

Studies on Morphological Variations in *Tephrosia* Pers. Species of Indian Thar Desert

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ABSTRACT

Variation in morphological characters of eight *Tephrosia* Pers. species of the Indian Thar desert region were investigated in order to make their identification easy in vegetative, flowering and fruiting stages. We examined morphological characters including plant growth form, stem, leaf, floral and fruit characters. Leaf shape, hairiness, petiole length, stipule shape and size were helpful for identification in the vegetative stage, whereas inflorescence type, floral axis length, peduncle length were found to be significant in identification in the flowering stage. Pod and seed characters can be considered for species identification.

Key words: Leaf, flower, fruit, vegetative

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Introduction

The Indian Thar desert is a large arid region that lies between 68°E to 71°E longitude and 24° N to 28° N latitude of western Rajasthan. This desert extends over about 0.32 m km² and covers almost 10 per cent of the total geographical area of India and most densely populated desert of the world (Sharma & Mehra, 2009). This desert has high biodiversity as compared to other deserts of the world and characterized by extreme environmental conditions such as high temperature, low and uneven rainfall, high wind velocity, high evaporation and high water stress conditions throughout the year. Vegetation is sparsely distributed due to limited availability of water. Most plant species appear in the rainy season when the soil gets moisture.

The genus *Tephrosia* Pers. (Fabaceae, Papilionoideae, tribe Millettieae) is distributed in tropical and subtropical regions of the world. This genus comprises of 300 to 400 species (Mabberly, 2005). In India there are about 27 species, one subspecies and one variety of *Tephrosia* are reported (Kumar & Sane, 2003), among them 10 species were reported in Rajasthan (Singh & Shetty, 1987). Eight species of *Tephrosia* were reported from the Indian Thar desert (Bhandari, 1978). The species namely *T. falciformis* S.V. Ramaswami, *T. leptostachya* DC., *T. purpurea* (L.) Pers., *T. strigosa* (Dalzell) Santapau & Maheshwari, *T. subtriflora* Baker, *T. uniflora* Pers. subsp. *Petrosa* (Blatt. & Hallb.) Gillett & Ali, *T. villosa*

(L) Pers., *T. wallichii* Graham ex Fawcett & Rendle were considered for study.

Most species of this genus locally known in Rajasthan as 'biyani' or 'sarphanko', grow as wasteland weed, some in rocky and sandy habitats (Bhandari, 1978). These species exhibited various types of growth habits, erect herb to under shrub. This genus is characterized by imparipinnate leaves, leaflet opposite, leaf opposed raceme or solitary or geminate flowers in the axil of leaves, calyx tube campanulate with subequal and distinct teeth, clawed petals with sub-orbicular standard, stamen diadelphous, ovary linear with many ovule, flattened 2-valved pods with many seeds (Hooker, 1879).

The present study was conducted as a revisionary work with some additional characters. In present investigation district Bikaner was also included which was not considered in previous study, that was done almost 40 years back (Bhandari, 1978). As it is understood that in the long duration of time environmental conditions might be changed, and these changes affected the occurrence and phenology of flora of that region which expressed in their morphological traits. In this long duration of time, many small changes would have appeared and disappeared. Thus it is necessary to revise the previously reported information so that any significant changes, if occur in any taxa with time duration could be found out and used as an aid for the

identification of taxa. The study was aimed to report any major or minor changes in morphological traits in *Tephrosia* spp. so that any variation from the earlier studies could be reported as well as further comparison could be possible.

Materials and Methods

Plant collection and identification:

Plant samples were collected from various sites of Jodhpur, Jaisalmer, Barmer and Bikaner (Table 1). Field visits were conducted twice—once at the flowering stage and once at the time of fruit ripening. Notes were made at the collection site on the habitat, associated plant species and surrounding vegetation. Plant identification was done by taxonomists of Botanical Survey of India, Jodhpur with authentication number BSI/AZRC/I.2012/Tech/2019-20 (PI.Id)/526 except *T. wallichii*, which was identified using the Flora of Indian Thar desert and specimen number 729, collected on 03.08.60 by M.M. Bhandari, Jodhpur. Voucher specimens of collected plant samples were deposited in the herbarium of the Department of Botany, Jai Narain Vyas University, Jodhpur.

Table 1. Location of collection sites of different *Tephrosia* spp.

Districts	Collection sites
Jodhpur	Massuria hills, Kailana, Machia safari park, Arna jharna, Bhoothnath, Siddhanath, New campus (JNVU), Jaleli Faujdaran village, Shikargarh, Mandore, Osian, Bilara, Khariya Meethapur, Padamsar, Shergarh, Jhalamand, Dechu, Kali beri, Doodabera, Dediya
Jaisalmer	Pokhran, Khoodi, Kuldhara, Desert national park, Parewar, Sonu, Amarsagar, Chacha, Phalsund
Barmer	Balotra, Chauhtan, Sheo, Beebara, Kiradu, Siwana, Mokalsar
Bikaner	Mukam, Jaseraser, Kakra, Kolayat, Ranjeetpura,

For study, three plants were selected per population and minimum five populations were selected, consequently 15 readings were considered for estimation of morphological variations. Some morphological observations were made in the field such as plant growth habit, plant height, stem colour, surface, flower colour and time of opening of flower buds. For the study leaf, flower and reproductive characters and for herbarium sheets preparation, plant samples were collected with

flower or fruit or both. The present study incorporated androecium and gynoecium characters such as length of staminal tube, cohesion, free stamen length, carpel length, ovary size and hairiness of ovary in addition to earlier reported characters, such as habit, stem, leaf, inflorescence, flower, calyx, corolla, pod and seed characters (Bhandari, 1978). All measurements of morphology were taken using a scale.

Results

The plant species found with *Tephrosia* species included *Crotalaria burhia*, *Ziziphus nummularia*, *Senna* spp., *Prosopis cineraria*, *Aerva persica*, *Calotropis procera*, *Capparis decidua*, *Calligonum polygonoides* and *Leptadaenia pyrotechnica*. *T. uniflora* ssp. *petrosa* was particularly found in association with *Euphorbia caducifolia* in rocky habitat. *T. strigosa* was mainly growing on rocks with wild grass such as *Cenchrus* spp., *Eragrostis* spp., *Aristida* spp., *Brachiaria* spp. and *Digitaria* spp. along with *T. uniflora* ssp. *petrosa*. *T. purpurea* and *T. leptostachya* were growing together at many locations along with *Boerhavia diffusa*, *Tribulus terrestris* and *Indigofera* spp.

Morphological variations in vegetative and reproductive stages were observed for eight species of *Tephrosia* and are presented in Tables 2-5.

Growth habit of studied species varies from the caespitose habit of *T. strigosa*, procumbent suffruticose in *T. uniflora* ssp. *petrosa* to undershrub *T. falciformis*, *T. villosa* and *T. wallichii* (Table 2; Fig. 1). When the stem becomes mature it becomes stripped in *T. falciformis*, *T. villosa* and *T. wallichii*. The stem of *T. leptostachya* was significantly dark purplish-red when grows in open sandy plains, whereas stem was densely clothed with hirsute hairs in *T. subtriflora*. In *T. strigosa* young stem was green and covered with white small hairs, while in mature stem hairs were absent and it was reddish-brown in colour (Table 2; Fig. 2).

Tephrosia species can be identified on basis of the morphological characters studied. When flowers or fruits are not available, leaf characters are useful identification because the characters like leaf type, leaflet shape, number, apex, pubescence, petiole and rachis length, stipule shape and size differ in the studied species (Table 2; Fig. 3). In flowering condition identification was easy due to the two inflorescence type - raceme and axillary, in the second type pair or fascicles of flowers were present in leaf axil (Table 3; Fig. 4). In raceme

Table 2. Vegetative characters of the studied species of *Tephrosia*.

Character	<i>T. fulcifformis</i>	<i>T. leptostachya</i>	<i>T. purpurea</i>	<i>T. strigosa</i>	<i>T. subtriflora</i>	<i>T. uniflora ssp. Petrosa</i>	<i>T. villosa</i>	<i>T. wallichii</i>
Growth form shrub	Annual under	Annual Herb	Perennial Herb	Annual caespitose herb	Annual or Perennial	Annual Herb shrub	Perennial under shrub	Perennial under
Stem Habit	Erect, Suffruticose much branched	Erect, Suffruticose	Erect, Suffruticose	Prostrate hairy, wiry	Erect, densely clothed with hair, Suffruticose	Procumbent & wiry, Suffruticose	Erect, densely hairy when young	Erect or prostrate branches Suffruticose densely hairy
Stem color	Silver red – green when young, stripped when mature	Reddish when young, grayish-green when mature	Green when young, grayish green when mature	Light green, reddish at base when matures	Dark green	Young branches sometime red, mature stem at base	Green when young stripped brown when mature	Red when young, stripped when mature
Plant height (Feet)	3.1(4.2)5.4	1.2(2.1) 2.7	2.5(3.2)3.8	1.3(1.6)2.4	0.9 (1.1)1.4	1.1(2.0)2.8	3.6(3.9) 4.6	2.5(3.0)3.3
Leaf Type	Compound Imparipinnate	Compound Imparipinnate	Compound Imparipinnate	Simple unifoliate	Compound Imparipinnate	Compound Imparipinnate	Compound Imparipinnate	Compound Imparipinnate
Leaf arrangement	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate
Leaflet Number	7-11-13-15	9-11-13-15	7-9-13-15-17	1	3-5-7	3-5-7-9	11-15-17	15-17-19
Stipule shape	Long Linear	Subulate spreading	Subulate, erect or reflexed	Subulate, erect	Subulate reflexed, hairy	Linear, erect	Subulate, erect	Subulate, erect
Stipule Size (cm)	0.4 (0.5) 0.6	0.2 (0.3) 0.4	0.3 (0.3) 0.4	0.1(0.1) 0.1	0.3 (0.3) 0.4	0.3 (0.3) 0.4	0.3 (0.3) 0.4	0.6 (0.7) 0.8
Petiole length (cm)	1.9 (2.7) 3.5	0.7(1.2) 1.8	1.3 (1.6) 2.1	0.2 (0.2) 0.3	2.2 (2.8) 3.6	0.4 (0.8) 1.3	0.6 (0.8) 1.0	1.0 (1.4) 2.0
Rachis length (cm)	7.0 (10.0) 12.0	2.2 (3.9) 4.9	5.8 (7.0) 8.5	—	1.5 (2.3) 3.5	1.0 (1.3) 1.6	6.0 (6.8) 8.0	7.4 (8.3) 9.1
Petiolule length (cm)	0.2 (0.3) 0.4	0.1 (0.1) 0.1	0.2 (0.1) 0.2	—	0.1 (0.1) 0.1	0.1 (0.1) 0.1	0.1 (0.1) 0.1	0.2 (0.2) 0.2
Leaflet shape	Oblanceolate	Obovate	Oblanceolate-elliptic, obovate	Lanceolate	Oblong -lanceolate	Elliptic-oblanceolate	Oblanceolate - obovate	Elliptic-Obovate
Leaf apex	Mucronate	Emarginate	Mucronate	Apiculate	Mucronate	Mucronate	Mucronate	Mucronate
Leaflet colour	Silver whitish -green	Dark green	Green	Light green	Green	Dark green	Dark green	Light green
Upper leaflet surface	Dense adpressed hair	Hairs sparsely distributed	Glabrous	Glabrous, few hair near margins some time	Glabrous	Glabrous	Sparsely hairy	Sparsely hairy
Lower leaflet surface	Densely pubescent	dense adpressed hair present	Densely hairy with adpressed hairs	Dense adpressed long hair	Densely hairy	Densely hairy with adpressed hairs	Dense adpressed hairs present	Dense adpressed hairs present
Leaflet base	Cuneate	Cuneate	Cuneate	Cuneate	Cuneate	Cuneate	Cuneate	Cuneate
Leaflet size (cm) L X W	5.3 (6.8) 8.0 x 0.9 (0.9) 1.1	0.9 (1.7) 3.0 x 0.5 (0.7) 1.1	2.1 (3.2) 4.3 x 0.7 (0.9) 1.2	4.1 (5.7) 6.9 x 0.5 (0.5) 0.7	1.7 (3.1) 4.6 x 0.7 (0.9) 1.4	1.2 (2.2) 3.4 x 0.6 (0.8) 1.1	1.2 (2.1) 2.7 x 0.7 (0.9) 1.3	1.9 (2.1) 2.5 x 0.6 (0.6) 0.9



Figure 1. Plants in natural habitat. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

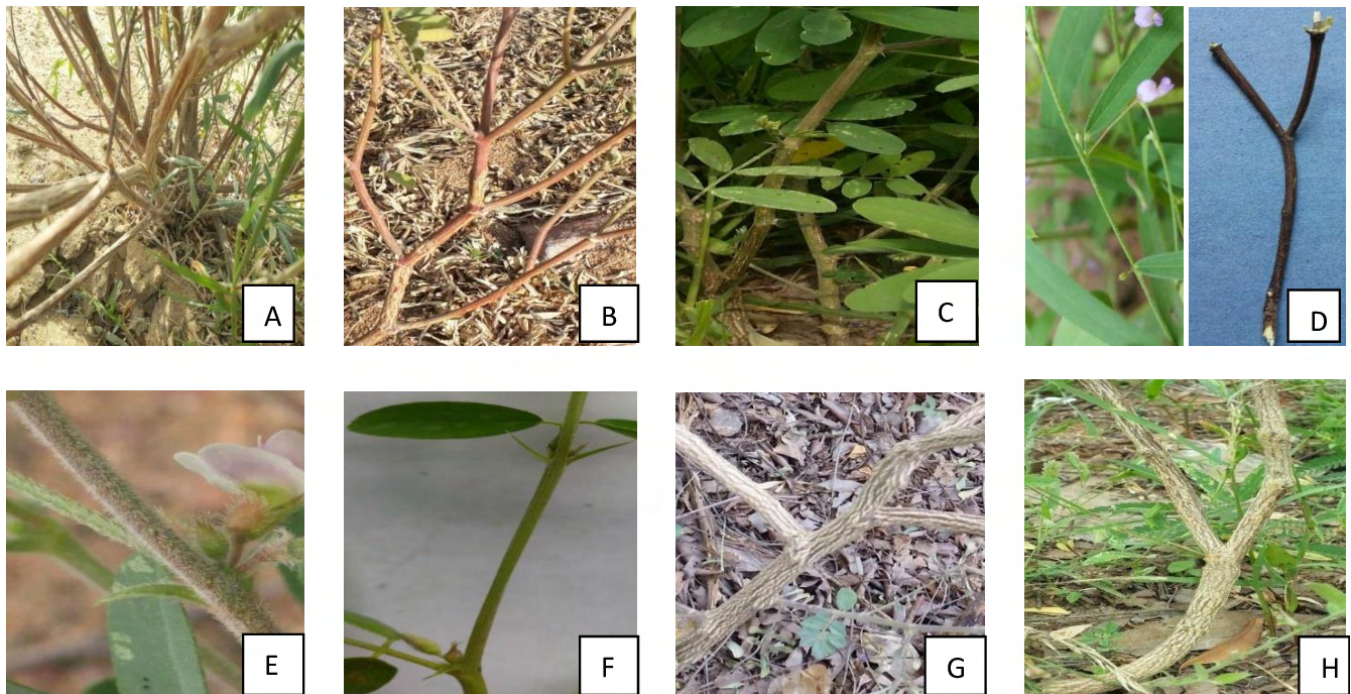


Figure 2. Variation in stems of *Tephrosia* species (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

inflorescence the length of floral axis and peduncle was varied which was considered for identification. *T. purpurea*, *T. leptostachya* and *T. wallichii* inflorescence was seem to similar in appearance which further recognized by the condensed and short floral axis in *T. wallichii* and long peduncle and lax floral axis with

less number of flower in *T. leptostachya* as compared to *T. purpurea*. Axillary inflorescence was found in *T. strigosa*, *T. subtriflora* and *T. uniflora* ssp. *petrosa*, which were further discriminated on basis of flower. The flowers of *T. falciformis* were very conspicuous at the time of flowering due to dark purplish-pink

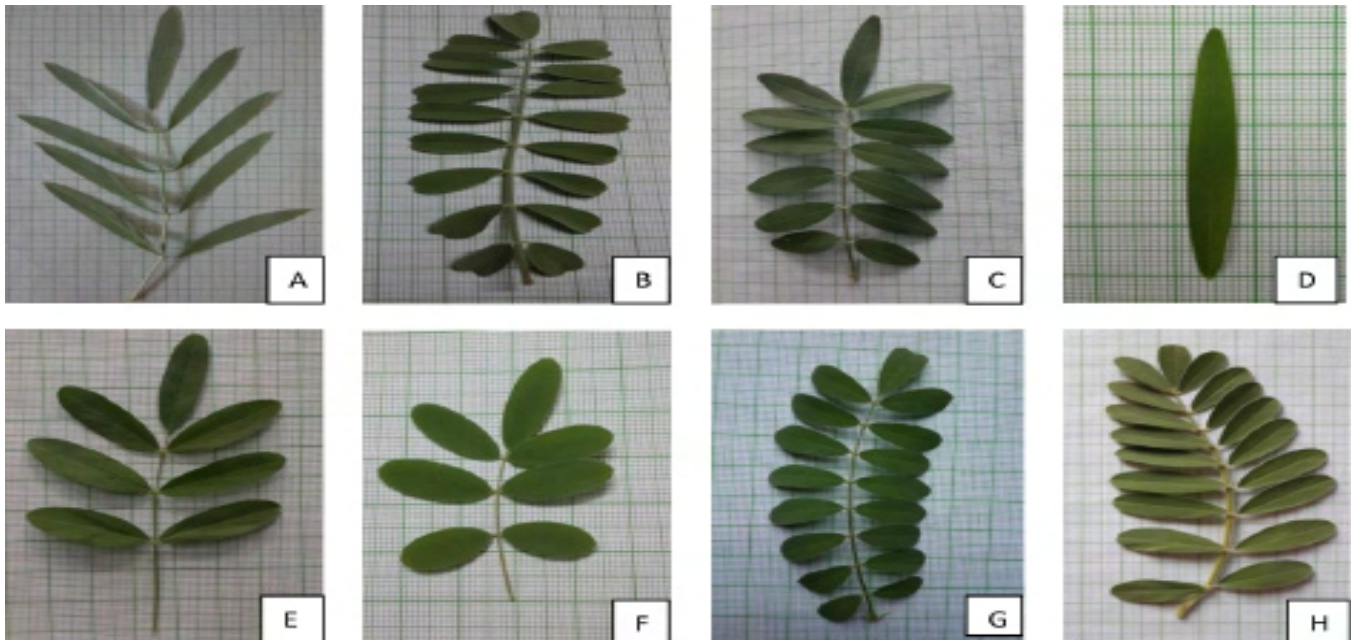


Figure 3. Variation in leaves of *Tephrosia* species (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

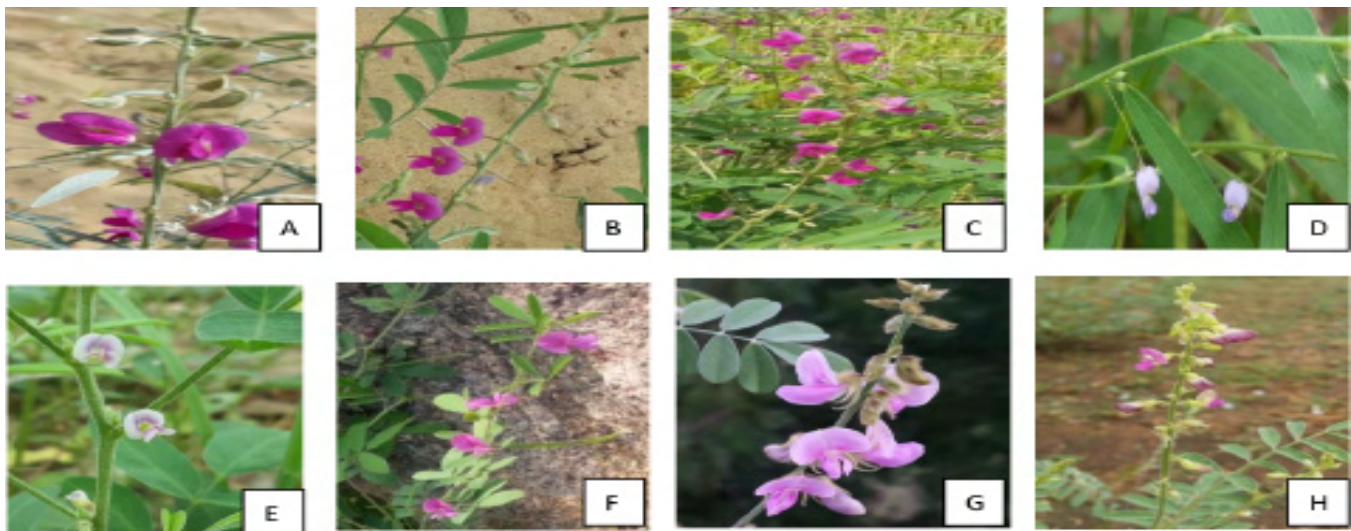


Figure 4. Variation in inflorescences of *Tephrosia* species (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

colour and can easily be recognized when ever growing with other species of *Tephrosia*. The smallest size of flower found in *T. strigosa* (Table 3; Fig. 5). Flowers of *T. uniflora* ssp. *petrosa* and *T. villosa* are open only in evening time while in other species flowers opens in day time. Calyx and corolla have noteworthy differences among species. Variation in colour, size and shape of corolla parts - standard, wing and keel were considered for identification. Standard margins were recurved backwards except in *T. strigosa*, *T. villosa*

and *T. uniflora* ssp. *petrosa* in which the standard has spreading margins (Table 3; Fig. 6). Calyx characters such as length and shape of upper calyx teeth, lower-middle tooth length, hairiness of calyx surface and calyx tube length showed considerable variations which were very helpful in species identification (Table 3; Figs. 7 & 8).

Differences in reproductive characters were also observed in studied species. Length of staminal tube showed variations between species. The maximum

Table 3. Inflorescence and floral characters of studied species of *Tephrosia*.

Character	<i>T. fulciformis</i>	<i>T. leptostachya</i>	<i>T. purpurea Petrosa</i>	<i>T. strigosa</i>	<i>T. subtriflora</i>	<i>T. uniflora</i> ssp.	<i>T. villosa</i>	<i>T. wallichii</i>
Flowering Period	August-October	August-October	July-November	August-October	August-October February	July - september	November-	August- November
Inflorescence type	Raceme	Raceme	Raceme flower in leaf axis	Axillary 1-2 in leaf axis	Axillary 2-6 flower in leaf axis	Axillary 1-3 flower	Raceme	Raceme
Floral axis length (cm)	16 (24.1) 30	13 (16.5) 20	26.0 (37.0) 50.0	—	—	—	10.0 (11.5) 14	8.5 (10.4) 13.0
Peduncle length (cm)	3 (4.8) 5.5	3.5 (5.1) 6.6	4.2 (6.4) 8.5	—	—	—	2.5 (3.5) 5.0	2.5 (3.2) 4.1
Bract length (cm)	0.2 (0.2) 0.3	0.2 (0.2) 0.2	0.2 (0.2) 0.3	0.1 (0.1) 0.1	0.1 (0.1) 0.1	0.1 (0.1) 0.2	0.2 (0.2) 0.3	0.3 (0.3) 0.4
Pedicel length (cm)	0.9 (1.3) 1.5	0.2 (0.3) 0.3	0.3 (0.3) 0.4	0.8 (1.2) 1.5	0.1 (0.2) 0.2	0.3 (0.3) 0.3	0.2 (0.2) 0.3	0.1 (0.2) 0.2
Flower colour	Dark purplish-pink	Bright pink-purple	Purplish -pink	Bluish-purple	Pale purple	Reddish Pink	Light Pink	Bright pink-purple
Opening time	Day	Day	Day	Day	Day	Evening	Evening	Day
Calyx Surface	Densely clothed with white silky hairs	Densely Pubescent with small hairs	Densely Pubescent with small hairs silky hairs	Sparsely pubescent with Small white	Pubescent with sparse, straight	Densely clothed with long hairs soft hairs	Densely clothed with long white and soft hair	Densely Pubescent
Calyx upper teeth shape	Long and lanceolate	SmallSubulate	Smalldeltoid triangular	Very small	Small, teeth tip hairy	Long subulate	Long lanceolate	Long subulate
Calyx tube length (cm)	0.2 (0.2) 0.2	0.2 (0.2) 0.2	0.2 (0.2) 0.3	0.2 (0.1) 0.2	0.2 (0.2) 0.2	0.2 (0.2) 0.3	0.2 (0.2) 0.2	0.2 (0.2) 0.3
Calyx upper teeth length (cm)	0.3 (0.3) 0.4	0.1 (0.1) 0.1	0.1 (0.1) 0.1	0.05 (0.05) 0.05	0.1 (0.1) 0.2	0.2 (0.2) 0.2	0.3 (0.3) 0.4	0.2 (0.2) 0.3
Lower middle teeth length (cm)	0.3 (0.3) 0.4	0.1 (0.2) 0.2	0.1 (0.1) 0.2	0.1 (0.1) 0.1	0.1 (0.1) 0.2	0.2 (0.2) 0.3	0.6 (0.6) 0.7	0.4 (0.4) 0.4
Corolla (cm)								
Standard	1.3 (1.4) 1.6 × 1.2 (1.3) 1.5	1.0 (1.0) 1.1 × 0.9 (0.9) 1.0	0.6 (0.8) 0.9 × 0.6 (0.8) 1.0	0.3 (0.4) 0.5 × 0.2 (0.2) 0.2	0.6 (0.6) 0.7 × 0.6 (0.6) 0.7	0.9 (1.1) 1.2 × 1.0 (1.0) 1.1	0.9 (1.0) 1.1 × 0.9 (1.0) 1.1	0.8 (0.9) 0.9 × 0.7 (0.7) 0.9
Wing	1.0 (1.2) 1.4 × 0.5 (0.6) 0.7	0.9 (0.9) 1.1 × 0.4 (0.4) 0.5	0.7 (0.7) 0.8 × 0.3 (0.2) 0.4	0.3 (0.3) 0.4 × 0.1 (0.1) 0.1	0.7 (0.7) 0.7 × 0.2 (0.2) 0.3	1.0 (1.0) 1.1 × 0.4 (0.4) 0.5	1.1 (1.1) 1.1 × 0.3 (0.3) 0.4	0.7 (0.7) 0.8 × 0.3 (0.3) 0.4
Keel	0.8 (0.8) 0.9 × 0.4 (0.4) 0.6	0.4 (0.5) 0.6 × 0.4 (0.4) 0.4	0.6 (0.6) 0.7 × 0.3 (0.3) 0.4	0.3 (0.3) 0.3 × 0.1 (0.1) 0.1	0.4 (0.5) 0.5 × 0.2 (0.2) 0.2	0.8 (0.8) 0.9 × 0.3 (0.3) 0.4	0.8 (0.8) 0.8 × 0.3 (0.3) 0.4	0.6 (0.6) 0.6 × 0.3 (0.3) 0.3



Figure 5. Variation in flowers of *Tephrosia* species (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

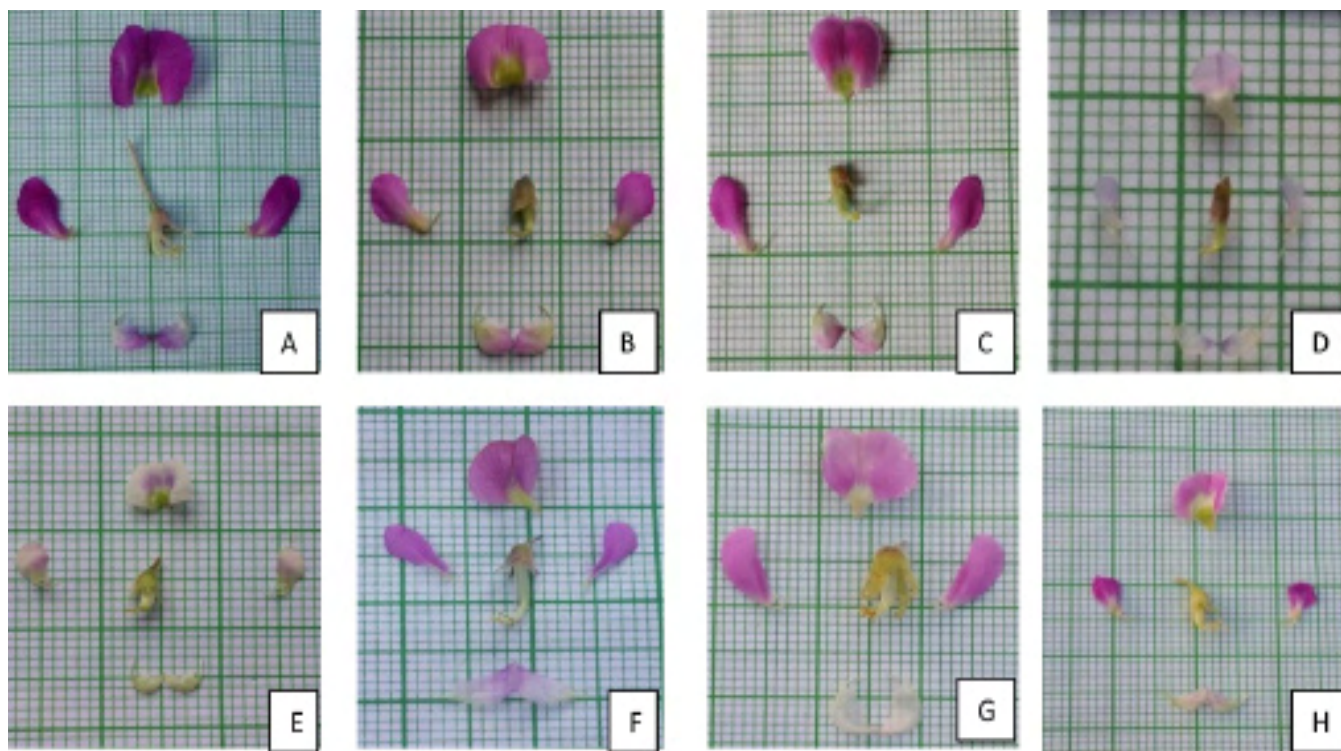


Figure 6. Variation in floral parts of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

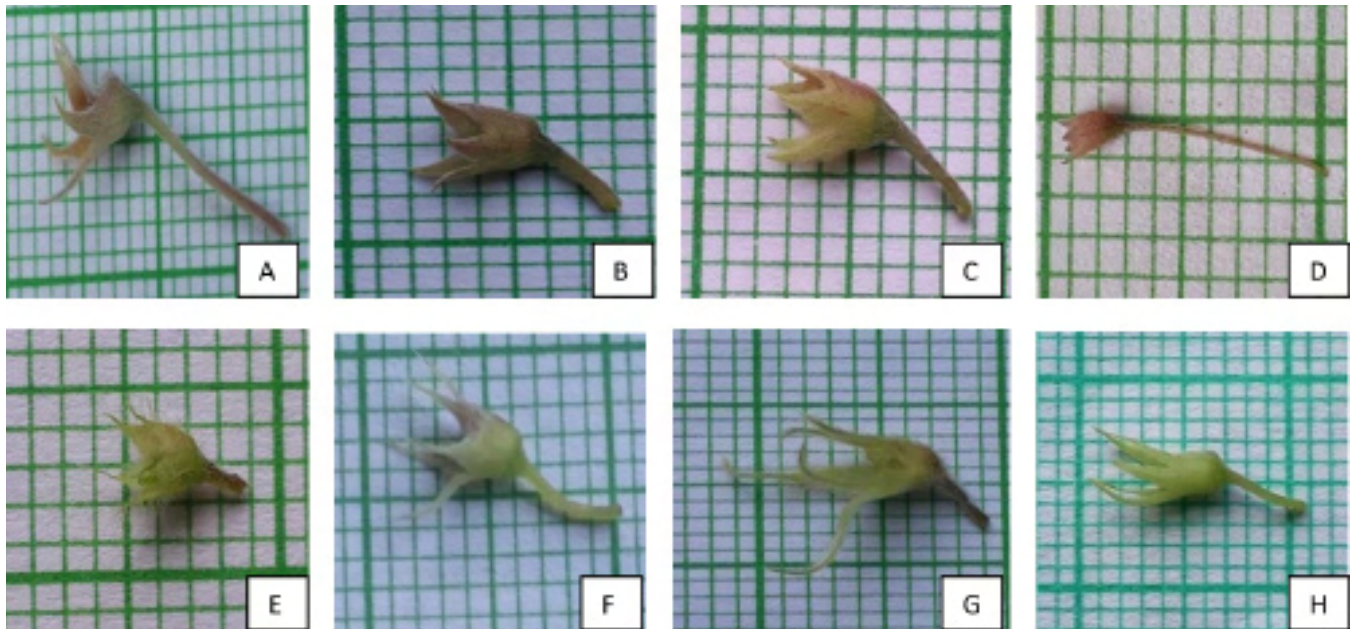


Figure 7. Variation in the calyx of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

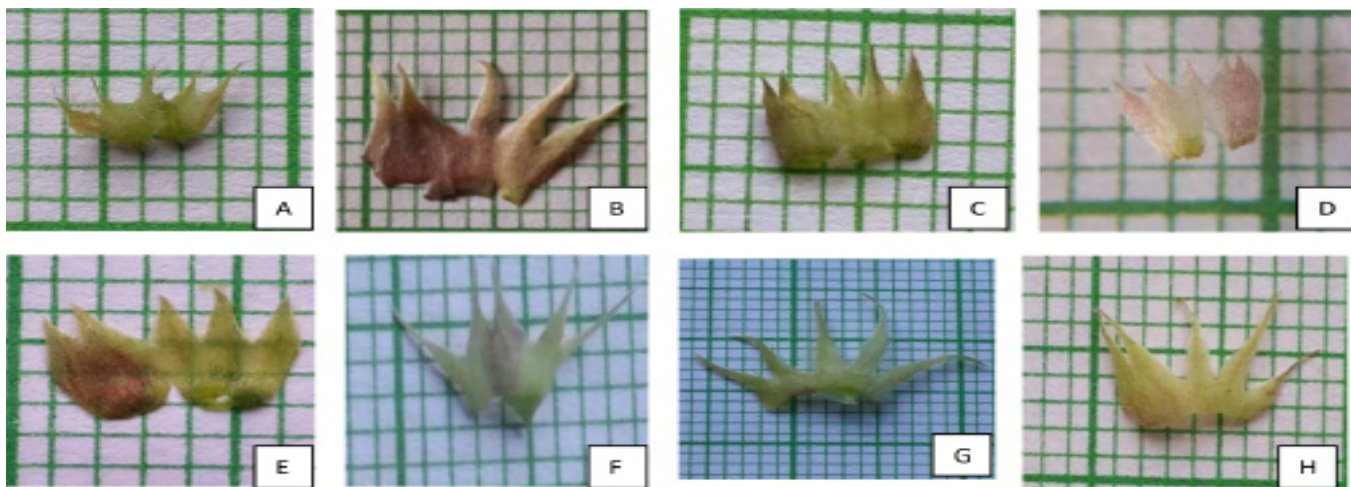


Figure 8. Variation in the shape of calyx teeth of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

length of the staminal tube and free stamen reported in *T. uniflora* ssp. *petrosa* was 0.9 and 0.8 cm respectively followed by *T. villosa* (0.8 cm, 0.7 cm) and *T. falciformis* (0.8 cm, 0.7 cm) whereas it was minimum in *T. strigosa* (0.4 cm, 0.3 cm) (Table 4; Fig. 9). Maximum carpel length recorded in *T. falciformis* (0.9 cm), followed by *T. villosa* (0.8 cm) and *T. uniflora* ssp. *petrosa* (0.8 cm) both, and minimum length was reported in *T. strigosa* (0.3 cm). Ovary and stigma revealed significant variations (Table 4; Fig. 10). Ovary characters like hairiness of ovary surface and carpel length were considered for identification. Density and

length of stigma hairs were vary in *Tephrosia* species. *T. villosa* has long and dense hairs on stigma while in *T. strigosa* stigma was lobed, papillate and not hairy. *T. falciformis*, *T. purpurea*, *T. subtriflora* and *T. wallichii* have capitate stigma with few medium length hairs.

Pod and seed characters- shape, colour, surface and seed coat pattern were found significantly different in present investigation (Table 5; Fig. 11 & 12). The shape of pods was ranged from linear to falcate. *T. falciformis* has highly falcate pods which makes its identification easy in the field. In *T. villosa* pods were slightly falcate towards tip with velvety tomentose

Table 4. Reproductive and fruit characters of studied species of *Tephrosia*.

Character	<i>T. falciformis</i>	<i>T. leptostachya</i>	<i>T. purpurea</i>	<i>T. strigosa</i>	<i>T. subtriflora</i>	<i>T. uniflora</i> ssp. <i>Petrosa</i>	<i>T. villosa</i>	<i>T. wallichii</i>
Androecium (cm)								
Length of staminal tube (cm)	0.7(0.8)0.9	0.6(0.6)0.7	0.5(0.6)0.6	0.4(0.4)0.5	0.4(0.4)0.5	0.8(0.9)1.0	0.7(0.8)0.9	0.6(0.6)0.7
Height of staminal tube (cm)	0.1(0.1)0.1	0.1(0.1)0.1	0.1(0.1)0.1	0.05(0.05)0.05	0.1(0.1)0.1	0.1(0.1)0.1	0.2(0.2)0.2	0.1(0.1)0.1
Length of cohesion (cm)	0.5(0.5)0.7	0.4(0.4)0.5	0.4(0.4)0.5	0.3(0.3)0.4	0.3(0.4)0.4	0.7(0.8)0.9	0.6(0.6)0.7	0.4(0.5)0.5
Length of free stamen (cm)	0.7(0.7)0.8	0.5(0.6)0.6	0.4(0.4)0.5	0.3(0.3)0.4	0.3(0.4)0.4	0.8(0.8)0.9	0.7(0.7)0.8	0.4(0.4)0.5
Gynoeceum (cm)								
Carpel length (cm)	0.9(0.9)1.0	0.7(0.8)0.8	0.6(0.6)0.7	0.3(0.3)0.3	0.4(0.4)0.5	0.8(0.9)0.9	0.8(0.8)0.9	0.6(0.6)0.7
Ovary size (cm)	0.5×0.08	0.5×0.06	0.4×0.05	0.3×0.02	0.4×0.06	0.6×0.08	0.6×0.13	0.4×0.08
Ovary surface	Pubescent with small hairs	Pubescent with small hairs	Pubescent with medium hairs	Pubescent with small hairs	Densely pubescent with long hairs	Densely pubescent with white long hairs	Densely clothed with hairs	Densely clothed

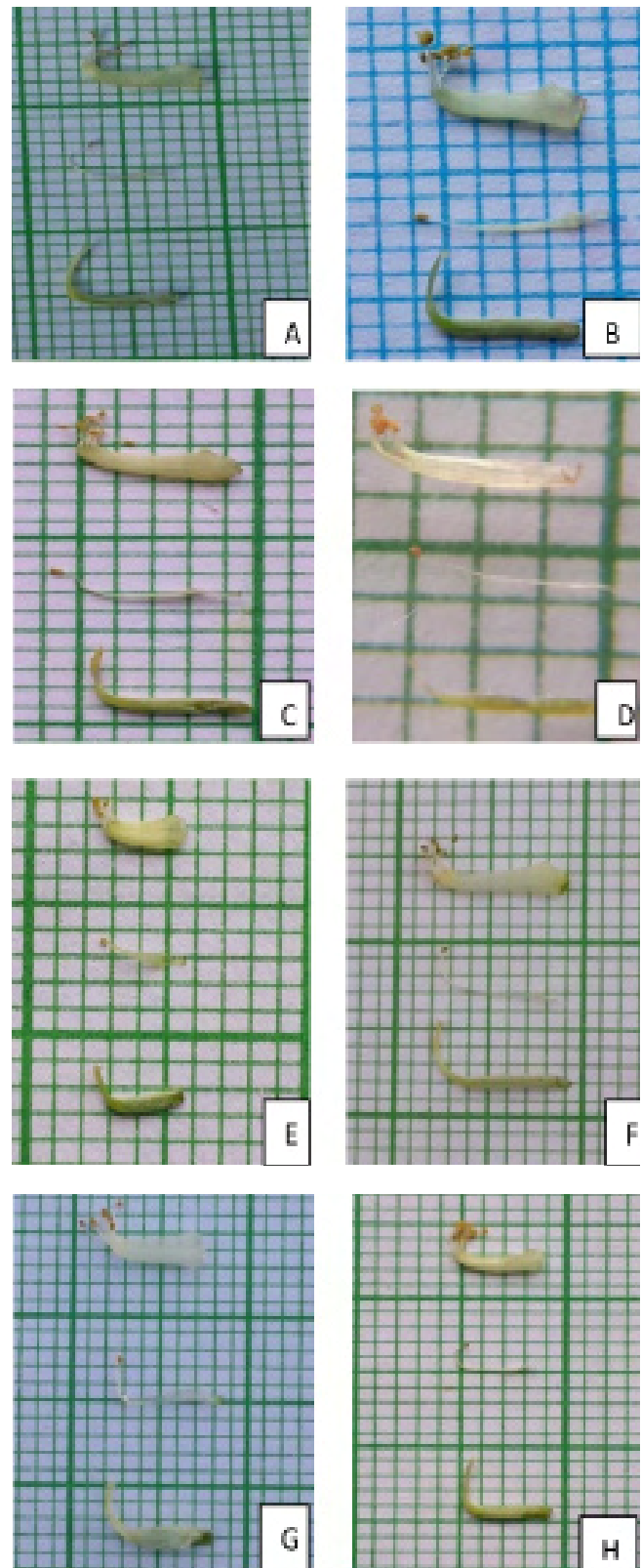
Figure 9. Variation in androecium and gynoeceum of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

Table 5. Fruit characters of studied species of *Tephrosia*.

Character	<i>T. falciformis</i>	<i>T. leptostachya</i>	<i>T. purpurea</i>	<i>T. strigosa</i>	<i>T. subtriflora</i>	<i>T. uniflora</i> ssp. <i>Petrosa</i>	<i>T. villosa</i>	<i>T. wallichii</i>
Pod characters								
Shape	Falcate	Linear	Linear, tip slightly curved	Linear	Linear	Linear, tip slightly curved	Slightly falcate, tip curved	Linear upward
Colour	Yellowish brown	Brown	Light Brown	Straw colour	Dark brown	Light brown or Dark brown	Blackish brown	Dark brown
Surface	Densely pubescent	Sparsely pubescent	Pubescent with small hairs	Sparsely pubescent	Densely pubescent with spreading hairs	Softly and sparsely hairy	Velvety tomentose	Sparsely hairy with very small hairs
Size (cm)	7.8 (8.9) 9.9 × 0.5 (0.5) 0.7	4.2 (4.4) 4.6 × 0.3 (0.3) 0.3	4.3 (4.7) 5.3 × 0.4 (0.4) 0.4	1.5 (1.6) 2.3 × 0.2 (0.2) 0.3	2.9 (3.0) 3.2 × 0.4 (0.4) 0.4	3.8 (4.4) 4.9 × 0.3 (0.4) 0.4	2.0 (2.7) 3.3 × 0.5 (0.5) 0.5	2.8 (3.0) 3.2 × 0.4 (0.4) 0.4
Seed characters								
Seeds per pod	4-7	7-8	5-7	6-9	5-6	6-8	3-7	4-7
Shape	Reniform	Sub reniform	Sub cylindrical	Sub orbicular	Ovoid	Sub cylindrical	Irregular	Reniform
Colour	Light brown	Brown	Brown	Blackish-brown	Brown	Brown brown	Brown	Pale or reddish
Seed texture	Glaucous	Smooth	Smooth	Shiny and smooth	Smooth	Smooth	Wrinkled	Smooth
Seed coat Pattern	light marking	Dark reticulate	Simple reticulate	Mottled	Light brown markings	Multi reticulate	Blisterous markings	Blackish blotches
Hilum position	Central	Sub central	Sub central	Sub Central	Sub central	Sub central	Sub central	Sub central
Membrane on seed	Present	Present	Absent	Absent	Absent	Absent	Absent	Absent
Seed Size	0.4 (0.5) 0.5 ×	0.3 (0.3) 0.4 ×	0.5 (0.5) 0.6 ×	0.1 (0.1) 0.1 ×	0.2 (0.2) 0.2 ×	0.3 (0.3) 0.4 ×	0.3 (0.3) 0.4 ×	0.3 (0.3) 0.4 ×
L×W (cm)	0.3 (0.3) 0.3	0.3 (0.3) 0.4	0.2 (0.2) 0.2	0.1 (0.1) 0.1	0.1 (0.2) 0.2	0.1 (0.1) 0.2	0.2 (0.2) 0.2	0.2 (0.2) 0.3

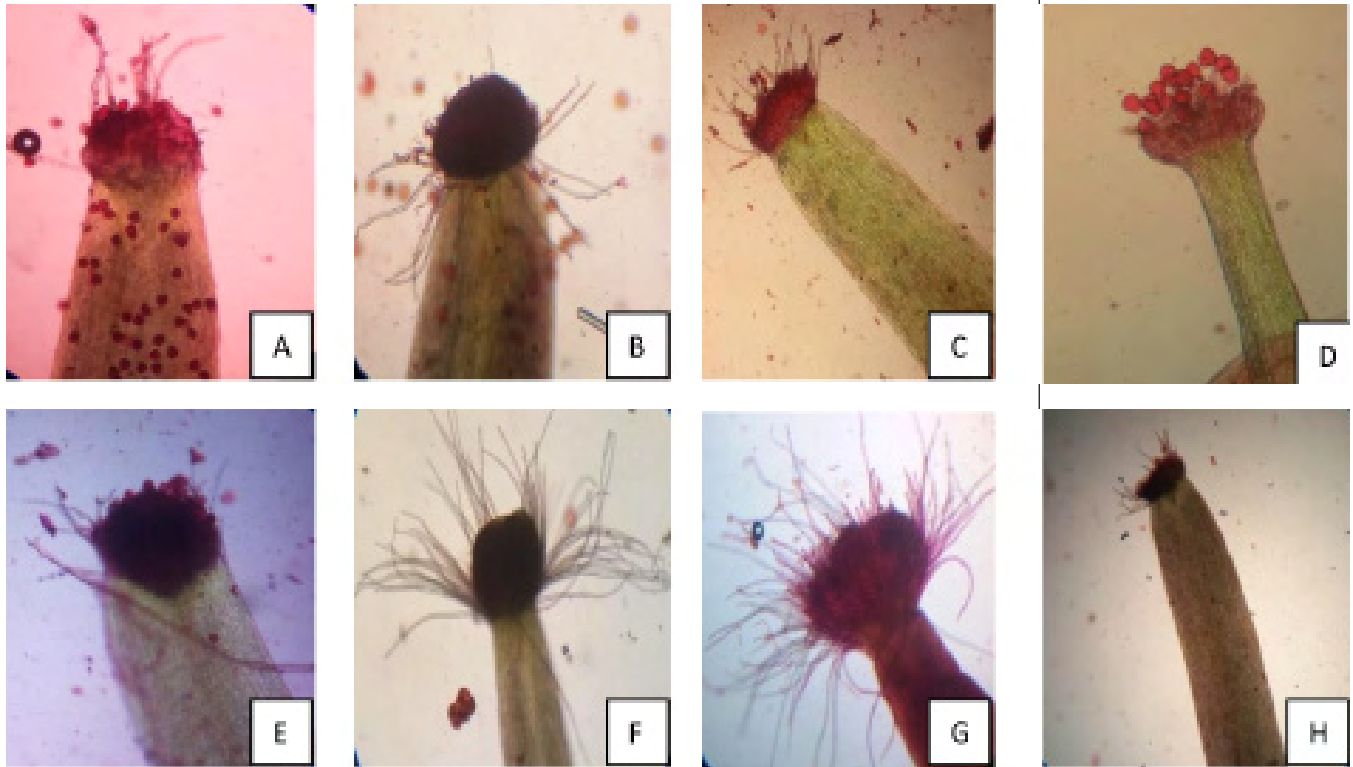


Figure 10. Variation in stigma and style of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

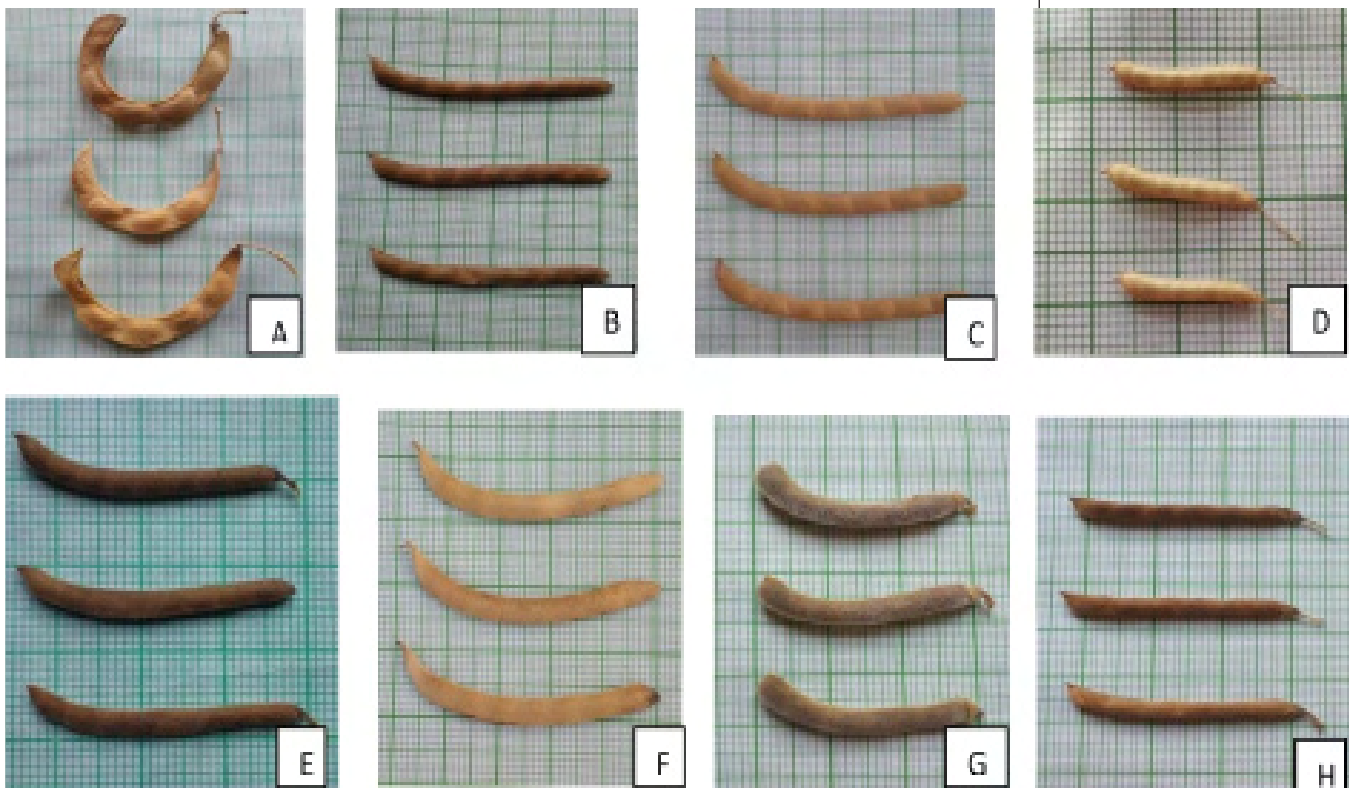


Figure 11. Variation in pods of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

surface. Pods in *T. subtriflora* was dark brown and densely pubescent. The maximum (7.8-9.9×0.5-0.7 cm) and minimum size (1.5-2.3×0.2-0.3 cm) of pods were reported in *T. falciformis* and *T. strigosa*, respectively (Table 4). Number of seeds differs in all the species, maximum number of seeds per pod found in *T. strigosa*. Shapes of seeds were reniform in *T. falciformis* and *T. wallichii*, where as sub-orbicular in *T. strigosa*, ovoid in *T. subtriflora*, irregular with compressed ends in *T. villosa*, subcylindric in *T. purpurea* and *T. uniflora* ssp. *petrosa*. Smallest pods and seeds were reported in *T. strigosa* among studied species. Seed coat was characteristically wrinkled in *T. villosa*, in contrast, *T. falciformis* has smooth and shiny seed surface. Seed size was the maximum in *T. falciformis* and *T. purpurea*. Seed coat patterns were found significant in species identification.

Discussion

Morphological characters were extensively used in taxonomic studies and considered as prime base for identification and classification of plant species. Morphological studies are significant on higher as well as the lower level of classification. In present study, eight species of genus *Tephrosia* has been thoroughly investigated for qualitative as well as quantitative characters to report significant variations. In present investigation no major morphological changes were observed from the previous study except few significant changes (Bhandari,1978). The significant morphological characters are discussed under three categories.

Vegetative characters

In absence of flowering or fruiting, leaf characters are helpful in the preliminary identification. Leaves were stipulate and stipules were linear or subulate in studied species. Stipule size was significantly differed within species and recommended for identification. Present study reported slight variations in stipule size from the earlier study (Bhandari,1978), such as in *T. purpurea* and *T. falciformis* stipules were found bigger than previous findings and reported comparatively smaller in *T. subtriflora*. The shape of leaves ranged from obovate, elliptic, oblanceolate to lanceolate in studied species, these findings are in line with earlier findings (Bhandari,1978). Leaves of *T. falciformis* were conspicuously silvery white due to the presence of dense adpressed hairs on both surface which is an adaptation to face extreme climate of desert thus justify its occurrence in sandy habitat on dry sandy slopes and plains. It was observed that in Bikaner, population of *T. falciformis* was dense and bushy, leaves much green instead of silvery white colour and smaller in size than plants found in Jaisalmer and Jodhpur.

Floral characters

Two types of inflorescence were reported in studied species-first with terminal and leaf opposed raceme and second with axillary inflorescence with 1-6 flowers in the axil of leaf further the species shows difference in floral axis length. In *T. purpurea*, average length of the floral axis was 37 cm whereas in *T. leptostachya*, *T.*

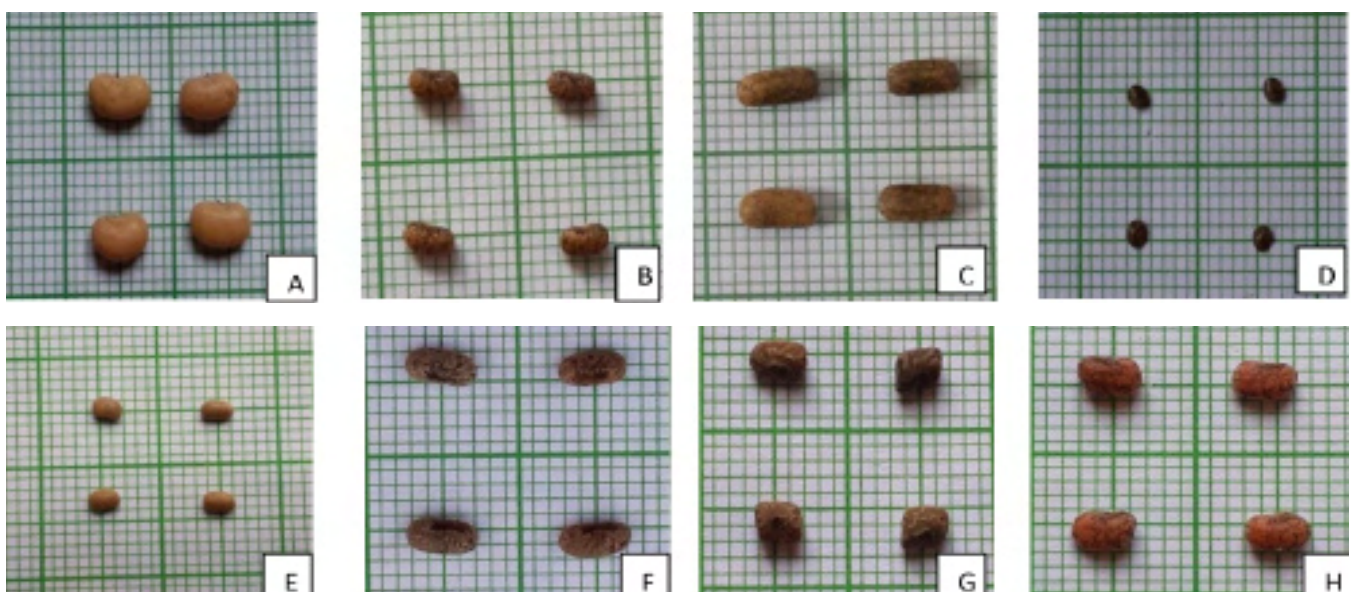


Figure 12. Variation in seeds of *Tephrosia* species. (A) *T. falciformis*, (B) *T. leptostachya*, (C) *T. purpurea*, (D) *T. strigosa*, (E) *T. subtriflora*, (F) *T. uniflora* ssp. *petrosa*, (G) *T. villosa*, (H) *T. wallichii*

villosa and *T. wallichii* floral axis average length was 16.5 cm (Table 3). The reported length of inflorescence was shows significant differences in *T. purpurea* and *T. falciformis* and slight difference in *T. leptostachya*, *T. villosa* and *T. wallichii* than previous findings from earlier study (Bhandari, 1978). Length of inflorescence in *T. purpurea* was almost double as compare to its Saudi Arabian counterpart (Al-Ghamdi, 2013). In *T. uniflora* ssp. *petrosa* and *T. villosa* flowers open in evening time only while in rest of the species flowers open in day time, thus it is a significant character for identification. This character was not considered in earlier study done on *Tephrosia* species (Bhandari, 1978). In contrast to the present finding previous study in Saudi Arab (Al-Ghamdi, 2013) reported evening time for flower opening in *T. purpurea*.

Reproductive characters were found to be significant in species distinction. Earlier study on *Tephrosia* species of the Indian Thar desert did not include the androecium and gynoecium characters except the hairiness of stigma and style (Bhandari, 1978).

Staminal tube length, cohesion length, length of free stamen and carpel length of *T. purpurea*, *T. leptostachya* and *T. uniflora* ssp. *petrosa* were slightly differ from their Saudi Arabian counterpart (Al-Ghamdi, 2103). Presence or absence of hairs on style was earlier used as classification criteria by some taxonomists. Brummitt (1980) used it as significant character to divide genus *Tephrosia* of Africa into two subgenera – *Tephrosia* subgenus *Tephrosia* and *Tephrosia* subgenus *Barbistyla* on basis of glabrous and pubescent styles. Species considered in the present study bear glabrous styles.

Fruit characters

Fruit characters such as shape, size, colour and surface of pods and seeds were found to be important in the proper identification of species. Earlier study reported these characters as valuable criterion in the identification of *Tephrosia* species of Egypt (Hosni & El-Karemy, 1993). The significance of seed morphological characters –size, colour, seed coat pattern, hilum position etc. was mentioned in the identification of South American species of *Tephrosia* (de-Queiroz et al, 2012). Previous study on *Tephrosia* species of Indian Thar Desert cited the significance of pod and seed characters in identification and the present findings are in line with earlier observations (Bhandari et al., 1985). In *T. leptostachya* and *T. falciformis* a thin reticulate membrane was present on seed which lack in other

species; this membrane was dry, apparent and papery in *T. leptostachya* while it was slightly fragile in *T. falciformis*. The membrane on the seed in the two species was not mentioned by Bhandari (1978). Earlier studies on seed micromorphology of 12 Indian species of *Tephrosia* revealed wrinkled seed coat in *T. uniflora* ssp. *petrosa* (Subba Rao & Shanmukh Rao, 1992), on the contrary present investigation smooth seed coat was reported in *T. uniflora* ssp. *petrosa*. Seed coat pattern in investigated species appeared from light marking to simple reticulate, multi-reticulate, mottled, blisterous marking or blotches, similar findings were observed in *Tephrosia* spp. in earlier studies also Bhandari,1985; Subba Rao & Shanmukh Rao, 1992; Al-Ghamdi & Al-Zahrani, 2010).

On the basis of macro morphological taxonomic characters two taxonomic keys for the identification of the eight studied species can be proposed as below:

Taxonomic key for identification of *Tephrosia* species on basis of vegetative and floral characters

- 1a Leaves simple uni-foliolate *T. strigosa*
- 1b Leaves imparipinnate compound 2
- 2a Inflorescence Axillary 3
- 2b Inflorescence Raceme 4
- 3a Stipule subulate, calyx teeth short, *T. subtriflora*
flower open in day time
- 3b Stipule linear, calyx teeth long, *T. uniflora* ssp.
flower open in evening time *petrosa*
- 4a Floral axis long 5
- 4 b Floral axis short 6
- 5a Flower with long pedicel, stipule *T. falciformis*
long and linear, upper calyx teeth
shape lanceolate
- 5b Flower with short pedicel, stipule *T. purpurea*
small and subulate, upper calyx
teeth deltoid
- 6a Leaf apex emarginated, calyx teeth *T. leptostachya*
smaller or equal to calyx tube
- 6b Leaf apex not emarginated, calyx 7
teeth longer then calyx tube
- 7a Leaflet elliptic-obovate, stipule size *T. wallichii*
0.6-0.8 cm, flower open in day time,
stigma less hairy with medium hairs
- 7b Leaflet oblanceolate-obovate, stipule... *T. villosa*
size 0.3-0.4 cm flower open in
evening time, stigma densely hairy
with long hairs

Key for identification of studied *Tephrosia* species on basis of fruit characters

- 1a Pod falcate 2
 1b Pods linear 3
 2a Pods highly falcate, pod surface *T. falciformis*
 densely pubescent, seed surface
 glaucous with light marking
 2b Pods falcate towards tip, pod surface .. *T. villosa*
 velvety tomentose, seed surface
 wrinkled with blisterous marking
 3a Pods dark brown 4
 3b Pods not dark brown 5
 4a Seed sub reniform, membrane *T. leptostachya*
 present on seed, seed coat
 pattern dark reticulate
 4b Seed ovoid, membrane absent on *T. subtriflora*
 seed, seed coat pattern with light
 marking
 5a Pods length 4-5 cm, seed sub cylindrical 6
 5b Pod length less than 4-5 cm, seed
 not sub-cylindrical 7
 6a Seeds 5-7 per pod, seed coat pattern ... *T. purpurea*
 simple reticulate, seed size 0.5 × 0.2cm
 6b Seeds 6-8 per pod, seed coat pattern ... *T. uniflora* ssp.
 multi reticulate, seed size 0.3×0.1cm ... *petrosa*
 7a Seed sub orbicular, seed coat mottled .. *T. strigosa*
 7b Seed reniform, seed coat with *T. wallichii*
 black blotches

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References

- Al-Ghamdi, F.A. 2013. Morphological diversity of some *Tephrosia* species (Fabaceae) in Saudi Arabia. *American Journal of Plant Sciences*, 4: 543.
- Al Ghamdi, F.A. & Al Zahrani, R.M. 2010. Seed morphology of some species of *Tephrosia* Pers. (Fabaceae) from Saudi Arabia. Identification of species and systematic significance. *Feddes Repertorium*, 121: 59-65.
- Bhandari, M.M. 1978. Flora of the Indian Desert. Scientific Publishers, Jodhpur, India, 117-123 pp.
- Bhandari, M.M., Gehlot, M.S. & Anand, S.K. 1985. Identification of Indian desert species of *Tephrosia* (L.) Pers. by seed characters. *Journal of Plant Morphology*, 2: 41-50.
- Brummitt, R.K. 1980. Reconsideration of the genera *Ptychlobium*, *Caulocarpus*, *Lupinophyllum* and *Requienia* in Relation to *Tephrosia* (Leguminosae: Papilionoideae). *Kew Bulletin*, 30: 459-473.
- de Queiroz, R.T., de Azevedo Tozzi, A.M. G. & Lewis, G.P. 2013. Seed morphology: an addition to the taxonomy of *Tephrosia* (Leguminosae, Papilionoideae, Millettieae) from South America. *Plant Systematics and Evolution*, 299: 459-470.
- Hooker, J.D. 1879. The Flora of British India, Vol. 2. Missouri Botanical Garden, London. 110 pp.
- Hosni, H. A. & El-Karemy, Z. A. R. 1993. Systematic revision of Leguminosae in Egypt. 1. *Tephrosia* Pers. *Sendtnera*, 1: 245-257.
- Kumar, S. & Sane, P.V. 2003. Legumes of South Asia: A Checklist, 536. Royal Botanic Gardens, Kew.
- Mabberley, D.J. 2005. The Plant Book (1st South Asian ed.). Cambridge University Press, Cambridge, New York. pp
- Subba Rao, J. V. & Shanmukha Rao, S. R. 1992. LM and SEM studies in seed morphology in some *Tephrosia* Pers. (Leguminosae). *Feddes Repertorium*, 103: 339-343.
- Sharma, K.K. & Mehra, S.P. 2009. The Thar of Rajasthan (India): ecology and conservation of a desert ecosystem. In *Faunal Ecology and Conservation of the Great Indian Desert*, Springer, Berlin, Heidelberg. 1-11pp
- Shetty, B.V. & Singh, V. 1987. Flora of Rajasthan, Vol. 1. Botanical Survey of India, Kolkata. 262-266 pp.