirmala 2001, 2010b). In the progenies of hybrids of *C. gigantea* and *C. aquatica*, alien-addition and alien-substitution lines were obtained (Sapre and Deshpande 1987, Barve and Sangeetha 2008). Some combinations of these, in appropriate ecological niches may establish themselves as well adapted and productive alien-addition and alien-substitution chromosome races (Rao and Nirmala 2010b), though the extra chromosomes in the former were presumed as B-chromosomes by Sapre and Deshpande (1987).

When the population size is declined in the two species, *C. aquatica* and *C. gigantea*, due to environmental hazards, habitat upheavals, weeding operations or grazing, forced inbreeding occurs resulting in random fixation of genotypes. The inherent chromosomal instability amply compensates (each mosaic individual is effectively equal to two or more plants) not only for maintaining the existing chromosomal diversity but also to flourish strongly in favourable situations and expand their domain (Rao and Nirmala 2010b).

The genome of *C. lacrymajobi* is quite stable, spontaneous variations being extremely rare. Artificial induction of autopolyploids and from them autotriploids and aneuploids could be achieved with reasonable ease (Venkateswarlu *et al*. 1976, Rao 1977).

Adaptive and Survival strategies

A wider search for the species revealed that besides their habitats mentioned earlier, *C. gigantea* grows vigorously in small streams and lakes in semifloating condition with aerial roots in Tamil Nadu, and on small bunds and tanks of streams, with well developed root system, and sometimes specially grown on the bunds of fields for soil binding in Karnataka; it is also found in higher altitudes of about 1900m in subtropical Western Ghats with excessive summer rains, growing vigorously in marshes with soft culms serving as good feed for the deer in the forests of Kerala (Jacob, personal communication). All the above ones are with 2n:4x=40 (Christopher and Jacob 1991, Christopher *et al.* 1989). This number is met with in other areas also in Western Ghats (Nirodi 1955), in material from Myanmar, and mixed up with other chromosome numbers (2n=1822) from Relegaon hills in Western Ghats, Maharashtra (present study). Bor (1960) also mentioned that *C. gigantea* is found in hot valleys but will invade moist areas like rice fields when it can become such a menace as to render the fields unfit for rice cultivation; it can grow even on sandy soils.

In the Eastern stretch of Australia, *C. lacrymajobi* is known to occur along wayside watery trenches and drains and other marshy areas as large dense clumps. In Anantagiri (Andhra Pradesh) its variety *lacrymajobi* was found as a floating, partly submerged weed rooting at nodes in a hill stream at 1000 m altitude, in which the male spikelets were either rudimentary or absent, reproduction was suspected to occur asexually through apomictic seed formation and vegetatively through breaking of the rooted stems (present study). Rooted stems when transferred to pots or field conditions, grew erect with prop roots, normal staminate spikelets, good pollen output and sexual reproduction. Transplant experiments back to a free flowing stream resulted in the plants resorting to floating habit, underdeveloped staminate spikelets, vegetative reproduction and asexual seed development (present study). Genetic experiments using marker traits (green vs purple seedling base, white vs purple style and hairy vs glabrous leaf) following Burton (see

Burnham 1962) proved the apomictic seed formation in about 4% of seed produced (Venkateswarlu and Rao 1969). When a few plants were isolated and bagged with periodical removal of staminate spikelets, in 11% of the involucres seed was set, the rest turned chalkywhite, empty and sterile, indicating that seed formation occurred through autonomous apomictic development (present study) which reflects, as presumed, the mode of seed set in its natural habitat. Cytological check of embryosacs by squash technique (see Bradley 1948) revealed two or more 5-nucleate unreduced aposporous sacs (one egg, two each of synergids and polar nuclei) in each ovule as in *Tripsacum dactyloides* (Venkateswarlu and Rao 1967) but unlike in most other grasses in which 4-nucleate unreduced embryosacs is the norm (Brown and Emery 1958). Also in the progenies of 4x and 2x populations of *C. lacrymajobi*, and when they were involved in intergeneric, interspecific and other crosses, sporadic recovery of parthenogenetic and androgenetic haploids, diploids and aneuploids is indicative that apomixis is often resorted to in this species (Rao 1974b, Venkateswarlu and Rao 1975, present study).

Occurrence of vegetatively propagating, highly stabilized, aquatic and sterile hybrids of *C. gigantea* (4x) and *C. lacrymajobi* (2x) in China (Han *et al*. 2004, Rao and Nirmala 2010b), suggests that their natural hybrids also are adapted successfully to wetlands (see Rao and Nirmala 2010b).

C. aquatica, though originally described as aquatic, it can grow erect with prop roots, without stolons, turn annual when cultivated in field conditions. It is also found as weed in rice fields and around on bunds in Tamil Nadu and Kerala with 2n=12 (two different ecotypes) and in Andhra Pradesh with 2n=10 having translocations, trisomy etc. These races or lines have plant and leaf dimensions mimicking rice plants, in juvenile stages, as a survival strategy, as such some of them can escape rouging operations especially in broadcast rice fields (Christopher and Jacob 1991, Jacob and Christopher 1992, Venkateswarlu and Chaganti 1966, 1973, present study).

The above, in the three species, imply that they have evolved originally in aquatic habitat and migrated to semidry and drier regions bringing about the necessary modifications in plant structure like growing erect with prop roots, basal suckers and becoming annual as adaptive measures. It should however be pointed out that while they adapted to drier habitats, they retained their native ability to survive in the wetlands, because when they were shifted back to marshy conditions they did survive with equal efficiency, reversing the plant modifications. Even the same strain or individual plant behaves differently in different habitats. What impact these adaptational modifications have on the anatomy and physiology of plant remains to be investigated.

Aneuploidy, Allopolyploidy, Ecogeographic adaptation and speciation

It is surmised that *C. aquatica* (2n=2x:10) arose from an ancestor with x=5 small chromosomes with accumulation of duplicate segments and heterochromatin by which process its chromosomes became longer. It remained in wet habitat. Two similar ancestors with n=5 small chromosomes (one of them the same that gave rise to *C. aquatica)* through allopolyploidy produced two forms adapted to nonaquatic habitats, one, *C. lacrymajobi* (2n=20) was subjected to cultivation and differentiating into morphological varieties, and the other, *C. gigantea* (2n=20) evolving into different chromosome races (Rao and Nirmala 2010b).

The two aneuploid species (2n=32) show more or less the same meiotic behaviour (six large and 10 small bivalents). Chromosome information is not available in vars. *major* and *minor* of *C. lacrymajobi* and the rest of the four endemic species (see Rao and Nirmala 2010b).

Both natural and artificially obtained interspecific hybrids in most combinations were available (Rao and Nirmala 2010b). In the hybrids involving *C. aquatica* with the other two conventional species, its large chromosomes could always be distinguished from the small chromosomes of the other two species at meiosis, such that inter and intragenomic pairing in haploid state of the parental genomes could be studied. *C. lacrymajobi* showed almost no intragenomic pairing, but *C. gigantea* revealed the same frequently. *C. aquatica* had some intragenomic paring. Intergenomic pairing of large and small chromosomes also occurred frequently (Rao and Nirmala 2001, 2010b).

In the F_1 hybrids of *C. aquatica* with *Coix* aneuploid species, M.P. form and W.B. form, the large chromosomes of the parental species paired, and the small chromosomes paired among themselves frequently as bivalents in the latter hybrid (Christopher *et al.* 1995), and they remained as univalents in the former hybrid (Koul 1965), simulating the haploid pairing in *C. lacrymajobi* and *C. gigantea*. It is therefore evident that the two aneuploid species, M.P. form and W.B. form are allopolyploids of *C. aquatica* (2n=12 race) as one parent, and *C. lacrymajobi* in the former, and *C. gigantea* in the latter as the other parent (Rao and Nirmala 2001, 2010b).

Mimeur (1951) placed *C. ouwehandii* and *C. poilanei* close to *C. gigantea* and *C. aquatica* respectively. Bor (1960) placed *C. puellarum* close to *C. lacrymajobi* var. *monilifer*. It is believed that these species originated through genetic and chromosomal changes and adapted as ecogeographic species from their respective closely placed species; *C. gasteenii* is believed to have originated as an allopolyploid of *C. gigantea* (2x) and *C. lacrymajobi* (2x) and flourished at the ecogeographic site that it exists now (Thomson and Burnham 2004, Rao and Nirmala 2010b).

American Maydeae, Asiatic Maydeae and *Coix*

Tribe Maydeae is distinguished into two geographical groups, American Maydeae including *Zea* (maize and teosinte) and *Tripsacum*, and Asiatic Maydeae comprising *Coix*, *Chionachne*, *Polytoca*, *Sclerachne* and *Trilobachne*.

Attempts of intergeneric hybridization between *Coix* and members of American and Asiatic Maydeae were not successful (Nowacki *et al.* 1972, Venkateswarlu *et al.* 1977) which show that *Coix* is distinct from both the groups, a conclusion also reached on morphological grounds (Weatherwax 1954, Galinat 1963). On cytomorphological basis Celarier (1957) split Maydeae into three parts, i) the genus *Coix*, ii) other Maydeae from South-East Asia and iii) the American Maydeae.

A perusal of the natural distribution of Maydeae shows that none of the Asiatic members occur to the East beyond Indonesia and North-Eastern part of Australia, but *Coix* (*C.lacrymajobi*) extends to the farthest South Sea Islands (Polynesia) like Hawaii and the Tuamotu archipelago which are nearest the American continent on the West Coast from where the distribution of American Maydeae commences. This taken together with knowledge of existence of some similarities of pachytene chromosomes between job's tears and maize (Venkateswarlu *et al.* 1976) and of aposporous embryosacs of job's tears and *Tripsacum* suggests that the genus *Coix* occupies an intermediate position between Asiatic and American Maydeae.

***Coix*, Class work and Demonstration material**

The three species can be obtained from NBPGR, New Delhi and maintained easily. They are well suited for karyotype study, and for pachytene structure and pairing (though not easy) and other stages of meiosis. It is also suitable for study of chromosomal translocations, their orientation and segregation at meiosis in *C. aquatica*, intra- and interplant variations in chromosome number, bivalent pairing in aneuploids and polyploids and racial existence in *C. aquatica* and *C. gigantea*. Vegetative propagation and apomictic reproduction, induction of autotetraploidy, chromosome associations in tetraploids, triploids and aneuploids at meiosis, and different varieties based on fruit case morphology in *C. lacrymajobi* can be studied, interspecific hybridization and study of intra- and intergenomic pairing in the F_1 hybrids taking advantage of chromosome number and size differences and assessment of relationships, study of chromosome composition in the alien-addition and substitution lines, pollen fertility in hybrids, and other different chromosome categories are possible. It is also not difficult to maintain the special stocks, like chromosome races, hybrids etc. for a couple of seasons by separating and replanting the rooted culms.

The students can examine the material by themselves or the teacher can demonstrate the same from permanent slides and live specimens.

Judging from all these features *Coix* could be an excellent material for training of students in several aspects and phenomena of classical cytogenetics.

Dedication and Tribute

I wish to dedicate this article to the memory of my revered teacher, mentor and erstwhile colleague late Professor J. Venkateswarlu (1912-1978), Head of the Department of Botany (1951-1972), Andhra University, Visakhapatnam, express my gratitude and pay tribute on his birth centennial (21-3-2012). I am grateful to him for introducing me to the fascinating genus *Coix*. He was one of the most renowned personalities in Plant Sciences in India. He rendered laudable service to the Indian Botanical Society in various capacities. He never accepted anything less than perfect in research and never missed even minute detail. Dr. M. S. Swaminathan once referred him as a scientist among scientists. His name became synonymous with pachytene chromosome analysis of crop plants and inspired many in this direction. He developed the Botany Department not only as a PG teaching establishment but also as a first-class research institution, which was recognized by the U.G.C. in 1972 as one of the major Centres of Excellence in Cytogenetics. The Department, which over the years expanded further into other fields as Agricultural Biotechnology, Horticulture etc., and the Cytogenetic Centre into biochemical and molecular aspects, stands today as a tribute and symbol to the challenge and success of his academic and scientific endeavours.

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