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SOME OBSERVATIONS ON SYSTEMATICS OF *CROTALARIA* SPECIES

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This paper deals with the systematics of 22 species available in the National Herbarium of Cultivated Plants (NHCP), NBPGR, New Delhi. An effort has been made to work out linkage of *C. juncea* L. with other related species using important vegetative and reproductive key characters. A Himalayan specis *C. tetragona* Roxb. ex Andrews appears to be the closest wild related species of the cultivated *C. juncea*. The section Calycinae to which *C. juncea* belongs, is well represented in India. Another section called Crotalaria shares many characters intermediate to this group is also concentrated mainly in the peninsular region. Besides distribution of different sections such as Grandiflorae, Hedriocarpae, Macrostachyae, etc. has also been discussed. A working key for identification of Indian species was developed based on this study.

Key words : *Crotalaria*, systematics, diversity/distribution

The genus *Crotalaria* Dill. ex L., a large group of annuals or perennial herbs/sub-shrubs, shrubs is distributed in tropics and subtropical regions of the world showing major distribution in tropical Africa followed by centre of variability in the south east Asia and Central America. The genus belongs to tribe Genisteae in subfamily Papilionaceae of Leguminosae. Of about 450 species, over 300 occur only in Africa. About 90 species occur in India, of which over 30 are confined to the peninsular region. Many species are important source of fibre, green manure, fodder, paper pulp, ethnomedicines, etc. Some of the important species such as *C. juncea, C. striata, C. burhia, C. retusa, C.spectabilis, C.verrucosa* are available form variable habitats. *C. juncea* is the most widely cultivated fibre plant in India, Pakistan and Brazil. Baker (1914) has reviewed the taxonomic history and monographical work on the African species as Bentham (1943) has enumerated species from South Asia and Central and South Africa. Senn (1939) has also worked on North and Central American species of *Crotalaria*. There is no comprehensive work on Asian group although Hooker (1879), Gamble (1957) and Cook (1958) have described the Indian species in their floristic works. Since then the efforts by various workers are

lying segregated for researcher's use. Therefore, a completely new treatment of the entire genus though difficult but would be desirable.

The most important species *C. juncea* L., commonly cultivated for bast fibre is a shrubby annual, varying in height from 1.8-3.6 m with bright yellow flowers. Sunhemp of commerce derived from its stem is highly economic fibre with great value in export. Besides this, diverse uses are reported from other species including some wild and cultivated species. *C. juncea*, a source of Indian hemp (also called Madras hemp, Brown hemp), yields a fibre which is more durable than jute, fairly resistant to moisture, mildew and micro-organisms and is much hardy even in salt water (Wlth. India, 1950). It is the oldest fibre cultivated in Indo-Pakistan subcontinent (Watt, 1889). This species has never been reported in wild form nor does its origin known. Tremendous variability has been reported from this region. In the present work, effort has been made to study the species available using certain important vegetative and reproductive characters as key markers to delineate different groups and the species. Based on this, wild species closer to the cultivated *C. juncea* were pinpointed. Effort has been made to establish linkage within these species. A working key has been presented for ready use.

Distribution of Diversity in Cultivated and Wild taxa

Several plant species are native to Asian Tropics. There are about 2,000 plant species that are known to be endemic to the Indian region. About 90 species belonging to the genus *Crotalaria* occur in varied habitats. Amongst these, 35 species are endemic to peninsular region, Assam and temperate Himalayas. India stands second to tropical Africa in its richness of diversity of *Crotalaria* species. Species endemic to peninsular region and confined to Nilgiris and Palni hills are *C. maduraensis* Wight, *C. sandoorensis* Bedd. ex Gamble, *C. grahamiana* W. & A. Species having wider distribution from north western Himalayas to the tropical region are *C.retusa* L., *C. spectabilis* Roth, *C. albida* Heyne ex Roth, *C. mysorensis* Roth, *C. medicaginea* Lamk., *C.striata* DC. The Calycinae and Crotalaria are major sections represented in India with tremendous diversity in each type (Table 1). Other sections such as Hedriocarpae, Incanae, Grandiflorae, Macrostachyae are poorly represented. *Crotalaria* are mainly concentrated in the peninsular region whereas Calycinae occur more widespread in diverse habitats. Several species were found to be widely adaptable to different habitats; some of them are even available up to 3000 m altitude in the Himalayan region. *C. albida* and *C.medicaginea* represent many ecotypes occurring even at high altitudes of sub-temperate regions (1500 - 2000 m), peninsular and Myanmar region. Their absence from north eastern region is indicative of their specific habitat requirement for low humid/low rainfall conditions.

Table 1. Classification and distribution of *Crotalaria*

Sections (after Baker, 1914)	Sections* (after Polhill, 1968)	Main area of distribution	Habitat
Diffuae	Calycinae,	Peninsular region,	Open forest land, grassy slopes, dry
	Crotalaria	N W Himalayas	forest areas
Alatae	Crotalaria	Peninsular region	Dry grass lands
		N W Himalayas	
Calycinae	Calycinae	Peninsular, Diverse	
	Crotalaria	North-west & North-eastern regions	margin of swamps, forest clearings
Glaucae	Crotalaria	Peninsular region	Grassy areas, coastal land
Erectae	Crotalaria	Peninsular; (few Himalayan species)	Swamps, open dawns, hill slopes
Eriocarpae	Crotalaria,	Peninsular region,	Open dawns
	Calycinae	Himalayas	Waste places, dry habitat
Trifoliolatae Dispermae	Dispermae,	Peninsular, NE & N W Himalayas	Low hills & coastal areas
	Diffusae		
Trifoliolatae Polyspermae	Calycinae, Crotalaria, Incanae, Hedriocarpae, Grandiflorae	wide spread	Hill slopes, forest areas, grassy lands
Multifoliolatae	Crotalaria	Peninsular region	Slopes, coastal areas, semi-ever green forests

* Classification based on specimens studied

Crotalaria : generally confined to peninsular region, more bushy types, erect

Calycinae : adaptable to diverse habitat, semi-diffused types

Other groups: scattered all over

Variability was found in *C.ferruginea* for drought resistance, *C.burhia* for dry low rainfall requirements, *C. triquetra* for salt tolerance. Ecotypes in marshy/coastal parts of peninsular region are available. Some of the endemic types such as *C.sandoorensis, C. penduclularis* Grah. ex W. & A., *C. lutescens* Dalz. are now reported to be rare and endangered probably due to habitat disturbance (Nayar and Sastri, 1987).

MATERIAL AND METHOD

Species included in this investigation are listed in table 2. The material was used from the National Herbarium of Cultivated Plants (NHCP), at NBPGR, New Delhi. Seeds of some species were grown in pots and the fresh flowers used for study. Besides, material was also used for comparative studies from other national and international herbaria.

Table 2. Species studied for vegetative and reproductive Characters

Section		Species
Arinariae	Calycinae	*C. burhia* Hamilt.
Diffusae	Calycinae	*C. filipes* Benth.
		C. prostrata Rottle ex Willd.
Alatae	Calycinae	*C. alata** Buch.-Hamilt. & Roxb. ex D. Don
Calycinae	Calycinae	*C. calycina* Schrank
		C. albida Heyne ex Roth
		C. hirta Willd
		C. pusilla Heyne ex Roth
		C. nana Burm.
		C. mysorensis Roth
		C. sessiliflora L.
Glaucae	Crotalaria	*C. lutescens** Dalzell
Erectae	Crotalaria	*C. retusa* L.
		C. sericea Retz. = *spectabilis* Roth
Eriocarpae	Calycinae	*C. juncea* L.
	Crotalaria	*C. verrucosa* L.
		C. triquetra Dalzell
		C. fulva Roxb. = *berteriana* DC.
		*C. tetragona** Roxb. ex Andrews
Trifoliolatae (Dispermae)	Dispermae	*C. medicaginea* Lamk.
	Calycinae	*C. orixensis* Willd.
(Polyspermae)	Incanae	*C. incana* L.
	Macrostachyae	*C. striata* DC.
	Grandiflorae	*C. laburnifolia* L.
Multifoliolatae	Crotalaria	*C. quinquefolia** L.
		C. grahamiana W.&A.

* Material used from other herbaria

For study of herbarium material, customery method (Lawrence, 1964) involving floral dessections was used. This involved removal of dried flowers from herbarium specimens, treating with hot water (40°C) for 40-50 minutes, dessecting well spreading them with help of needle and brush on glass slide. The dried dessections (using blotters) were mounted on glass slide/paper and examined under the dissecting microscope (with 10 X and 20 X magnifications).

Based on study of vegetative and reproductive key characters (Table 3), the species were classified into seven sections (Table 4). A schematic diagram was drawn to illustrate the relatedness of different sections (Fig. 1). Species closely related to *C. juncea* were studied and compared. The line diagrams of different representative species studied, have also been illustrated (Fig. 2).

RESULTS AND DISCUSSION

Species with apparently diverse morphology were classified into different sections/groups by several earlier workers. Based on study of vegetative as well as floral/reproductive characters alongwith anatomy of plant parts, species were classified into different sections. Thus majority of the species were placed in sections Calycinae and Crotalaria which represented 36 per cent and 39 per cent of the total species diversity in this region. Others sections such as Hedriocarpae, Incanae, Grandiflorae, etc. were poorly represented. In general, the sections Crotalaria represented by more bushy, erect types having specific habitat requirement and less adaptability to diverse ecological conditions. Majority of taxa in this sections were confined to peninsular region. On the contrary, Calycinae with diffused to semi-diffused habit, were more adaptable to diverse habitats. They were wide-spread as compared to the previous group. Based on analysis of the distribution pattern, two centres of diversity and variability were pinpointed- the Peninsular region and the Eastern region.

Table 3. Important key characters used for study of different species of *Crotalaria*

Vegetative characters :	*Reproductive characters* :
Habit	Inflorescence
Stem	Flower
Stipule	Calyx
Leaf	Standard
Leaflets	Wing
Indumentum	Keel
	Style
	Stamen
	Pod
	Seeds/pod
	Size of seeds
	Colour of seed
	Texture of seed coat

Table 4. Sectional distribution of certain floral and vegetative characters in genus *Crotalaria* in India

Sections	Stipule	Calyx	Corolla/ Standard (with respect to appendages)	Beak of the keel	Style	No. of species in India/ Introduced species
Gradiflorae	0	equally lobed	Appendages extending on to claw	Untwisted	Curved	1, 2*
Incanae	+	2 lipped	"	Twisted/ Untwisted	Curved & geniculate	1, 1*
Hedriocarpae	+	equally lobed	"	Twisted/ Untwisted	Curved	3, 1*
Macrostarchyae	±	equally lobed	"	Untwisted	Curved	1*
Calycinae	0/+	2 lipped	Appendages on blade only (reduced)	Twisted	Curved & geniculate	36
Crotalaria	+	Calyx tube protracted on the lower side	"	Twisted (sometimes) or untwisted	Curved & geniculate	38, 1*
Dispermae	–	"	"	Twisted	Geniculate	5

* Introduced species

The floral morphology indicated that Calycinae and Crotalaria represented the highly specialised groups with complex floral structure. The former with deeply cleft calyx as long as keel differed from the latter in having calyx protracted downwards. The section Dispermae, closer to Crotalaria appeared to be a specialised one with low seed numbers. The other sections represented comparatively simpler floral morphology.

C. juncea after critical examination of vegetative and reproductive parts was found to be an intermediate species between Crotalaria and Calycinae. Characters such as type of stipule (narrow, minute), standard (lined/veined from outside), bracts and bracteoles bring it closer to Crotalaria than to Calycinae. Based on morphological, taxonomical, anatomical studies, a Himalayan species *C. tetragona* appeared to be the closest among species related to *C. juncea*. So far only a few workers (Rani Mangotra and Bhargava, 1989) have used other markers like the flavonoid characteristics to classifying genus *Crotalaria*. Their studies also supported the closeness of the two species.

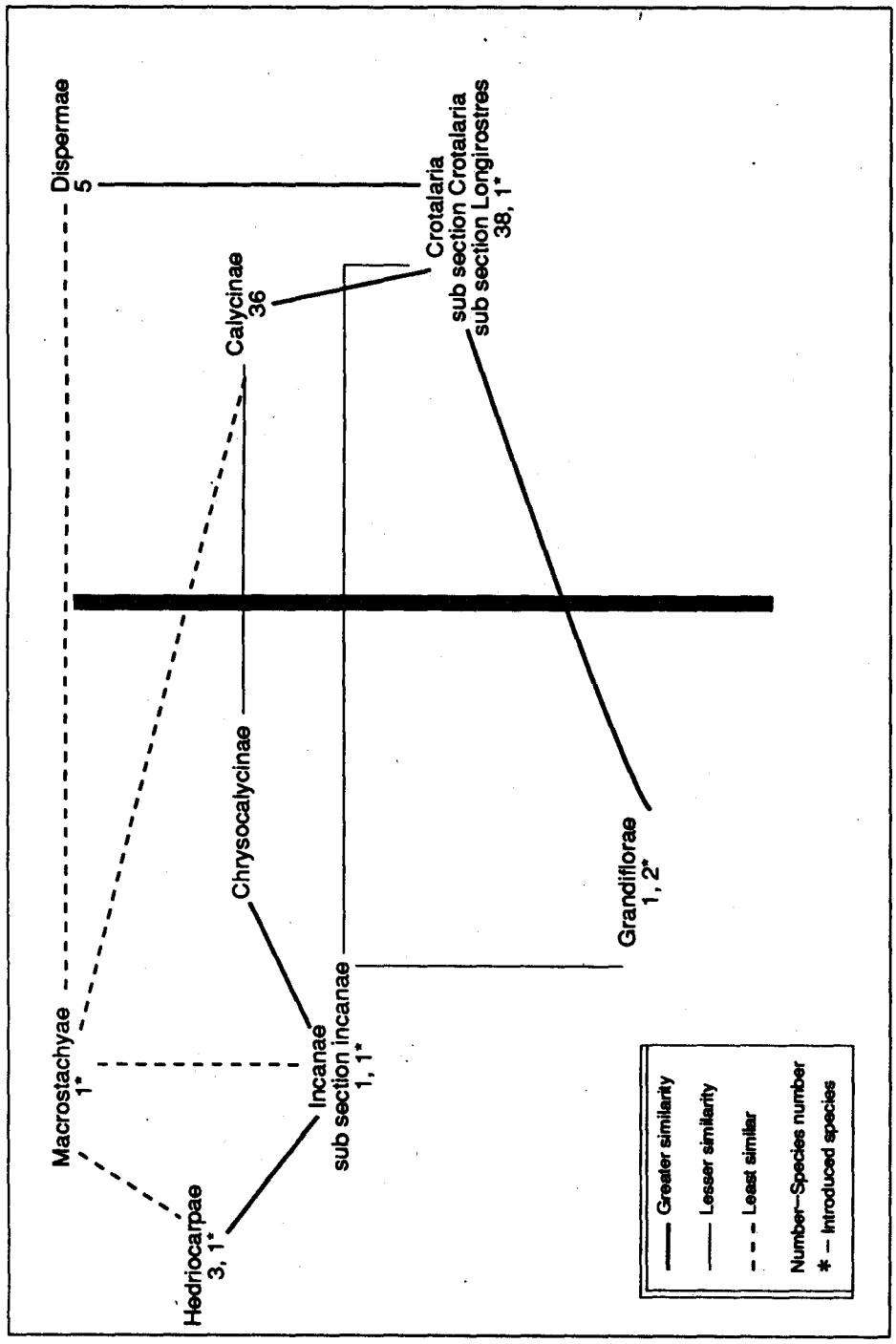


Fig. 1. Schematic arrangement of various sections (Polhill, 1968) and species in genus Crotalaria in India

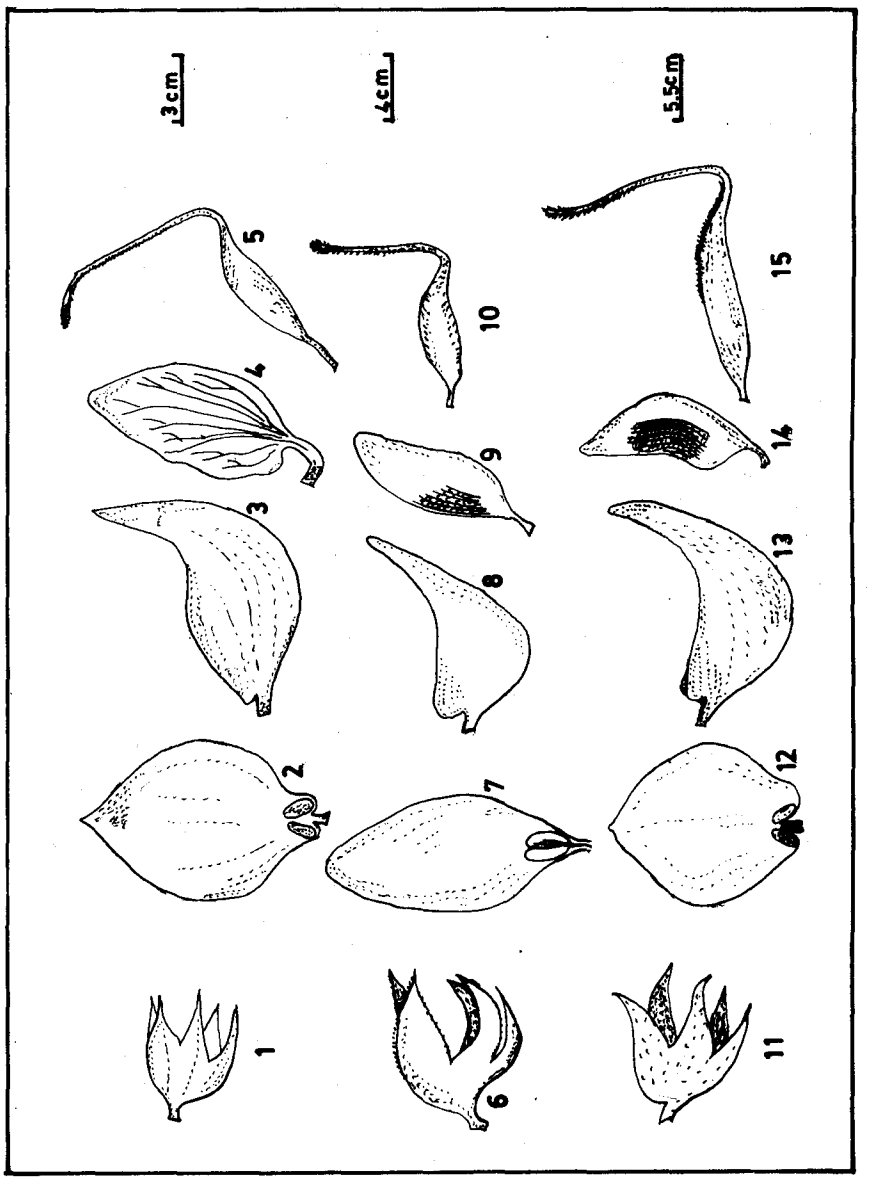
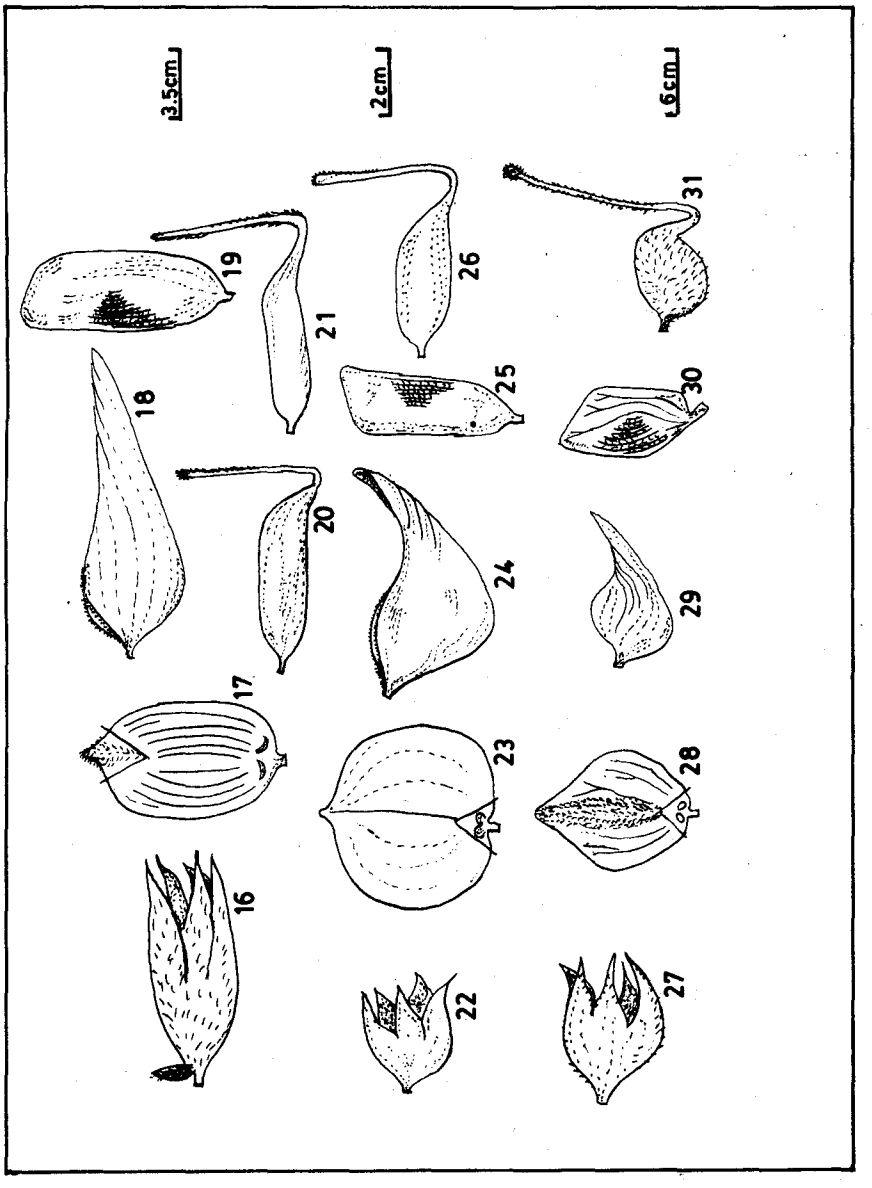


Fig. 2. Line Diagrams of Floral parts of some *Crotalaria* species : C. laburnifolia (sec. Grandiflorae), 1. Calyx; 2. Standard (inner view); Keel (side view); 4. Wing; 5. Gynoecium. C. *incana* (sec. Incanae), 6. Calyx; 7. Standard; 8. Keel (side view); 9. Wing; 10. Gynoecium. C. *striata* (sec. Macrostachyae), 11. Calyx; 12. Standard (inner view); 13. Keel (side view); 14. Wing; 15. Gynoecium. C. *calycina* and C. *albida* (sec. Calycinae)



16. Calyx; 17. Standard (inner view and a part of top outer view; 18. Keel (side view); 19. Wing; 20 & 21. Gynoecium of *C. calycina* and *C. albida*. *C. grahamiana* (sec. Crotalaria), 22. Calyx; 23. Standard (outer with a sector of inner basal view); 24. Keel (side view); 25. Wing; 26. Gynoecium. *C. medicaginea* (sec Dispermae), 27. Calyx; 28. Standard (outer with a section of inner basal view); 29. Keel (side view); 30. Wing; 31. Gynoecium

Key to the species

1 Leaves multifoliolate

1A Leaves 5-7 foliate

2 Leaflets 5, linear-oblong or rarely narrow, oblanceolate; petioles with narrowly lanceolate stipules

..... *C. quinquefolia*

2 Leaflets 5-7, oblanceolate, petiole long & stout with very thin, stipule linear, stem angular

..... *C. grahamiana*

1A Leaves 3 foliate, petiole articulate

3 Seeds 2; pod obliquely sub-globose, small, sessile, beaked, seeds in different shades of gray to brown

..... *C. medicaginea*

3 Seeds many;

4 Pod and stalk less than 2.5 cm, seeds 8-10, mottled, cylindrical, obtuse at both ends, glabrous

..... *C. orixensis*

4 Pod and stalk more than 2.5 cm

5 Stalk of pod shorter than 2.5 cm

6 Pod and stalk less than 2.5 – 3.5 cm, pod cylindrical, recurved, loosely pubsecent, 20-30 seeded, seeds yellowish to dark brown, leaflets membranous, obovate

..... *C. incana*

6 Pod and stalk 3.5-5 cm, cylindrical-falcate, puberulous when young, seeds many, leaflets thick, obovate-emarginate, seeds brown

..... *C. striata*

5 Pod stalk more than 2.5 cm;
Pod cylindrical, 20-30 seeded, glabrous, gynophore filiform, seeds grayish, mottled, glabrous, flowers very large with prominent incurved keel

..... *C. laburnifolia*

1 Leaves unifoliolate; petiole not articulated

7 Stipule decurrent as persistant wing on the branchlets/stem

7 Stipule none or small, not decurrent

8 Raceme terminal and lateral

9 Raceme terminal and lateral, many flowered, low shrubs, deciduous, stifly branched with erecto-patent branchlets- terminal, leaf opposed, often 1-flowered; postrate herbs, leaves obliquely ovate to cordate, rigid

10 Pos small, 10 seeded, shortly stalked, 1-3 flowers, seeds dark brown

..... *C. filipes*

10 Pods longer up to 20 seeded, sessile/nearly so, pods linear oblong, peduncle finely silky, 2-4 flowered, seeds greenish maroon and shiny

..... *C. prostrata*

8 Recemes mainly terminal or a few lateral, many flowered, rarely in age opposite leaves

11 Pods glabrous or very nearly so, stipule none or very minute (may be deciduous)

12 Pod several times longer than calyx, rarely twice long as long as calyx

13 Erect herbs/shrubs, glabrous throughout, leaves membranous, narrow-lanceolate, 6-15 flowers distantly arranged, gynophore=calyx, pod-attenuate, broadening upwards

..... *C. lutescence*

13 Erect herbs/shrubs with silky /pubescent foliage

14 Stipule and bracts minute, linear, leaves retuse at apex, obtuse, glabrous above, puberulent below, pods distantly stalked, linear-oblong, flowers 12-20, seeds in shades of brown, not shiny

..... *C.retusa*

14 Stipule and bracts ovate-acuminate, reflexed, foliaceous, leaves acute, mucronate at apex, pubescent beneath, many flowered, pods rounded at base with flat stalk, seeds dark brown-black, shiny

..... *C.spectabilis*

12 Pods shorter or little longer than calyx, rarely twice as long, glabrous/pubescent, diffused annuals

15 Upper calyx lobe connate except at tip, flowers very small, leaf opposed, in umbells, corolla shorter than calyx, pods slightly exerted, 10-12 seeded, black

..... *C. nana*

15 Upper calyx lobe not connate or only from below; pods shoter than calyx

17 Plants with densely silky hairs, turn golden brown on maturity

18 Flowers not yellow;

Herbs very small with adpressed brown silky hairs, stipule 0, flowers white with pink tinge, become wooly on maturity, 4-8 seeded

..... *C. pusilla*

18 Flowers yellow

19 Diffused undershrubs, thinly clothed with short spreading hairs, stipule setaceous, deciduous,raceme capitate, 2-4 flowered, corolla yellow, pods oblong, seeds 15-20, maroon

..... *C. hirta*

19 Erect plants with long silky, erecto-patent hairs, stipule persistant, linear, flowers many, corolla yellow with maroon streaks, pod ovate, seeds 30 or more, shiny, maroon

..... *C. mysorensis*

17 Plants with short adpressed silky pubescence, turn gray on drying; no stipules, few seeded;

Low diffused undershrubs, flowers 15-20 in laxy terminal/rarely lateral racemes, leaves thick, cuneate, gland- dotted, pods 8-10 seeded, seeds greenish brown

..... *C. albida*

11 Pods hairy

Pods = or shorter than calyx

20 Flower in raceme

21 Flower yellow

22 Flowers in single racemes, terminal or lateral or terminal and lateral both;

stipule ovate or lanceolate, branches 3-angled, very slender, flowers pale yellow, pod thinly silky/ velvetty, seeds blackish brown

..... *C.triquetra*

22 Flower in racemes, generally branched, stiff shrubs with pubescent slender branches, raceme laxy, terminal/ lateral, calyx very deep, densely silky, velvetty with persistant hairs

23 Seeds more than 20

Flowers large (2.5 cm), leaves variable, standard yellow ovate, rounded/ emarginate, with tuft of hairs on back, otherwise glabrous, pods 20-30 seeded, seeds ivory coloured, shiny, whole plant silky.

23 Seeds not more than 20

24 Leaves membranous, calyx 2-2.5 cm, corolla lemon yellow, standard orbicular with blunt apex, scanty hairs on back, pods 12-20 seeded, seed blue-black

..... *C.tetragona*

24 Leaves firm, calyx 1-2 cm, corolla bright orange/ yellow, with maroon stripes, standard ovate-elliptical with acute apex, long dense hairs on mid rib on back, otherwise scattered, 10-20 seeded, seeds brown-black

..... *C.juncea*

21 Flower not yellow

25 Corolla not exerted, standard glabrous except a few tuft of hairs on back (tip), emarginate, moderately firm leaves;

Leaves narrow on both the ends, flower blue or white, in elongated racemes, pod = calyx, seeds blackish gray/gray, stipule setaceous, minute

..... *C.sessiliflora*

25 Corolla exerted, blue/white with violet rays, standard glabrous, pod much longer than calyx, glabrous at maturity, seeds 10-15, deep yellow, rugose, leaves variable - elliptical to lanceolate, membranous, stipule semi - lunate, stem / branches angular

..... *C. verrucosa*

20 Flowers in panicle

Pods short, scarcely if at all longer than calyx, leaves obovate- lanceolate, densely silky with shiny golden hairs, stipule subulate, small or 0, erect, standard elliptical, pods with recurved persistant style, seeds 2, shiny, light brown

..... *C. berteriana*

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