DISCUSSION

The exploration work intended with classical and experimental taxonomy of genus Abutilon in India have resulted into many interesting outcomes. The genus is distributed with less number of taxa in India as compare to world distribution, still the diversity observed in characters is remarkable.

Distribution:

Result of this study says that the genus Abutilon is represented in India with 12 species and 2 varieties, viz., A. australiense, A. bidentatum, A. fruticosum, A. hirtum, A. indicum, A. neelgerrense var. fischeri, A. neelgerrense var. neelgerrense, A. pannosum, A. persicum var. narasimhianii, A. persicum var. persicum, A. ramosum, A. ranadei, A. theophrasti.

Abutilon hirtum, A. indicum and A. pannosum commonly distributed throughout the country and generally grow along roadsides, waste places and as weed on farmlands. Except, A. pannosum other two species have wide range of distribution, whereas A. pannosum is recorded from only from old countries. A. bidentatum also commonly occurs at roadsides, farmlands or waste places, its distribution is recorded from Asian countries. Whereas, in India its occurrence is known from Northern states, extended up to Gujarat and Maharashtra. It has also been recently reported from Karnataka State (Annigeri et al., 2011), but neither observed nor reported from rest of the Southern Peninsular India. A. fruticosum is distributed only in two northern states of country viz., Gujarat and Rajasthan grows on rocky substratum and prefers exposed situations.

In many Indian works Abutilon australiense is enumerated under infraspecific classification of A. indicum, as given by Borssom Waalkes (1966). Chandrabose (1970) has reported this species as new record to India, which was solely based on the collections by Sebastine (Sebastine 9803, MH) from Krishna River bank, Nagarjunsagar, Nalgonda district, Telangana. Subsequent reports by Paul (1993); Pullaiah & Chennaiah (1997); Pullaiah et al. (2002); Pullaiah & Rao (2002); Rao et al. (2001); Pullaiah(2015) from India are based on previous record of Chandrabose, (1970) only.

However, the species neither has been collected for last six decades nor been conveyed in the book on the family Malvaceae in peninsular India by Pradeep and Sivarajan (1996), nor in recent floristic account of Telangana state by Reddy and
Reddy (2017). In addition, we also failed to locate the specimen/s collected by Sebastine 9803 deposited at Madras Herbarium (MH), resulting the occurrence of the variety in peninsular India ambiguous.

During studies under references, in one of the excursion to the Nagarjunsagar, Guntur district (Andhra Pradesh) we have had success to locate and collect the specimens of *A. indicum* subsp. *albescens* var. *australiense*, a little known species from peninsular India, had been overlooked for six decades, probably because of its sympatric occurrence with typical subspecies viz. *A. indicum* subsp. *indicum*.

*Abutilon indicum* var. *australiense* is described by Britten (1900) based on Hochreutiner’s manuscript. Unknown to the Britten’s publication, Hochreutiner in 1902 described the variety viz. *Abutilon indicum* var. *australiense*, an illegitimate later homonym. Borssum in 1966 in his treatment of Malaysian Malvaceae, altered the status of *Abutilon indicum* var. *australiense* as *A.indicum* subsp. *albescens* var. *australiense* of Hochreutiner’s and overlooked the Britten’s (1900).

Though Britten (1900) and subsequent workers measured morphological characters to retain *A. indicum* var. *australiense* as variety, the conspicuous characters such as long, acuminate, entire leaves, sepals exceeding or almost equal to schizocarp, stellate hairy staminal column, globular fruits, and densely hairy seeds mark this as far distinct than the typical variety and therefore treated here as a distinct species.

*Abutilon guineense* is also treated here as a distinct species instead of subspecies of *A. indicum* as the species has distinct morphological features and it also has sympatric occurrence with main subspecies. It is distributed in Asia, Africa and Australia. In India the species is recorded from Tamil Nadu, Andra Pradesh, Telangana and Rajasthan.

*Abutilon ramosum* is reported as common from many parts of India, but it cannot be observed as common. It always prefers shady situations, grows under canopy of trees, also observed in forest fringes. ENVIS Centre on floral Diversity (Hosted by Botanical Survey of India) generated data on distribution status of some threatened plants of India. According to the report *A. ramosum* has rare distribution in Tamil Nadu and Karnataka. However, the species could be located only from Junnar tehsil of Pune district in Maharashtra.

An endemic species *A. neelgerrense* prefers semi-shady and moist situation and high elevations, has its occurrence restricted to South India. An infraspecific
taxon *A. neelgerrense* var. *fischeri* described by Paul and Nayar in 1985 based on C.E.C. Fischer’s collection, housed at CAL (*C.E.C. Fischer 1581*) from Coonor river bank, Coimbatore dt. (Tamil Nadu). Fischer collected the specimen in January, 1910, predates more than 100 years. Many floristic studies from south Indian regions (Nayar and Sastry, 1987; Chandrabose and Nair, 1988; Sivarajan and Pradeep, 1996; Pullaiah and Chennainah, 1997; Pullaiah and Rao, 2002; Mohanan and Rao, 2005; Nayar et al., 2006; Ravichandran and Karppusamy, 2016) have not documented this variety. During the present study, the individuals of this taxon are collected from Theni district of Tamil Nadu, rediscovering the variety after more than a century.

Another species which occur in semi deciduous forest and preferably high altitude is *A. persicum*, recorded from many parts of India. Usually prefers slopes of forest and can also be observed as undergrowth. *A. persicum* var. *narsimhanii* is described from Eastern Ghats of Tamilnadu and its distribution is also recorded from forest fringes of Southern Western Ghats.

A critically endangered species *A. ranadei* is endemic to Maharashtra state (Northern-Western Ghats). Its populations and number of individuals are decreasing at an alarming rate. Necessary action toward conservation is an urgent need of the species which will also help to conserve the organisms associated with it.


Though *A. theophrasti* is an invasive species for many new world countries, *A. theophrasti* has relatively scarce distribution in India and mainly distributed in Northern states of country. According to Spencer and Sankaran (1984) its record from West Bengal is based on plants grown at former East India Company’s Botanical Garden, Kolkata and Prain (1903) also put light on its rarity in Bengal and Dacca. The only available record of *A. theophrasti* from South India (Tamil Nadu) is based on collections by Chandrabose (1973). He collected specimens (*Chandrabose 29963, MH*) from city of lakes i.e. Coimbatore, adding its locality near Valan kulum, one of
the lakes in city. Attempts to see the plants near Valan kulam and many other lakes in city are ineffective. Occurrence of this species from Rajasthan can be traced from collection observed at CNH and BSJO (Rajasthan: Khanpur, Wadhwa 9581). Floristic studies from Rajasthan haven’t reported the species (Bhandari 1978, Sharma and Tiagi 1979; Shetty and Singh 1987, Sharma, 2002) and during the present investigations species couldn’t be located from Rajasthan and Gujarat. Almeida (1996) enlisted species from Maharashtra citing locality ‘Nandur–Madhmeshwar’ of Nashik district, collection of which could not be seen at BLAT, and attempts to observe the plant from Nandur Madhmeshwar (Bird Sanctuary) are failed. But its occurrence in Maharashtra state is confirmed by its collection from Bhigwan, Ujani dam backwater area, one of the famous places from Maharashtra for watching migratory birds, Flamingos.

At the end of this discussion about distribution and occurrence of *A. theophrasti* in India, it is observed that, except extreme northern part of country the species is reported from the areas like lakes and ponds, where migratory birds usually stay for a while. This can also be correlated to its records from Rajasthan and Saurashtra & Kutch of Gujarat (Shah, 1978) that fall on the known routes of these migratory birds. One of them is Flamingo city, located in Rann of Kutch is actually an island and breeding ground for migratory flamingo birds.

Spencer and Sankaran (1984) studied about natural enemies of this species with the vision of biological control. According to them, limited spread of this weed at Coimbatore, a cotton breeding area and vicinity is because of cotton bug *Oxycarenus laetus* which infests mature fruits. Absence of the species from previously recorded localities can also be supported by this investigation and inferences.

Along with some of above mentioned taxa many studies have reported *A. pakistanicum* from India. It was first described by Cooke (1903) as *A. cornutum* based on Dalzell’s MS, also citing specimens collected by Dalzell (K, K000659534) and Perry with localities ‘Sind’ and ‘Karachi to Mugger peer’ respectively. The localities were part of the then ‘Bombay Presidency’. The name applied by Cooke is however a later homonym, therefore Jafri (1966) replaced it by *A. pakistanicum*. Earlier homonym was applied by Sweet (1830) based on *Sida cornuta* Humb. & Bonpl. ex Willd. Bhandari (1978) in his floristic work on Indian Desert reported its occurrence based on two specimens deposited at BLAT, localities mentioned as Jodhpur (5662)
and Jaisalmer (5656). But analysis of the specimens resulted into their identity as of *A. fruticosum* and Hemadri also added determination slip (dated 17.03.1966) on the specimens of *A. fruticosum*. Paul (1993) reported the species from North-west Rajasthan but no supporting specimens were cited in the work. Field exploration as part of present study from Rajasthan and several other localities in India was ineffective. Meanwhile Abedin (1979) very clearly notified that *A. pakistaniicum* is restricted to Karachi region and is endemic to Pakistan. Therefore, it can be said that the species is so far known to Pakistan only and does not occur in India.

An introduced species, *A. auritum* has been reported by Venkanna and Das (2000) from Pune district of Maharashtra, with a note for locality is ‘occasional on hill slopes’ without citing any specimen. While examining the specimens kept at BSI, two specimens with the locality ‘Jooner’ (Junnar tehsil from Pune district, Maharashtra) filed as *A. cornutum*, are identified as of *A. auritum*. The specimens collected by W. A. Talbot (*Talbot s. n.* and *Talbot* 4821) in 1906, more than a century ago. Attempts were made to locate the plant from hills in Pune district and nearby areas, but the plants of this species couldn’t be observed after extensive survey. Before the collection by Talbot and report of Venkanna and Das (2000), Masters (1874) just mentioned *A. auritum* preceding his enumeration of *Abutilon* spp., stated as ‘Javanese plant, cultivated in India and sometimes met with as an escape from gardens’. Actually the name based on Wallich catalogue number 1860: *Sida aurita*. In the catalogue Wallich also mentioned it as ‘Cultivated at Calcutta Botanical Garden (HBC), introduced from Java’. This leads to validate its introduction for cultivation from Java. Another specimen of *A. auritum* is deposited at DD without date, place and collector’s name. Though the specimens kept at BSI and DD indicate its occurrence in Maharashtra and Northern part of country and eventually in India but the record dated back to hundred years. And as a part of the present study the plant could not be observed in field anywhere. Moreover, *A. auritum* neither reported from India in any floristic work nor represented in any Indian herbarium, except mentioned above. Therefore, it can be said that the species seems unsuccessful to naturalize and leads to its non-occurrence from Indian land. Another introduced and cultivated species *A. grandifolium* is enlisted by Choudhari and Wadhwa (1984) in analysis of flora of Himachal Pradesh, with a comment ‘a Peruvian plant, cultivated and often occur as an escape’; also included by Paul (1993) as cultivated species. Three specimens (*Rao* 2618, 1957 Himachal Pradesh; *Goel* 64623 Uttarakhand; *Uniyal* 78686, Uttarakhand) of *A. grandifolium* from BSD (BSI, Dehradun) and one is from
BLAT (13551, Bombay) could be observed. Except these confirmations the species is not enlisted in any other floristic literature related to Uttarakhand, Himachal Pradesh, Maharashtra or any other regional floristic study and could not observed in field survey. It indicates that the *A. grandifolium* is not well naturalized here. Moreover, neotropical species of *Abutilon* viz., *A. megapotamicum*, *A. striatum* and *A. pictum* which are introduced and cultivated in India for ornamentation, are now transferred to new genus *Callianthe* (Donnell et al., 2012) which is followed in present study.

**Infrageneric classification**

There are some discrepancies regarding the infrageneric classification proposed by different researchers which lead to artificial assemblage of the species, because the classification is proposed for different geographical areas. *Abutilon* spp. which occur in South India are treated under different sections (Sivarajan and Pradeep, 1966) proposed by earlier workers. As stated earlier, section *Pluriovulata* Fryxell includes Neotropical species which has chromosome number 8, according to Fryxell (2002) the section should be elevated to generic level and his statement was considered by Donell et al. (2012) by proposing new genus *Callianthe* with detailed analysis. Treating pluriovulate species under the section *Pluriovulata* (or under genus *Callianthe*) which occur in India viz., *A. persicum* and *A. ranadei* would be artificial because both have base chromosome number 7 (Goldblatt and Johanson, 2010; Survase et al., 2012). Sivarajan and Pradeep (1966) also treated an endemic species *A. neelgerrense* under section *Armata* Presl along with *A. ramosum* based on character ‘flowers on axillary pedunculate umbels or cymes, Mericarp 5–15’. Fryxell in 1976 in the revision of Sect. *Armata* Presl for Mexican species of *Abutilon* also included the character of inflorescence as ‘ample terminal panicle’. But Presl (1835) in protologue of the section didn’t include character of inflorescence; he characterized the section as ‘Carpels with truncated cone, angular, pointed’; Presl treated species under section *Armata* having axillary solitary flower and some of them are with flowers in panicle. With this analysis treatment given for Indian species regarding sect. *Armata* is controversial and artificial.

**Morphology**

Many earlier studies have reported genus *Abutilon* as diverse in morphology which was also experienced during the present study. Some of the species such as *A.*
*fruticosum* and *A. guineense* do not exceed 1 meter height, whereas other grow up to 3-4 meters. Leaves are rounded or oval in *A. guineense* and *A. pannosum*, triangular in *A. fruticosum* with entire or subentire margin, whereas in *A. australiense*, *A. bidentatum*, *A. hirtum*, *A. indicum*, *A. neelgerrense* leaves are triangular or oval with or without lobed appearance, sharply or coarsely serrat (sometime appear sharply dentate) margin. Cordate leaves without lobes, with comparatively long acuminate apex can be observed in *A. ranadei* and *A. persicum*, whereas *A. ramosum* is characterized by its peculiar trilobed leaves. Stipules commonly observed as lanceolate to triangular, but in *A. ramosum* and *A. neelgerrense* the structure is slender and in *A. pannosum* base of stipule is broader with 2–3 distinct costae. In all taxa of *Abutilon* studied here, flowers are axillary solitary except *A. ramosum* and *A. neelgerrense* in which 4-5 flowers are arranged in an axillary peduncle. Calyx commonly observed as campanulate in genus with lobes divided at middle or below the middle or above the middle. Length of calyx lobes seen as long as or exceeding the fruit apex in *A. australiense*, *A. guineense* and *A. persicum* var. *persicum* and *A. ranadei* function as significant delimiting character. Corolla is rotate and saucer shaped in most of the species, in *A. neelgerrense* it appears conical whereas in *A. ranadei* it is bell-shaped, petals get reflexed in fully bloomed flowers of *A. hirtum*, *A. pannosum* and *A. persicum*. Features of staminal column observed as significant in almost all taxa based on the pubescence and length of staminal tube. *A. ranadei* has longest and glabrous staminal tube whereas in *A. persicum* it is shorter and densely pubescent; in *A. theophrasti* the tubular part is almost stunted. Pubescence of staminal column serves as only resilient character to differentiate varieties of *A. neelgerrense*. Number of carpels in an ovary also plays vital role in delimitation of taxa in the genus, ranges from 5 to 20. On the basis of number of seeds in a carpel the taxa can be classified in 2 groups, 4–6 ovules in a carpel of *A. persicum* and *A. ranadei* whereas in others the number doesn’t exceed 3. Morphology of fruit observed as important character in all the taxa. Along with number, shape and size of the mericarp give distinct appearance to the fruit. Fruit appears cylindrical and truncate in *A. bidentatum*, *A. fruticosum*, *A. guineense*, *A. indicum*, *A. neelgerrense*, *A. ramosum* and *A. theophrasti*. In *A. hirtum* and *A. pannosum* fruits are globular and have more than 20 mericarps. But these are indented in *A. hirtum* and depressed at top in *A. pannosum* with velvety pubescence. Apex of mericarp is long acuminate in *A. bidentatum*, *A. persicum* var. *persicum*, *A. ramosum* and *A. theophrasti* whereas in *A. fruticosum*, *A. hirtum*, *A. pannosum* apex of mericarp with small mucro. Morphology
of seeds is another important aspect for taxonomy of species of *Abutilon* distributed in India. Pubescence and size of seeds provides specific delimitation pattern of identification. Details of the study discussed under title of scanning electron microscopic study of seeds.

**Anatomy**

**Stem anatomy**

Anatomical structure of transverse sections of stem of fourteen taxa of *Abutilon* have been studied. Some of the species are investigated for the first time, viz., *A. australiense*, *A. bidentatum*, *A. guineense*, *A. neelgerrense*, *A. persicum* and *A. ramosum*.

The anatomical structures exhibit typical Malvaceae characters by presence of simple, stellate and glandular hairs on epidermis, druses of calcium oxalate crystals and mucilage secreting cells in all the taxa studied (may or may not be revealed in image given for respective taxon). Variations in their size and frequency of occurrence have been observed within species, along with variations in features of other elements of the structure. *A. fruticosum* and *A. persicum* showed square and rectangular/barrel shaped cells respectively in hypodermal layer but the character is not constant in other individuals and populations of the species, showing its variable nature and changes during growth stages.

Features of cortex, vascular system and pith are studied with reference to Metcalf and Chalk (1950) and Aysegul et al. (2003), Alshymma et al. (2016), Naskar (2016), Srimant and Kare (2018).

**Petiole anatomy**

The study revealed typical anatomical structure of petiole related to Malvaceae, in which epidermis as outermost layer, followed by hypodermis and isolated collateral vascular bundles embedded into parenchymatous ground tissue. Taxonomic significance of this analysis is discussed below.

Transverse section of petiole, especially from median region, is useful to classify the taxa to some extent. Number of vascular bundles is significant character for members of Malvaceae (Metcalf and Chalk, 1950). Results obtained from the study support previous findings.
Studied taxa can be classified into three groups viz., taxa containing four vascular bundles (A. australiense and A. fruticosum), eight vascular bundles (A. bidentatum, A. guineense, A. hirtum, A. indicum, A. neelgerrense var. neelgerrense, A. neelgerrense var. fischeri, A. pannosum, A. ramosum, A. theophrasti) and ten or more than ten vascular bundles (A. persicum var. narasimhanii, A. persicum var. persicum and A. ranadei).

Except number of vascular bundles, no other taxonomically significant characters are observed. For each taxon mentioned above, though the outline seems to be different (rounded or somewhat rectangular, or undulate, appear like having ribs and furrows); it may vary. But obcordate outline of petiole of A. ramosum seems to be distinct, and it can correlate with petiole anatomy of genus Sida (unpublished thesis, Tambde, 2016). In all the species of Sida which occur in India, outline of petiole is obcordate. A. ramosum appears as most closer member of genus Abutilon to Sida while examining ITS as marker for molecular taxonomic analyses in present study. These finding along with inferences related to number of vascular bundles, can be helpful to trace intergeneric phylogenetic relation.

**Leaf anatomy**

It represents typical dorsiventral structure with epidermis with rectangular shaped cells having convex outer wall, one or two palisade parenchyma, vascular bundles of subveins embedded in it. Upper side of midrib is composed of collenchymatous tissue projection, lower side comprising arc shaped vascular bundle surrounded by schlerenchymatous cells. It is revealed that the structure does not possess significant taxonomic characters for genus. Other features of vascular system are studied with reference to Metcalf and Chalk (1950), Aysegul Guvenc et al. (2003), Alshymma et al. (2016), Naskar (2016), Srimant and Kare (2018), not showing significant taxonomic characters. Some variations are discussed below.

Though number of mucilage canals is not significant character, they are abundantly observed in A. persicum and A. ranadei. Outline of transverse section midrib vary in some species, A. persicum is of rounded outline, while in A. ramosum it is oval (similar to some Sida spp.). Overall thickness of leaf lamina is comparatively low in A. neelgerrense, A. persicum, A. ramosum and A. ranadei, shade loving taxa of the genus.
**Vessels**

Vessel elements from young and mature stem of 14 taxa of genus *Abutilon* is matter of discussion here. Small to medium sized vessels with simple perforation plates in some genera of Malvaceae observed by Metcalf & Chalk (1950). Similar observations also recorded by Inamdar et al. (1983). In present investigations, simple pitted vessel elements can be categorized under short (less than 300 µm) and medium sized (300–800 µm). Shortest simple pitted vessel is recorded as 75 µm (*A. ranadei*). Vessels from these categories are observed mainly in mature stem which are predominantly simple pitted. Scalariform thickening also observed. These observations agree with those of Metcalf & Chalk (1950) and Inamdar et al. (1983).

Besides, spirally thickened vessels seem abundant in young stem along with simple pitted and scalariform. Longer vessel elements (more than 700 µm) are observed in young stem, as the stem matures shorter vessels with wide lumen increase in number. Longest spiral vessel recorded as 1510 µm (*A. neelgerrense* var. *neelgerrense*) and longest simple pitted vessel recorded as 1155 µm (*A. guineense*).

Simple perforation plates are of occurrence all over the taxa studied, scalariform plate observed infrequently. Most common disposition of plate is oblique, next to this lateral and transverse disposition which are observed frequently. Median is rarely observed. Two perforation plates in a vessel are recorded in all taxa included for study, rarely one and three.

All features of vessel element are studied with reference to Metcalf and Chalk (1950), Inamdar et al. (1983), Karam (2005), Field and Wilson (2012), Pittermann et al. (2016). Though the study is helpful for understanding characters of vessel elements in genus *Abutilon*, it appears taxonomically insignificant, because all features of vessels are observed more or less similar in all taxa.

**Foliar epidermal features**

Study of leaf epidermis revealed many remarkable features from genus *Abutilon*.

Characteristics of **epidermal cells** (shape and pattern of anticlinal wall) observed more or less similar.
Four types of trichomes are observed while studying foliar epidermis viz., simple unicellular hairs, stellate hairs, short glandular hairs (unicellular base and multicellular globelike head) and long glandular hairs (multicellular base and unicellular head connected to base by single row of cells). Of which, short glandular hairs and stellate hairs are recorded from adaxial and abaxial layer of all species studied. Short glandular hairs exhibit uniformity in their distribution and size within the taxa studied. Stellate hairs are remarked with immense variation concerning density, number and size of arms. Long glandular hairs noted in *A. bidentatum* (Adaxial & Abaxial), *A. hirtum* (Adaxial & Abaxial), *A. indicum* (Adaxial & Abaxial), *A. pannosum* (Abaxial), *A. persicum* (Abaxial) *A. ranadei* (Abaxial) and *A. theophrasti* (Adaxial). Simple hairs observed in *A. pannosum* (Adaxial), *A. ramosum* (Adaxial & Abaxial), *A. ranadei* (Adaxial), and *A. theophrasti* (Adaxial).

**Stomata.** All taxa are amphistomatic except *A. ranadei* which is hypostomatic.

Three types of stomata are recorded viz., Anisocytic (three subsidiary cells of which one is distinctly smaller than other two), Anomocytic (stomata surrounded by many irregularly organized epidermal cells) and Staurocytic (stoma surrounded four more or less similar subsidiary cells, sometimes three or five, with anticlinal walls arranged transverse to the guard cells, the subsidiary cells more or less radially elongated, crosswalls randomly oriented to the long axis of the pore.

Anisocytic stomata observed as a common type in the genus, along with this anomocytic type is seen as dominant in abaxial epidermis of all species. Shaheen et al. (2009), Karthikeyan et al. (2012), Mohite et al. (2012), Fatima et al. (2014) and Chachad and Vaidya (2016) also recorded similar observation. Besides this, staurocytic stomata are recorded first time from genus *Abutilon*. The stomata are observed from adaxial epidermal layer of *A. australiense*, *A. bidentatum* and *A. fruticosum*. Some studies in Malvaceae viz., Essiett and Ewo (2014) and Shokefun et al. (2014), observed staurocytic stomata.

Stomatal index is remarked as important character for grouping of taxa. Highest stomatal index of abaxial (76.52) and adaxial (39.91) epidermis is recorded in *A. theophrasti*. Lowest of abaxial (25.11) and adaxial epidermis (0.64) is noted in *A. neelgerrense* var. *neelgerrense*. Highest value of stomatal index (76.52) for abaxial is followed by *A. fruticosum* (63.41). On the basis of the values for upper epidermis which ranges between 39.91 and 0.64, species can form two groups. Taxa which
ranges between 12.20–39.91 form one group and other group has range 0.64–4.82, includes taxa viz., *A. neelgerrense* var. *fischeri*, *A. neelgerrense* var. *neelgerrense*, *A. persicum* var. *narisimhanii*, *A. persicum* var. *persicum*, *A. ramosum*. Moreover, stomata on adaxial epidermis of these taxa observed as predominately concentrated near midvein and subveins or veinlets. Populations of these species always prefer semi–shady places. Moreover, in *A. ranadei*, which also occurs at shady situations, stomata could not be observed on upper epidermis.

All the characters are studied with reference to Metcalf and Chalk (1950), Van Cotthem (1970), Dinu et al. (2012), Chavan et al. (2014) and others mentioned above. This qualitative and quantitative (Table no. 5-8) analysis of foliar epidermal feature can be considered as useful supportive measure for taxonomic study of the genus.

**Seed morphology**

As stated by earlier workers (Barthlott, 1981, 2008; Cole and Behnke, 1975; Heywood, 1971), seed morphology in this study is recognized as vital means for taxonomic investigation and delimitation of taxa.

Shape of seed is more or less similar in almost all taxa studied, as triangular and compressed. But it differs in *A. persicum* and *A. ranadei*, where seeds appear as oval and depressed unevenly. Base observed as reniform throughout the plant group studies whereas apex is rounded or obtuse and bulgy.

According to size taxa can be grouped in two categories. Smaller seeds are observed where the size ranges in 1.5–2 × 1.5–2 mm. Species from this category are *A. australiense*, *A. bidentatum*, *A. fruticosum*, *A. guineense*, *A. hirtum*, *A. pannosum*, *A. hirtum*, *A. indicum*, *A. pannosum* and *A. ramosum*. Seeds of second category are larger and possess range of size viz. 2.5–3 × 2.5–3 mm. This group include taxa viz., *A. neelgerrense*, *A. persicum*, *A. ranadei* and *A. theophrasti*.

Color of seed is commonly observed as brown to black.

Presence of warts is a common character all over the genus. But the character seems to be more related to occurrence of hairs. SEM studies revealed that, wherever hairs are grown on seed surface, appear as emerged from top of warts or wherever hairs are not observed, warts exist as remnants of hairs. In *A. fruticosum* and *A. theophrasti*, warts are not observed distinctly, but they are observed as modified into small hairs. Whereas in *A. australiense* and *A. pannosum*, densely hairy seeds show
presence of both, hairs and warts. In seeds of these taxa a site with broken hair looks as wart with hole. In case of A. hirtum, warts are observed as topped with a hair or mostly with a pair of hair, and warts without hairs are seen with one or two pits. To conclude, seeds of the genus are always with warts.

Pubescence of seed is another significant character for taxonomic consideration. Scanning Electron Microscopy (SEM) revealed many interesting features about nature of hairs. Presence or absence of hairs on seed surface and at hilum can be discussed separately.

In A. australiense, A. fruticosum, A. hirtum, A. pannosum, A. theophrasti seed surface is hairy. Hairs are numerous, simple, long, c. 200–300 µm in A. australiense, where as in A. pannosum, seed are with less hair density but the range of length is extended, i.e. 300–400 µm. In A. fruticosum, hairs are very short, measured as 70–80 µm, appear like curved beak and possess parallel striations. Similar feature are observed in A. theophrasti but distribution of hair is sparse and hairs are slightly curved in seed surface of this species. Seed surface of A. hirtum covered with much peculiar type of hairs, which occur as single or in pair, many are paired, and are twisted creating many spiral striations. Seed surface in rest of the taxa is observed as glabrous.

Presence of hairs at hilum is important diagnostic feature. But after studying many populations of each taxon it is discovered that occurrence of hairs at hilum is variable for A. bidentatum, A. indicum and A. persicum. If present, hairs are stellate in A. bidentatum and A. indicum, whereas in A. persicum hairs are simple. Seeds of A. hirtum, A. neelgerrense var. fischeri, A. neelgerrense var. neelgerrense, A. pannosum and A. theophrasti are always with pubescent hilum. In A. hirtum and A. pannosum stellate hairy pubescence is extended from hilum to all over the scar of placental attachment, whereas in A. neelgerrense and in A. theophrasti bunch of hairs is observed only at concave part of hilum, and the hilum is stellate hairy in A. neelgerrense and hairs are simple in case of A. theophrasti. In rest of taxa seeds are glabrous at hilum including A. australiense in which seed surface is densely pubescent.

Seed surface in all species is observed as reticulate, or in some taxa (A. bidentatum, A. indicum, A. neelgerrense, A. theophrasti) it is multireticulate. Polygonal epidermal cells are commonly observed in all taxa included for study.
Anticlinal walls of the cells are raised or straight, sometime it is curved or wavy. It is thick in (*A. australiense*, *A. persicum*, *A. ramosum*, *A. ranadei* and *A. theophrasti*). Periclinal wall is more or less concave throughout the genus.

Results attained are similar with Abid et al. (2016) explaining importance of seed morphology in family Malvaceae by studying taxa which occur in Pakistan. Six (*A. bidentatum*, *A. fruticosum*, *A. hirtum*, *A. pannosum* and *A. theophrasti*) species of *Abutilon* included in their study are also part of Indian flora. Primary seed coat features are studied by Thakor (2009) for *Abutilon* spp. occur in Gujarat state of India. Besides this, no any detailed information of seed coat structure has been provided by researchers. Present study is the first attempt of documentation of minute details of seed surface of *Abutilon* spp. in India with the help of Scanning Electron Microscope which has extensively supported this revisionary work.

**Pollen grain morphology**

Analyzing pollen morphological characters of *Abutilon*, its use for taxonomic data is identified as helpful in taxonomic studies. The results are in accordance with Christensen (1986), Bibi (2010), Kunuur (2009) who emphasized on aperture, sculpture and quantitative characters related to spines.

Shape of the pollen grains is seen as spheroidal or spherical. Two categories according to size of pollen grain are observed in the genus viz., medium (25–49 µm) and large (50–99 µm). Medium pollen grains are observed in *A. bidentatum*, *A. fruticosum*, *A. ramosum* and *A. theophrasti* whereas in rest of the taxa pollen grains are large. Smallest pollen grains are recorded in *A. ramosum* i.e. 35–38 µm in diameter and largest size range for diameter is recorded from *A. australiense* (60–65 µm) and *A. hirtum* (64–70 µm). Trizonocolporate pollen grains observed commonly all over the genus which is said by Christensen (1986) as primitive pollen type from the family Malvaceae. Though they are monomorphic in all species studied, spines are recognized as important character for investigation with respect to their number and interspinal distance which can be correlated with size of the pollen grain (Table no.11). According to length of spine taxa are grouped into two categories (Erdtmann, 1952; Punt, 2007) viz., Spinose (>3 µm) and Spinulose (<3 µm). Pollen grains of *A. persicum* and *A. ranadei* are spinulose whereas in rest of the species they are spinose. Spinulose pollen grains are with inconspicuous basal cushion and spinose with prominent one. Spinulose character is considered as primitive than spinose in family
Malvaceae (Christensen, 1986). Tectum and basal cushion of spine commonly observed as microverrucate.

Characters for pollen grains from the genus *Abutilon* are ensured as useful supportive measure for delimitation and classification of the genus.

**Molecular Taxonomic analysis**

Taxonomic position of Indian *Abutilon* spp. was analyzed using nrITS sequence information, which occur in India. Phylogenetic tree (Fig. 15) obtained through Bayesian and maximum likelihood (IQ-TREE 1.6.10) analysis has separated Indian *Abutilon* spp. in different sister clades (subclade 1a and 1b). *A. neelgerrense, A. persicum, A. ranadei* and *A. theophrasti* are seen as monophyletic and remaining taxa *A. australiense, A. bidentatum, A. fruticosum, A. guineense, A. hirtum, A. indicum* and *A. pannosum* another subclade 1b.

*Abutilon ranadei* (endemic to Maharashtra state, India) and *A. persicum* (restricted to tropical Asia) observed to form sister group with *A. neelgerrense* (endemic to south India), and these three species together formed a clade with *A. theophrasti*, a native of Indian subcontinent and spread worldwide as invasive. The inference strongly support Indian origin of these species which are further grouped in subclade 1a with neotropical *Abutilon* spp. Position of *A. ranadei* and *A. persicum* in subclade 1a does not support its grouping with pluriovulate spp. of *Abutilon* (now genus *Callianthe*, Clade 3) and it is incongruent with treatment given by Sivarajan and Pradeep (1996).

The relationship among the taxa grouped in subclade 1b is not well resolved though they are grouped as monophyletic. But Infraspecific classification of *A. indicum* (Borssom Waalkes, 1966; Paul, 1993) currently applied is not appeared to be sustained by the nrITS sequence. Though it is polytomous, but infraspecific taxa of *A. indicum* viz., subsp. *albescence var. australiense* and subsp. *guineense* appeared at distinct positions. The result is also congruent with morphological analysis as discussed earlier.

Among *Abutilon* spp. i. e. *A. ramosum* has got derived position in the phylogenetic tree (Fig. 15) which includes 10 genera of tribe Malveae along with many *Abutilon* species. All the ITS sequences of this species obtained from different accessions have observed as autapomorphic at 8 sites in alignment which is
compatible with some morphological characters such as its peculiar trilobed leaves, 4-5 flowered axillary solitary peduncle and capsules with 8-10 carpels. Sivarajan and Pradeep (1996) treated this taxon under section *Armata* along with another endemic Indian taxon *A. neelgerrense*, this artificial classification cannot be supported by molecular taxonomic analysis. Though the inflorescence character is similar in both species but branching pattern is distinct and the species have many other distinct morphological features. For clear demarcation of this species further investigation is needed with more molecular markers.