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VASCULAR ANATOMY OF FLOWER OF *TRIGONELLA* (PAPILIONACEAE)[1]

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ABSTRACT

The vascular anatomy of the flower of ten species of *Trigonella* is described. All the species fall under Shuteria type' of Unihiate series. Each sepal either receives one or three bundles, petal and stamen are one traced and gynoecium is three traced. A nonvascular disc is found in all the species. Corolla androecium are of simple type except *T. polycerata* in which it is first variation of the medicagoid type. A key for the identification of different species based on floral characters has been given.

INTRODUCTION

Genus *Trigonella* belongs to tribe Trifoliae of family Papilionaceae and is represented by 100 species (Willis, 1973) out of which only ten occur in India (Baker, 1879). Floral anatomy of Papilionaceae has been described by Moore, 1936; Rao *et al.*, 1958; Datta and Maiti, 1968, Datta and Saha, 1970. The Floral anatomy of the other members of trifolieae has been investigated earlier by author *Ononis* (Murty and Gupta, 1975; Gupta, 1980), *Parochetus* (Gupta and Murty, 1978) and *Melilotus* (Gupta, 1977) but floral anatomy of *Trigonella* has remained untouched till today. Sirjaev (1928-33) reported that this genus is characterised by presence of simple as well as medicagoid type of corolla. Baum (1968) observed the presence of simple as well as medicagoid type of androecium. The present study deals with the floral anatomy of ten species of *Trigonella*.

MATERIALS AND METHODS

Suitable floral materials were collected from different places in the country and also from plants raised at Botanical Garden, Meerut Univ rsity, Meerut from seeds as detailed below: (1) *T. arabica*. Dehile (Bet Dagan, Israel), (2) *T. caerulea*, Ser (Ontario, Canada) (3) *T. callicerasoites*, Fish (Ontario, Canada) (4) *T. corniculata* Linn. (Meerut) (5) *T. cretica* (L.) Boiss (Ontario, Canada) (6) *T. foenum-graecum* Linn (Meerut, India) (7) *T. gracilis* Benth (Nainital, India) (8) *T. polycerata* Linn (Meerut, India) (9) *T. stellata* Forsk (Jerusalem, Israel) (10) *T. suavisima* Lindl (Canberra, Australia). Customary methods of dehydration and embedding were employed. Serial transverse and longitudinal sections were cut at 10 μm thickness and stained

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with crystal violet-erythrosin. Floral parts were cleared in lactic acid, stained in 1% aqueous safranin and mounted in glycerine.

OBSERVATIONS

Since the floral anatomy of all the species appears quite similar, therefore, a comparative account is given and variations are marked at appropriate places.

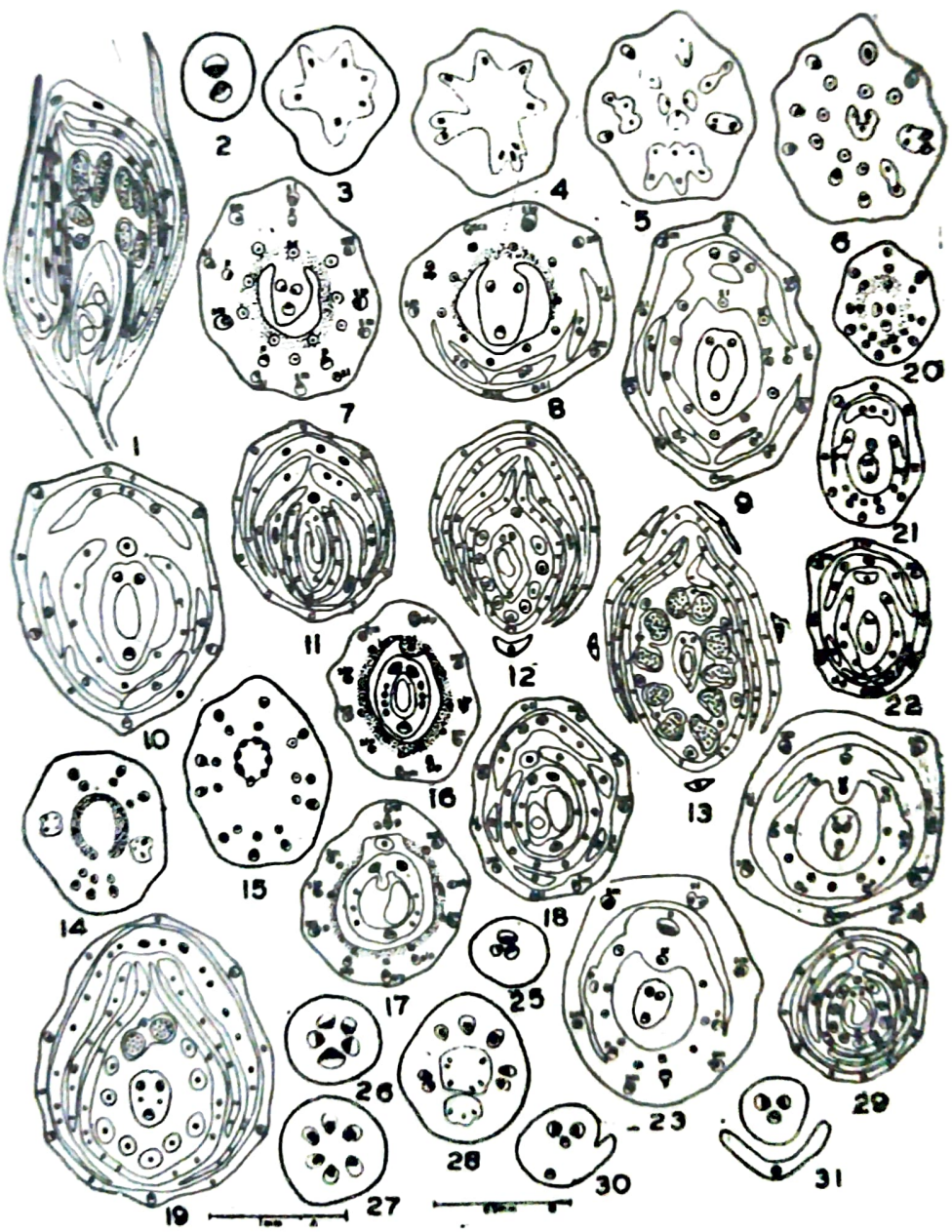
Bract in the axil of the flower is found in *T. arabica T. caerulea* and *T. polycerata* (Figs. 30, 31). In these species a trace moves outward from the vascular cylinder of the pedicel and supplies the bract. Phloem fibers associated with the bract bundle are found in *T. polycerata*. The vascular supply of the pedicel consists of two conjoint, collateral and open vascular bundles as in *T. arabica, T. cretica, T. corniculata* (Fig. 2) and *T. caerulea* or three (remaining species; Figs. 25, 31). Stomata are also found on the pedicel of *T. polycerata*. The bundles of the pedicel divide to form a complete ring as in *T. arabica, T. calliceraseites, T. corniculata* (Figs. 3, 4), *T. caerulea, T. foenum-graecum* and *T. stellata* or form an incomplete ring as in *T. cretica* or become 5 or 6 stranded as in *T. gracilis* (Figs. 26, 27), *T. polycerata* and *T. suavisima*. A lot of cohesion and adnation is observed among the vascular traces of different floral whorls. The receptacular stele gives out six traces by six gaps i. e., one posterior, two posterio-laterals, two laterals and one anterior (Figs. 4, 5, 27).

The posterior and two posterio-laterals do not divide while the anterior one divides radially into three and two anteriolaterals into two each (Figs. 4-6, 27, 28, 32-34). Thus the total number of traces becomes ten. In *T. arabica, T. stellata, T. gracilis* and *T. suavisima* the traces on the anterior side first differentiate from the receptacle while in the remaining species the traces of the posterior side. However, in *T. polycerata* all the traces depart at the same level. In all the species except *T. arabica, T. gracilis* and *T. cretica*, all the ten traces divide radially into an outer perianth trace and an inner stamen trace (Figs. 5, 6, 14-15, 20). In *T. arabica* (Figs. 32-34), *T. gracilis* and *T. cretica*, the six traces which depart from the receptacle first divide tangentially into outer perianth traces and inner staminal traces. Then the outer perianth and inner staminal traces divide radially to form ten traces. Out of ten perianth traces five constitute sepal medians and are distinct by virtue of their centrifugal position in comparison to other five which are conjoint sepal lateral-petal median traces (Figs. 6, 15, 34). Each conjoint sepal lateral median trace resolves into outer conjoint sepal lateral and an inner petal median trace (Figs. 7-8, 17, 35). In most of the flowers of *T. cretica* generally only the posterior conjoint sepal lateral petal median trace functions as conjoint in nature while the remaining four function as petal median trace (Fig. 23). In few flowers only the traces of wing petals are conjoint in nature (Fig. 24) while in other few flowers traces of all petals except one keel petal are conjoint in nature (Figs 21-22). Thus in all the flowers of *T. cretica* variations have been found in the number of conjoint seppl lateral petal median traces.

After furnishing supply to calyx, corolla and stamens the entire receptacular stele organizes and forms the vascular supply of the gynoecium in the form of three traces (one dorsal and two ventrals) except *T. foenum-graecum, T. suavisima* and *T. polycerata* in which gynoecium supply is multitraced (Figs. 5-7, 15-16). Table I indicates the length

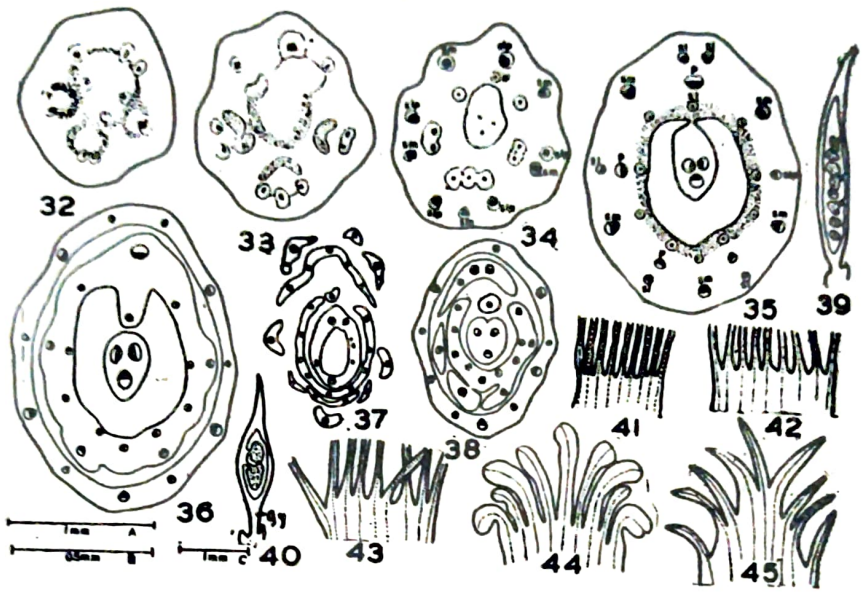
of the origin of different traces and different parts of a flower.

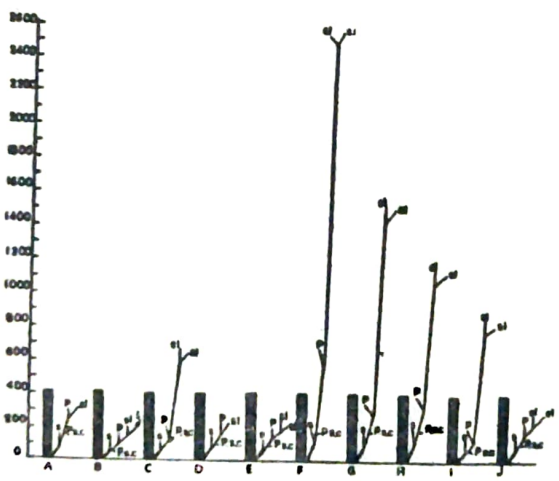
At a slightly higher level the receptacle differentiates into an outer thick region, the floral tube (hypanthium), containing the traces of sepals, petals and stamens arranged in two rings and a central region containing the gynoecium supply (Figs. 7, 16, 35). In all the species the basal part of the floral tube is lined by a deeply staining, adnate glandular disc (Figs. 7, 16, 20, 35). However, in *T. polycerata* disc is found only in 50% of the flowers.



Figs. 1-31. Fig. 1. *Trigonella gracilis*. Semi-diagrammatic longisection of a flower. Figs. 2-13. *T. corniculata*. Serial transverse sections of a flower showing vascular supply to different organs. Figs. 14-19. *T. foenum-graecum*. Transverse sections of a flower at different levels showing disc, hypanthium and multi-traced condition of ovary. Figs. 20-24. *T. cretica*. Transverse sections of a flower showing behaviour of conjoint sepal lateral-petal median, petal stamen tube and disc. Figs. 25-29. *T. gracilis*. T. S. flower showing right handed folded vexillum. Figs. 30-31. *T. polycerata*. Showing supply to the bract.

(Scale A for figs. 1, 11-22, 29. B for figs. 2-10, 23-28, 30-31.)





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Figs. 32-46. Figs. 32-36. *T. arabica*. Transverse sections of a flower at different levels. Fig. 37. *T. stellata* showing 6 sepal lobes. Fig. 38. *T. caerulea* Showing petal-stamen tube. Fig. 39. *T. caerulea* L. S. gynoecium showing gynophore. Fig. 40. *T. arabica* L. S. gynoecium. Figs. 41-45. Staminal tubes split open of different species. Figs. 41-44. Simple androecium. Fig. 41. *T. caerulea*. Fig. 42. *T. suavisima*, Fig. 43. *T. gracilis*, Fig. 44. *T. foenum-graecum*. Fig. 45. *T. polycerata*. First variation of the medicagoid type of androecium. Fig. 46. Histogram showing adnation of different floral parts in the species studied in microns.

A = *T. arabica*, B = *T. caerulea*, C = *T. callicerasoites* D = *T. corniculata*, E = *T. cretica*, F = *T. foenum-graecum*, G = *T. gracilis*, H = *T. polycerata*, I = *T. stellata*, J = *T. suavisima*.

Scale A for Figs. 37, 41-45. B for Figs. 32-36, 38. C for Figs. 39-40.

Abbreviations (sm=sepal median, slp=conjoint sepal lateral petal median, p=petal, st=stamens, sl=sepal lateral).

From the floral tube the calyx tube separates which contains five sepal medians and five conjoint sepal laterals (Figs. 9, 24, 36). In *T. arabica* (Fig. 36), *T. callicerasoites* and *T. suavisima* calyx tube consists of 11 bundles because of the immediate splitting of posterior conjoint sepal lateral while in *T. cretica* due to non-branching of conjoint sepetal median traces the tube may contain 6, 7 or 9 bundles (Figs. 22, 24). Occasionally in few flowers of *T. corniculata* only the traces of standard and one wing petal function as conjoint sepal lateral—petal median trace, thus, in these flowers calyx tube is only 7 veined. The calyx tube shows its first split after the separation of petals from the petal stamen tube at the anterio-lateral side in all the species except *T. foenum-graecum* and *T. callicerasoites* in which it is towards the posterior side (Fig. 12). Just below the level of the splitting of the calyx tube the conjoint sepal laterals branch and supply the adjascent sepal lobes in all the species except *T. arabica, T. corniculata* and *T. cretica*. Thus excepting these three species, each calyx lobe contains one sepal median and two sepal lateral bundles (Figs. 12-13). However, in *T. cretica* and *T. corniculata* conjoints if present are very short and do not reach up to the level of splitting. Occasionally, in *T. stellata* calyx tube is 6 lobed and lobes may contain only one median or one median and one lateral or only lateral bundles (Fig. 36). Phloem fibres associated with only median bundle is found in *T. cretica* and *T. callicerasoites*, with median and laterals in *T. polycerata*, *T. gracilis* and *T. stellata*.

Each petal receives only a single trace. In all the species except *T. foenum-graecum* petal stamen tube is found (Figs. 17, 18) although, variations have been observed in the constitution of the tube. In *T. arabica, T. callicerasoites* and *T. corniculata* this tube contains all the petals and 9 or 10 stamens at the base but at higher level it consists of only keel and wing petals and nine stamens (Figs. 9, 36). *T. cretica* (Figs. 23, 24) and *T. polycerata* also resemble with the former species but in flowers of these species standard and nine petal stamen tube is also found. In *T. gracilis* and *T. stellata* this tube consists of standard petal and nine stamens while in *T. caerulea* (Fig. 37) and *T. suavisima* tube contains 2-4 petals other than the standard and nine stamens. The standard petal of *T. gracilis* shows contortion to the right hand side (Fig. 29). In all the species both keel petals are independent at the level of their separation except *T. callicerasoites*. The epidermal cells of petals are papillate in *T. arabica*. In *T. foenum-graecum* and *T. polycerata* the bundle of the standard petal branches into 3 before entering the corolla tube (Fig. 17). In *T. corniculata* it branches in the corolla stamen tube while in the remaining species after its separation from the petal stamen tube (Figs. 21, 38).

The posterior stamen delimits at a lower level than the other nine which remain connate with one another to form a girdle. This androecial girdle remains to a good height before breaking them into nine distinct filaments (Figs. 10, 11, 18). The arrangement of vascular bundles within the staminal girdle is in two cycles except *T. polycerata* and in few flowers of *T. gracilis*. The posterior stamen is in the line with the five vascular bundles of the inner cycle of staminal bundles (Figs. 10, 11, 18). The inner can be first differentiated from the outer stamens on the basis of their lengths (Figs. 13, 19). Thus the filaments of the outer ring are comparati-

vely longer than those of inner (antespalous). In all the species the staminal girdle showsits spilitting into filament above the splitting of the calyx tube (Figs. 29, 51) except in *T. foenum-graecum* (Fig. 19), *T. caerulea* and few flowers of *T. gracilis*. However, in *T. corniculata* both caylx tube and stamen tube spilt at the same level (Figs. 11-13). In all the species staminal bundle is concentric and extends into the connective of the dithecous anther.

In all the species androecium is simple *Trigonella* type (Figs. 41-43) except *T. polycerata* (Fig. 45) in which it is the first variation of the medicagoid type. In *T. foenum-graecum* filaments are alternately thick and thin (Fig. 44). In *T. arabica* (Fig. 43) and *T. gracilis* nineth filament also separates at a lower level than the others.

Gynoecium is monocarpellary and receives as explained earlier one carpellary dorsal and two carpellary ventrals except the *T. suavisima*, *T. polycerata* and *T. foenum-graecum* where it is multitraced. The carpellary bundles branch and form lateral bundles in *T. calliceraso*ites even below the complete separation of gynoecium from the receptacle. A small gynophore containing three bundles is observed in *T. arabica* (Fig. 36), *T. cretica*, *T. caerulea* (Fig. 39) and *T. stellata*. All the bundles of the gynoecium traverse the ovary and run into the style. Each ovule receives a single trace from the ventral bundle of its side (Fig. 1). These ovular traces arising alternately from two ventrals. Thus ovules are arranged alternately in two rows. The ovular traces enter through the hilum, after entry making a bend and terminate in the chalaza. In all the species micropyle is inferior in position in comparison to the funicle. Stomata are also found on the ovary wall of *T. stellata*. Gynoecium is superior but flowers are perigynous. Only carpellary dorsal bundle extends up to the stigma.

DISCUSSION

From the present investigation some striking features come to the fore front. Moore (1936) reported 10 12 strands at the base of the pedicel in members of Trifolieae, but in the present study none of the species has shown more than three bundles. He divided Papilionaceae into two distinct groups on the basis of the relationship of the traces of the perianth and stamens in the flowers as 'unihiate' and dihiate'. In the former series single whorl of strands from the main axis provide traces to sepals, petals and stamens whereas in the latter perianth and stamens receive vascular supply from two gaps situated one above the another. Randhawa (1969) on the basis of the compounding of traces divided Unihiate' into

(1) *Erythrina* type—with one series of ten gaps each gap being associated with a trace.
(2) *Shuteria* type—with one series of six gaps each associated with a trace.
(3) *Astragalus* type—with only four vascular cords arising from four gaps.

All the species presently investigated are in confirmity with the '*Shuteria* type' of unihiate series. However, Moore (1936) assigned the members of Trifolieae in 'Lathyrus type' of dihiate series. In all the species there are 6 traces associated with six gaps situated one posterior, two posterio-laterals, one anterior and two anterio-laterals. The anterior one divides radially to form three and two anterio laterals into two each. Ten traces so formed undergo tangential splitting to form outer peri-

TAB

Name of species	Origin of com. trace		Origin of pt. and st. traces		Branching of slp.	
	Mean	Rd	Mean	Rd	Mean	Rd
T. arabica	137.50	67.50	207.50	57.50	373.33	96.66
T. caerulea	152.00	70.00	200.00	38.00	352.00	60.00
T. callicerasoites	97.50	60.00	162.50	35.00	233.33	86.66
T. corniculata	142.40	73.33	225.00	65.00	300.00	100.00
T. cretica	183.33	90.00	256.33	80.00	330.00	—
T. foenumgraecum	430.00	180.00	560.00	70.00	1110.00	240.00
T. gracilis	410.00	78.00	496.00	45.00	697.50	120.00
T. polycerata	203.33	93.33	323.33	56.00	530.00	123.33
T. stellata	110.00	50.00	165.00	50.00	230.00	70.00
T. suavisima	200.00	45.00	275.00	60.00	370.00	100.00

Abbreviation : Com=Common trace; pt=Perianth trace; st=Stamen trace; slp=conjoint sepal lateral-
*Mean and relative distance of five readings in microns.

anth traces and inner staminal traces. Petals are found adnate with conjoint sepal lateral. Thus there is condensation as evidenced by fusion of the traces of sepals and stamens. However, *T. cretica* shows reduction because less than five traces are functioning as conjoint sepal lateral petal median traces. Datta and Saha (1970) have regarded condition of shortest common bundles (cords for different whorls) as primitive and longest cords as advanced condition. In the present study by following Datta and Saha's view *T. foenum-graecum* being the highest evolved species of the genus followed by *T. polycerata* (Fig. 46 and Table I) and *T. suavisima* as primitive species. Similarly maximum adnation of sepal lateral and petal median is found in *T. foenum-graecum* followed by *T. polycerata* and minimum in. *T. caerulea* These observations are in confirmity with the earlier observations (Gupta, 1982) based on petal venation of the nine species studied, *T. polycerata* was found to be the most advanced as it had maximum number of anastomoses and medicagoid type of corolla. All the species are similar in presence of a floral tube (hypanthium) and disc surrounding the base of the floral tube. However in *T. polycerata* disc is found only in 50% of the flowers.

The phylogenetic origin of disc nectary in legume flowers is controversial. Some authors mention that they are outgrowths of receptacle, others argue that they represent a reduced whorl of

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Length of sl.		Origin of ovarian traces		Floral tube	Disk	Petal stamen tube (Length)			
						Total	5 petal 9 or 10 st.	Stand ard + 9 st.	Keel or wing + 9 st.
Mean	Rd	Mean	Rd	Mean	Mean				
—	—	202.50	67.50	115.00	170.00	125.00	70.00	—	62.50
392.50	970.00	212.50	47.50	97.50	103.33	36.66	—	—	36.66
690.00	510.00	175.00	35.00	70.00	100.00	80.00	36.66	—	56.60
—	—	232.50	42.50	65.00	75.00	65.00	25.00	—	52.50
370.00	—	283.33	66.60	53.50	136.50	60.00	20.00	60.00	50.00
2920.00	280.00	610.00	70.00	550.00	550.00	—	—	—	—
1837.50	518.00	506.00	34.00	205.00	200.00	72.50	—	72.50	—
1270.00	403.33	273.33	86.66	250.00	185.00	110.00	60.00	70.00	40.00
1090.00	860.00	113.33	50.00	75.00	75.00	80.00	—	80.00	—
425.00	1380.00	210.00	30.00	230.00	110.00	60.00	—	—	60.00

petal median trace; sl=conjoint sepal lateral; Rd=Relative distance;=—absent).

stamens. Moore (1936) concluded, on the basis of anatomy of mature flowers, that in Phaseolae nectary (a) resembles a staminal sheath, (b) is more closely associated with the stamen whorl than with the gynoecium (c) receives its vascular traces as branches from stamen traces. Waddle (1968) from the observations on nectary development interpreted and supported the view that the disc nectary is an outgrowth of the receptacle, not a reduced staminal whorl. Thus without studying the development of nectary only from the anatomical studies made on this genus, it is still difficult to interpret the nature of nectary whether staminal or receptacular.

In all the species except *T. foenum-graecum* interesting feature observed is the presence of a petal-stamen tube. Such a observation has not been recorded in any of the taxonomic works. The constitution of this tube varies in the species examined. Rao *et al.* (1979) have shown that trifolieae lacks corolla handedness but in the present investigation this feature has been found only in *T. gracilis*.

The stamens are single traced. These traces are arranged in two rings and tube is diadelphous. The androecium is of simple *Trigonella* type in all the species except *T. polycerata* in which it is first variation of the medicagoid type. Gynoecium is three traced in all the species except *T. foenum-graecum, T. suavisima* and *T. polycerata*. Sepals are 3 traced except *T. arabica, T. cretica* and

T. corniculata and their marginal traces arise connate with the dorsal trace of the petals. Gynophore is found only in *T. arabica, T. stellata, T. cretica* and *T. caerulea*.

Schulz (1901) placed this genus in Trigonelleae along with *Medicago* and *Melilotus* on the basis of the inferior position of the micropyle with reference to the funicle. The present study has confirmed the micropyle position and supports its placement in Trigonelleae.

The species of this genus are generally identified by fruit morphology but besides fruit morphology few floral characters can also be utilized for the delimitation of some of the species. A key for the identification of the species is as below :

(A) Androecium and corolla medicagoid type..... *T. polycerata.*

(B) Andorecium simple with filaments alternately thick and thin..... *T. foenum-graecum.*

(C) Androecium simple with all filaments equal in length.

(a) Gynophore present.... *T. arabica, T. caerulea, T cretica* and *T. stellata.*

(1) Calyx tube less than 10 veined.... *T. cretica.*

(2) Calyx tube 10 veined..... *T. caerulea, T. stellata.*

(3) Calyx tube 11 veined..... *T. arabica.*

(b) Gynophore absent .... *T. corniculata, T. suavisima, T. gracilis, T. callicerasoites.*

(1) Calyx tube 10 veined.... *T. corniculata, T. gracilis*

(a) Calyx lobe 1 veined..... *T. corniculata.*

(b) Calyx lobe 3 veined..... *T. gracilis.*

(2) Calyx tube 11 veined .... *T. callicerasoites, T. suavisima.*

(a) phloem fibers present..... *T. callicerasoites.*

(b) phloem fibers absent..... *T. suavisima.*

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