Results

4. Results

The present study aims to investigate the morphometric variation in leaf structures of Convolvulaceae family members found in western and central India. Using advanced computational techniques, including geometric morphometrics, elliptic Fourier descriptors (EFDs) and, Principal Component analysis. we have analysed the leaf morphology of several species within this family to assess their taxonomic relationships and potential for species identification.

Present study is based on the result of 4 years of extensive research in morphometric methods and their implications in analysis of members of family Convolvulaceae. This will provide information to person working in the field of Botany as well as statistics and computer applications. This study may serve as a manual for digital identification methods and may also serve as a database for digital leaf images.

During present study, 58 plant species belonging 13 genera of family Convolvulaceae have been collected and studied from various localities of western India majorly from Gujarat and Maharashtra states. Preliminary analysis shows that *Ipomoea* is the largest genus in family with collection of 31 species followed by *Argyreia, Distimake,* with 8 and 4 species respectively. *Merremia, Convolvulus, Evolvulus, Operculina,* and *Jacquemontia* are represented by two species each while *Stictocardia, Turbina,* and *Camonea* are represented by single species each (Table-1).

Table 1 - number of collected species in each genus

Sr. No	Genus	No. of collected species
1	*Argyreia*	8
2	*Camonea*	1
3	*Convolvulus*	3
4	*Distimake*	4
5	*Evolvulus*	2
7	*Ipomoea*	31
8	*Jacquemontia*	2
9	*Merremia*	2
10	*Operculina*	2
11	*Stictocardia*	1
12	*Turbina*	1
13	*Xenostegia*	1

4.1. Genus: *Argyreia* Lour.

***Argyreia* Lour.,** Fl. Cochinch.: 134 (1790)

Type: *Argyreia obtusifolia* Lour.

4.1.1. General Description of genus Argyreia

Perennial woody climbers or twiners or prostrate semi-woody shrubs, plant parts exude milky latex. Stem herbaceous towards tip, hairy, terete, green, or purple in colour, woody or semi-woody towards base, older stem warty, glabrous, terete, or sometimes lobed. Leaves simple, alternate, petiolate, margins entire, leaf lamina elliptic, lanceolate, ovate, orbicular, or cordate, hairy or glabrous adaxially, on abaxial surface usually white, brown or silvery shiny hairy or sometimes glabrous, secondary veins prominently raised on abaxially. Inflorescence an axillary cyme, capitate or paniculate loosely arranged cyme, few to many flowered, peduncle 0–20 cm long, terete, hairy. Bracts 2–3, outer bract leafy, flower bracts herbaceous or coriaceous, persistent in flower or early caducous, large or small, usually hairy outer, glabrous inside, reticulately veined. Sepals–5, free, subequal or unequal, sometimes outer two or three large, hairy outer, glabrous inside, persistent and enlarged in fruit. Corolla actinomorphic, petals 5, gamopetalous, with corolla tube and limb, pink, purple or carmine red in colour, infundibuliform or sometimes hypocrateriform, hairy outer on mid-petaline bands or rarely glabrous, 2–6 cm long. Stamens–5, attached to the base of corolla tube, included in or exserted out of corolla tube, equal or two long and 3 short; anthers two celled, pollens echinate, pantoporate, globular, basifixed, 3–4 mm long; filaments pink or white, dilated and glandular hairy at the base. Ovary 1–4 celled, glabrous, encircled by annular disc; style 1, filiform, included or exserted; stigma bi-globose, papillate, white or pink, equalling, or shorter than the length of stamens. Fruit a globular berry, 7–1.5 mm across, red, yellow, or brown in colour, fleshy, mealy, or dry. Seeds trigonal in shape, black or white in colour, with clear visible hilum.

A total of 8 species from genus Argyreia was collected during the study from different locations (Table-2). The leaves of Argyreia are simple, alternate, exstipulate, dorsiventral and always petiolate. Leaf character is of taxonomic significance to constitute broad groups. Leaf shape varies within genus and usually remains constant within a species. Two kinds of leaf shapes occur in the genus: broadly ovate to ovate leaves with cordate leaf base and other is with elliptic leaves with round to cuneate leaf base (Plate 9-11).

Table 2 - list of collected species of genus *Argyreia*

Sr. No	Scientific name
1	*Argyreia boseana* Santapau & V. Patel
2	*Argyreia cuneata* Ker Gawl.
3	*Argyreia elliptica* (Roth) Choisy
4	*Argyreia nervosa* (Burm.f.) Bojer
5	*Argyreia pilosa* Wight & Arn.
6	*Argyreia sericea* Dalzell
7	*Argyreia setosa* (Roxb.) Sweet
8	*Argyreia sharadchandrajii* Lawand & Shimpale

1. *Argyreia boseana* Santapau & V. Patel, Trans. Bose Res. Inst. Calcutta 22: 35 (1958)

Analysis:

Analysis of *A. boseana* leaves illustrates very less variation in terms of leaf shape and size (Plate – 1A). The leaf shape is constant and not changing very much. There are only six effective principal components extracted out of 116 total PC. It shows that all the variation present on the leaf shape can be depicted by these six variables (Table 3).

The first principal component (PC) was accounted for most variation of 55.79 %. It depicts the variation in leaf shape at the tip of the leaf and the roundness of the leaf. It also shows the variation of length-to-width ration and overall shape change. Second PC shows variation caused by leaf base and mid petaline are (width of the leaf). It depicts the small variation occurring at the right side of the leaf and the base of the leaf. The third, fourth and fifth PC shows very little variation and can be depicted as minor variation along the leaf margin, overall leaf roundness and leaf base (Plate *12*-A).

Table 3 - Eigenvalue and PCA of *A. boseana*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00586	55.79	55.79
PC2	0.00250	23.85	79.63
PC3	0.00087	8.29	87.92
PC4	0.00066	6.24	94.16
PC5	0.00043	4.05	98.21
PC6	0.00019	1.79	100.00

2. ***Argyreia cuneata*** (Willd.) Ker Gawl. Bot. Reg. 8: t. 661 (1822)

Analysis:

Examination of leaves of *A. cuneata* lead to extraction of 8 effective principal components (Table - 4). PC1 shows the highest amount of variation among all the calculated components. The variation depicted by PC1 was on the shape of the leaf base and variation on the distal part of the leaf lamina. PC2 depicted the variation among the shape of leaf base as well as on the length-to-width ratio. Variation depicted by third PC was on the leaf apex and overall width of the leaf. Variations depicted by consecutive PCs are very minor but can be considered important. PC4 and PC5 shows variation among shape of the leaf base and curvature of the leaf lamina while rest of the PCs (PC6, PC7 and PC8) shows minute variation on leaf apex roundness and length-to-width ratio (Plate – 12C).

Table 4 - Eigenvalue and PC analysis of *A. cuneata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.003209	64.02	64.02
PC2	0.000726	14.47	78.50
PC3	0.000358	7.15	85.64
PC4	0.000191	3.80	89.45
PC5	0.000140	2.80	92.24
PC6	0.000079	1.58	93.82
PC7	0.000068	1.36	95.18
PC8	0.000049	0.98	96.16

3. ***Argyreia elliptica*** (Roth) Choisy, Mém. Soc. Phys. Genève 6: 417 (1833 publ. 1834) [Conv. Or.: 35]

Analysis:

Analysis of Argyreia elliptica leaves shows major variation in leaf shape. There were six effective principal components derived from the data matrix which shows wide variety of variation (Table - 5). The first PC accounted for the 61.45 % of total variation seen. It depicts the variation to the length-to-width ratio. PC2 shows variation in leaf tip shape and overall roundness of the leaves. PC3 was accounted variation in leaf base shape. The rest of PCs accounts for very minor variance. they depict variation in the overall leaf shape, leaf base variation and leaf width variation respectively (Plate – 12B).

Table 5 - Eigenvalue and PC analysis of *A. elliptica* leaves

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01114	61.4508	61.4508
PC2	0.00429	23.6728	85.1236
PC3	0.00128	7.0557	92.1792
PC4	0.00046	2.5168	94.696
PC5	0.00023	1.2943	95.9904
PC6	0.00018	0.9766	96.967

4. ***Argyreia nervosa*** (Burm.f.) Bojer, Hortus Maurit.: 224 (1837)

Analysis:

Leaf image analysis of *A. nervosa* resulted in seven effective PCs (Table - 6). PC1 showed the major variation accounted for overall variance of 73.08%. the variation depicted by PC1 was majorly on leaf shape roundness, leaf base lobing, and length to width ratio. PC2 depicts variation among leaf margin and leaf tip development. PC3 and PC4 showed minor variations at leaf base, and some variation was seen on the left distal part of the leaf lamina. Rest of the PCs (PC5, PC6 and PC7) shows very little variation which can be seen on leaf margin and leaf overall roundness of the leaf (Plate – 13A).

Table 6 - Eigen value and PC scores of *A. nervosa*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02367	73.0815	73.0815
PC2	0.00281	8.6833	81.7648
PC3	0.00154	4.7664	86.5311
PC4	0.00099	3.0442	89.5753
PC5	0.00084	2.5854	92.1607
PC6	0.00070	2.1548	94.3155
PC7	0.00049	1.5028	95.8184

5. ***Argyreia pilosa*** Wight & Arn., Madras J. Lit. Sci. 5: 18 (1837)

Analysis:

Investigation of A. pilosa resulted in total nine effective PCs showing 96.86% cumulative variation (Table - 7). PC1 was accounted for 49.05% variation which was seen as leaf lamina development and length-to-width ration of lamina. PC2 and PC3 were accounted for variation of leaf tip development and lamina width variation at proximal end of leaf. PC4 and PC5 shows

variation at leaf base development and leaf maximum width development. Rest of the remaining PCs (PC6, PC7, PC8 and PC9) shows very minute variation. These variations can be seen as leaf margin variation and overall leaf shape development variation (Plate – 13B).

Table 7 - Eigen value and PC scores for *A. pilosa* leaves

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01414	49.05	49.05
PC2	0.00424	14.70	63.75
PC3	0.00351	12.16	75.91
PC4	0.00224	7.77	83.68
PC5	0.00182	6.32	90.00
PC6	0.00082	2.85	92.85
PC7	0.00050	1.75	94.60
PC8	0.00034	1.18	95.78
PC9	0.00031	1.09	96.86

6. ***Argyreia sericea*** Dalzell & A. Gibson, Bombay Fl.: 169 (1861)

Analysis:

Analysis of leaf images of Argyreia sericea resulted in nine effective principal components showing 98.20% cumulative variation in shape (Table - 8). Out of these none major of the variation was depicted by first three PCs. Variation accounted for PC1 was 49.28% depicting developmental changes from length-to-width ratio, overall leaf roundness, leaf tip development and overall leaf shape. Variation accounted by PC2 was depicting variation to the distal part of the leaf lamina and leaf base lobing. PC3 showed variation of leaf margin variation and petiole development. Variation depicted by PC4 and PC5 was minimal which showed variation at tip development and leaf base development. The variation recorded for rest of the PCs (PC6, PC7, PC8, and PC9) was very minimal and showed only minor difference at leaf tip and base development (Plate – 14A).

Table 8 - Eigen value and PC scores of *A. sericea*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01829	49.28	49.28
PC2	0.00743	20.02	69.30
PC3	0.00477	12.86	82.17
PC4	0.00237	6.37	88.55
PC5	0.00151	4.07	92.62
PC6	0.00073	1.97	94.60
PC7	0.00064	1.73	96.33
PC8	0.00035	0.95	97.29
PC9	0.00034	0.91	98.20

7. ***Argyreia setosa (Roxb.) Sweet, Hort. Brit., ed. 2: 373 (1830)***

Analysis:

Examination of A. setosa leaves turn out in seven effective PCs showing total of 98.61% cumulative variance (Table - 9). Approximately half of the variation was depicted by PC1. The variation depicted by PC1 was on the length-to-width ratio and left distal part of the leaf lamina. PC2 illustrates overall leaf shape, roundness of the leaf and leaf tip development. Variation accounted by PC3 (10.53%) illustrates leaf base and tip variation. PC4 and PC5 depicted variation in right distal part of the leaf lamina and leaf tip development. the last two PCs (PC6 and PC7) shows vary minor variation which can be seen as variation along the leaf margin (Plate – 14B).

Table 9 - Eigen value and PC scores of *A. setosa* leaves

Principal components	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00553	49.73	49.73
PC2	0.00265	23.79	73.52
PC3	0.00117	10.53	84.05
PC4	0.00072	6.48	90.53
PC5	0.00051	4.54	95.07
PC6	0.00022	1.93	97.01
PC7	0.00018	1.60	98.61

8. ***Argyreia sharadchandrajii*** Lawand & Shimpale, Rheedea 31: 19 (2021)

Analysis:

Investigation of leaf images of Argyreia sharadchandrajii resulted in ten effective PCs exhibiting 95.82 % cumulative variance (Table-10). PC1 of A. sharadchandrajii depicted low variance (35.15) compared to other Argyreia species. Showing very low shape variation in apex and overall leaf roundness and leaf shape. PC2 accounted for variance showing variation to the right proximal part and leaf base lobing. PC3 and PC4 and PC5 exhibited variation to the distal part of the leaf lamina and leaf base lobing development. rest of the PCs (PC6 to PC10) depicted very low variance values showing only minor variation along the &leaf margin and development of distal part of the leaf lamina and leaf tip. (Plate - 15A).

Table 10 - Eigen value and PC scores of *A. sharadchandrajii*

Principal components	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01725	35.15	35.15
PC2	0.01071	21.83	56.97
PC3	0.00699	14.24	71.21
PC4	0.00464	9.46	80.67
PC5	0.00354	7.22	87.89
PC6	0.00112	2.28	90.17
PC7	0.00093	1.90	92.08
PC8	0.00071	1.45	93.53
PC9	0.00062	1.26	94.79
PC10	0.00051	1.03	95.82

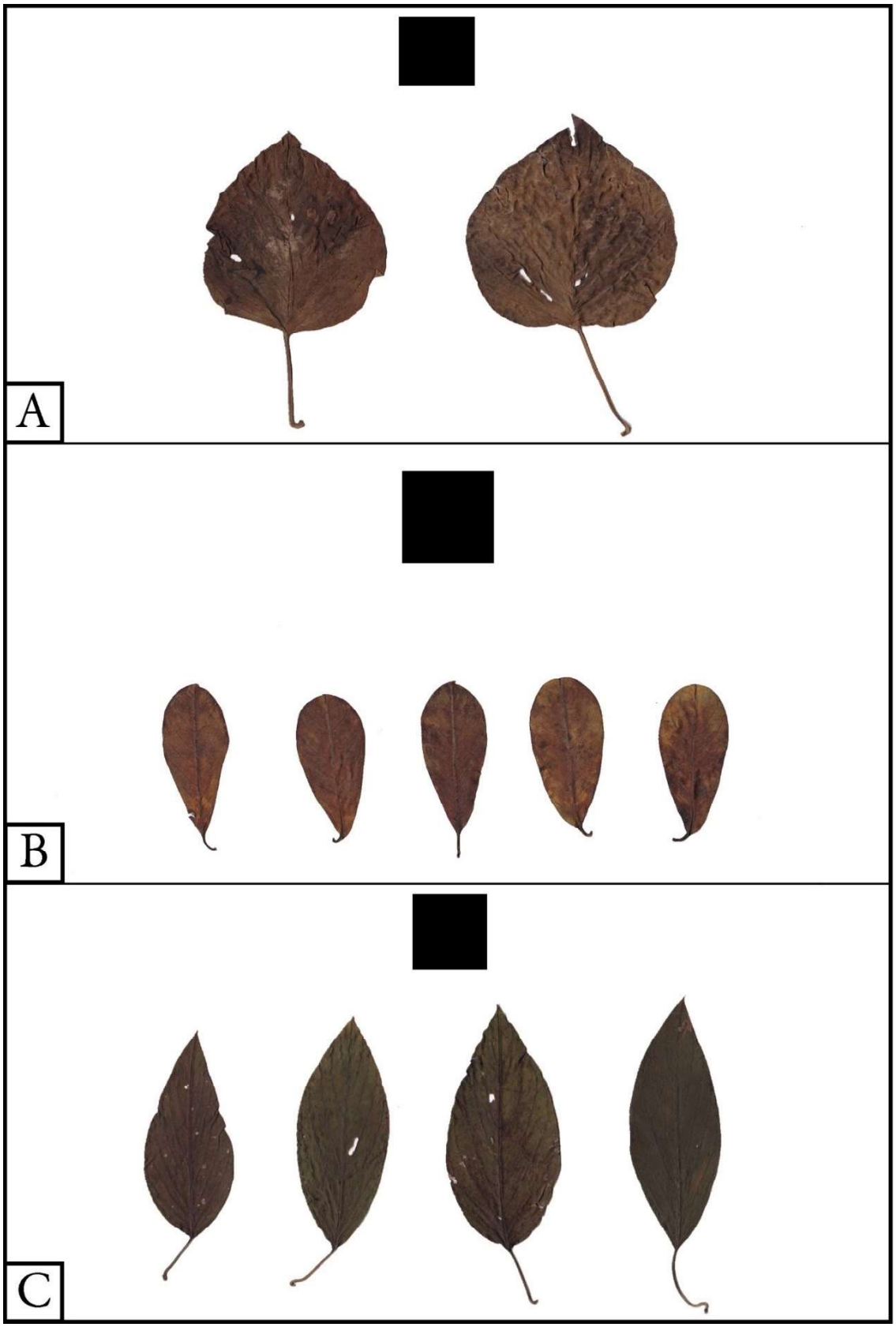

Plate 9 - Leaf sample of Argyreia species (**A**- *A. boseana*; **B**- *A. cuneata*; **C**- *A. elliptica*) (Scale-3 x 3 cm)

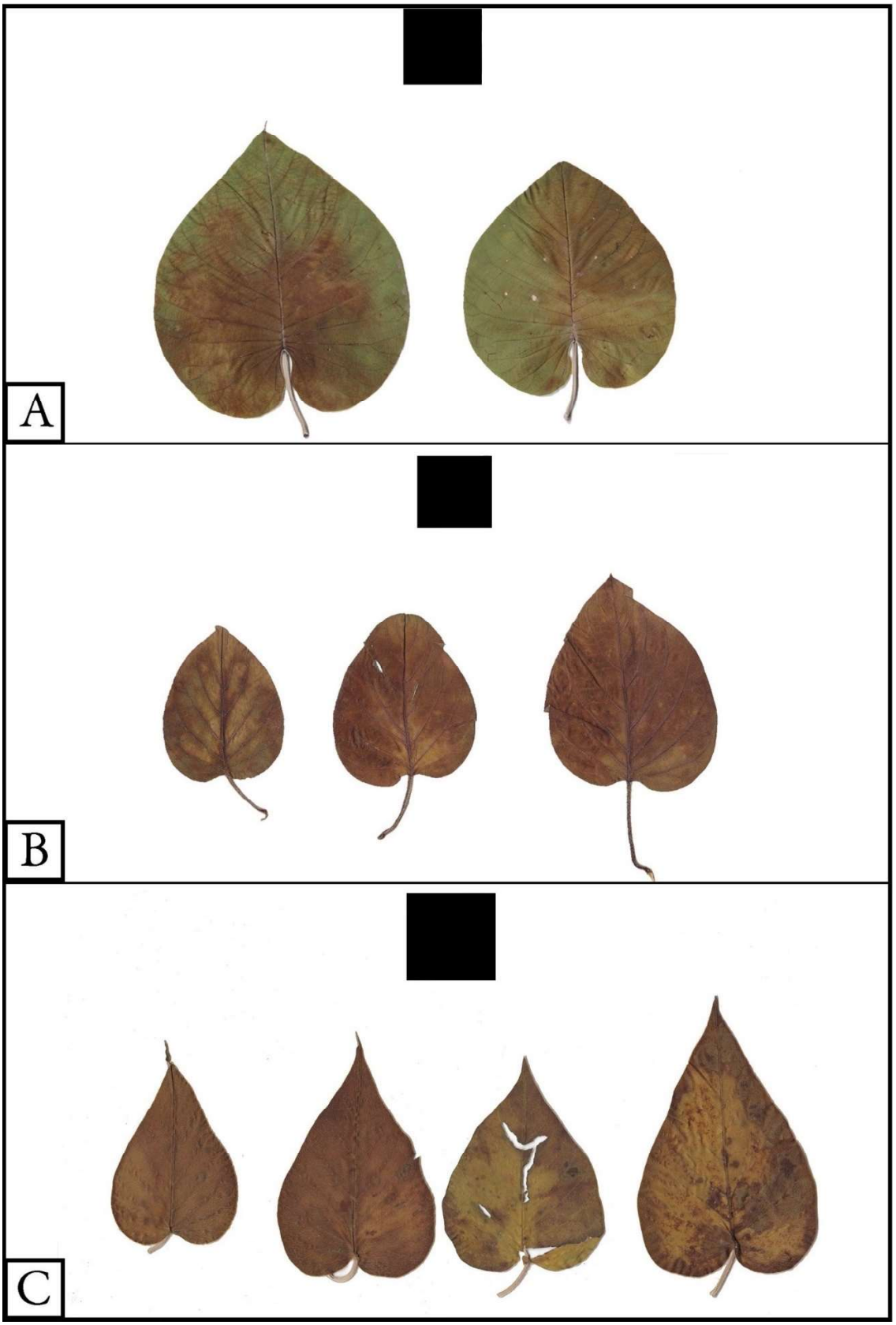

Plate 10 - Leaf sample of Argyreia species (**A**- *A. nervosa*; **B**- *A. pilosa*; **C**- *A. sericea*) (Scale-3 x 3 cm)

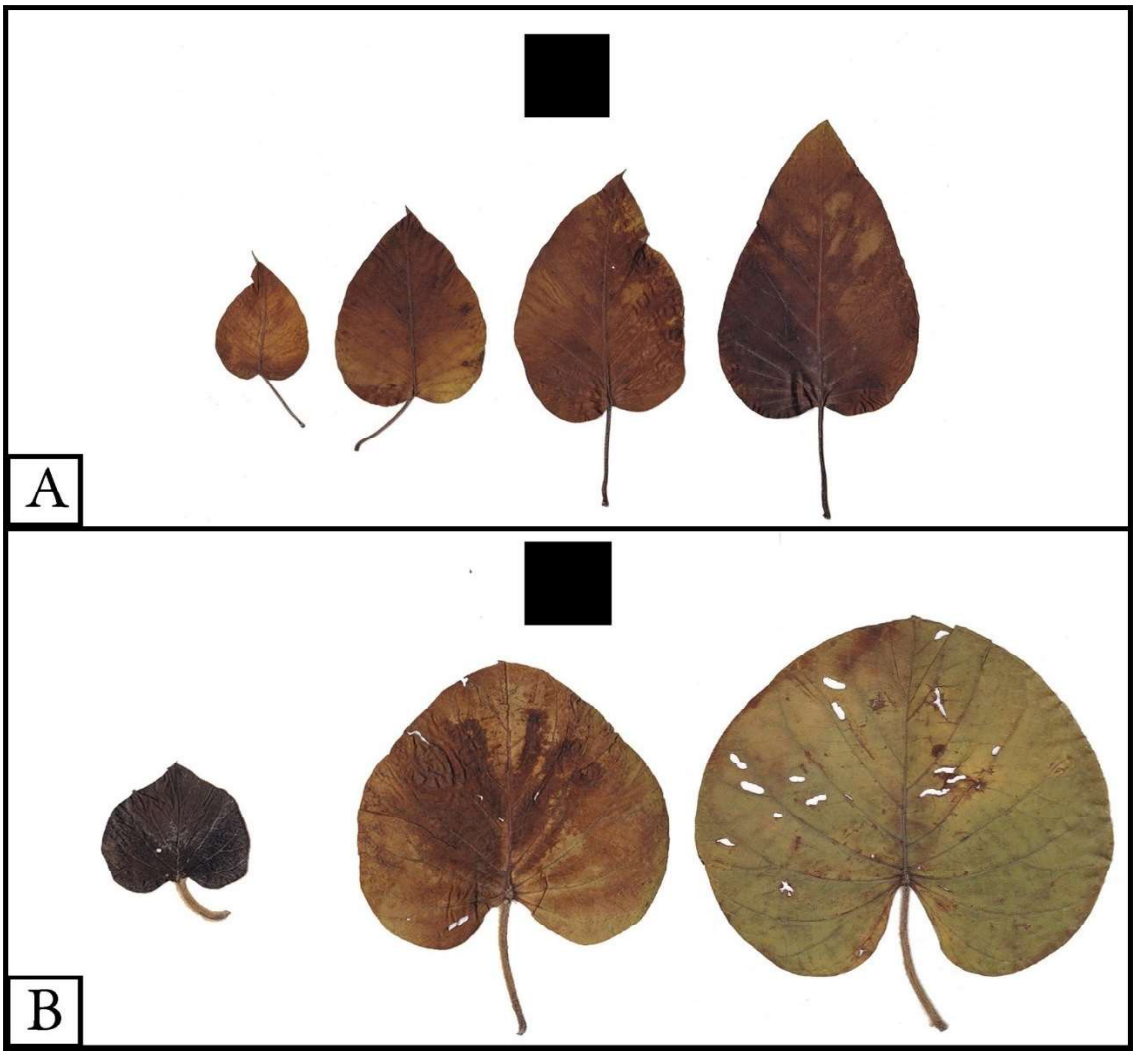

Plate 11 - Leaf sample of Argyreia species (**A**- *A. setosa*; **B**- *A. sharadchandrajii*) (Scale-3 x 3 cm)

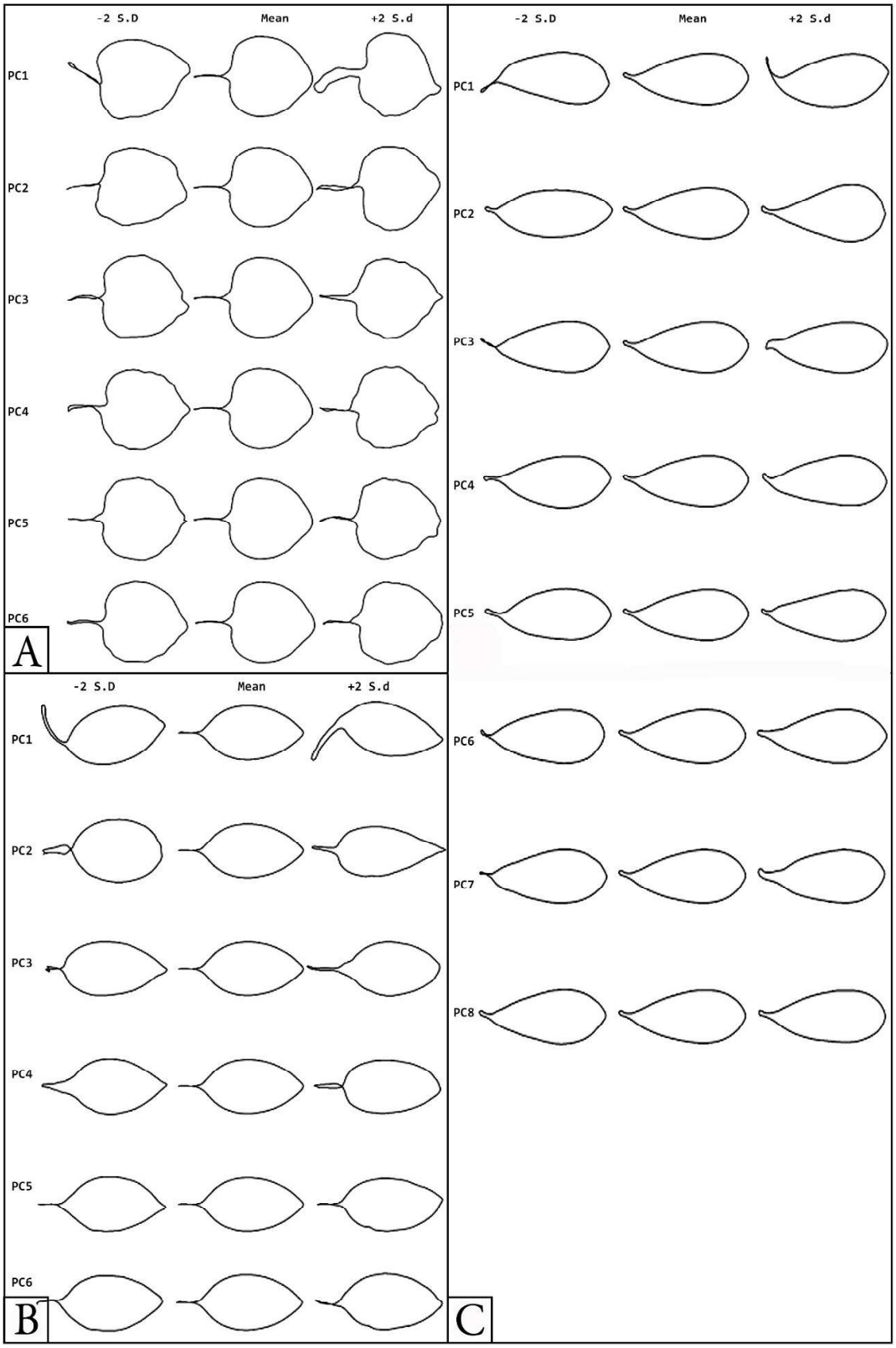

Plate 12 - Processed image showing leaf shape variation (**A**- *A. boseana*; **B**- *A. elliptica*; **C**- *A. cuneata*)

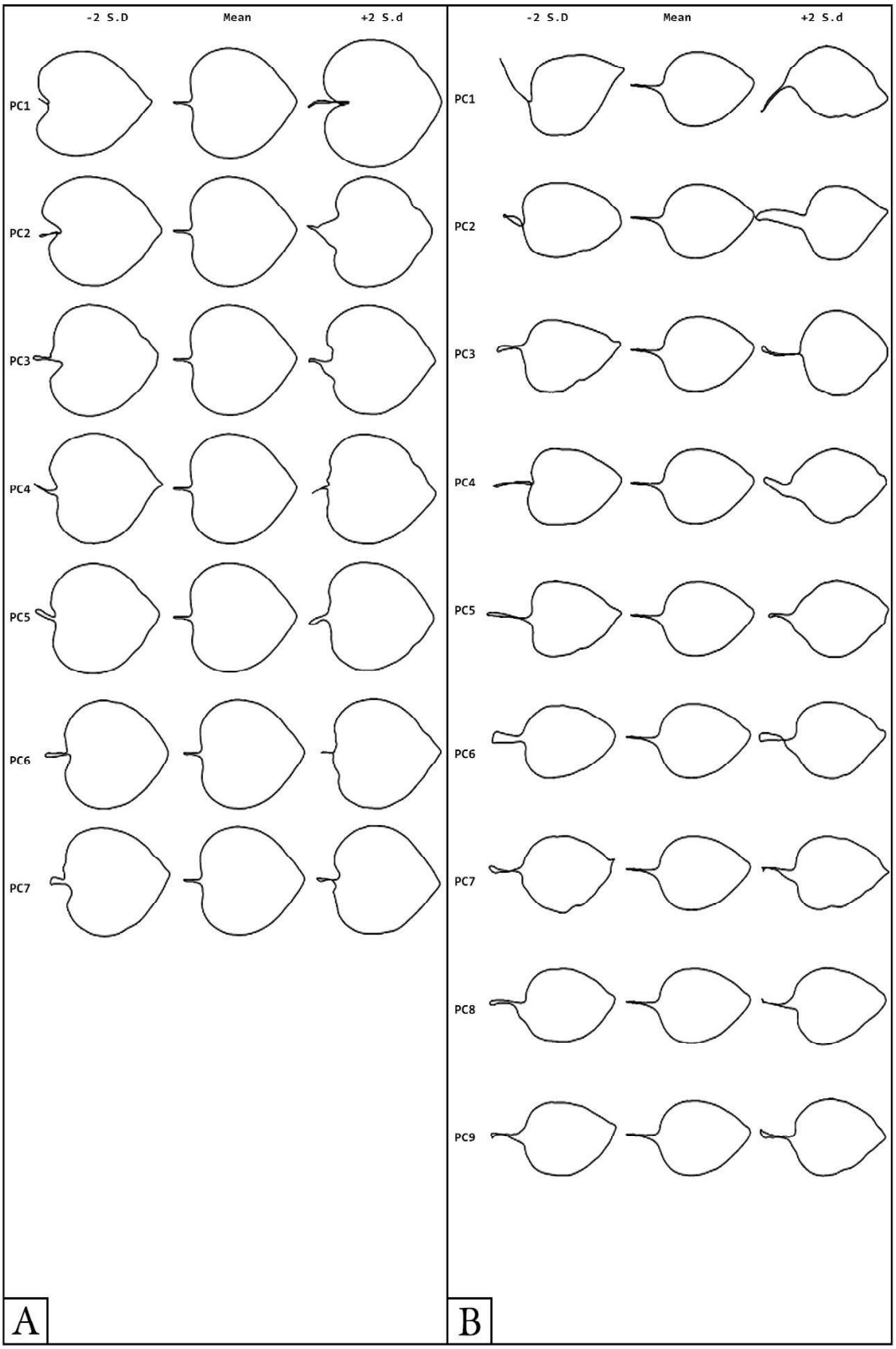

Plate 13 - Processed image showing leaf shape variation (**A**- *A. nervosa*; **B**- *A. pilosa*)

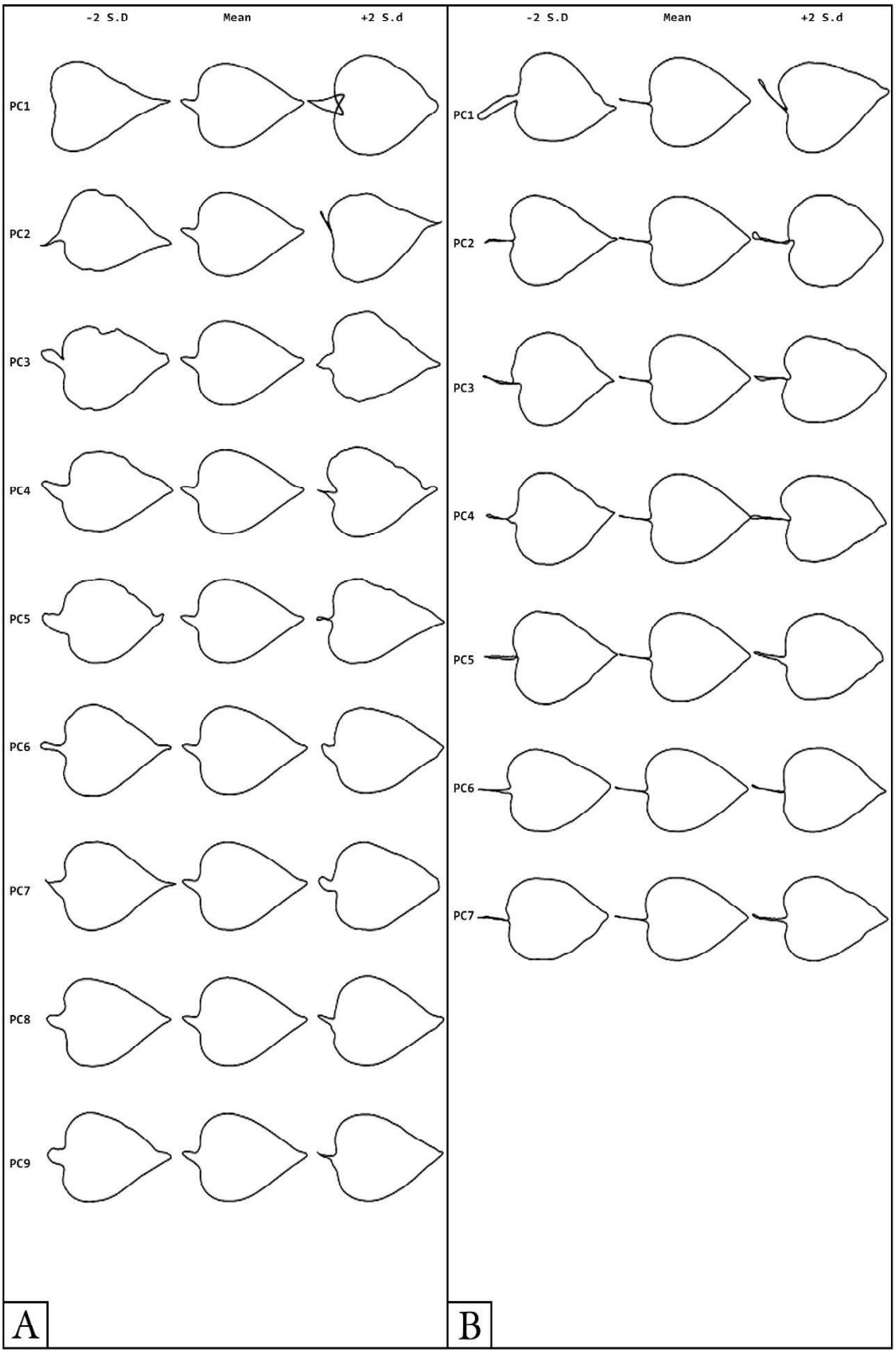

Plate 14 - Processed image showing leaf shape variation (**A**- *A. sericea*; **B**- *A. setosa*)

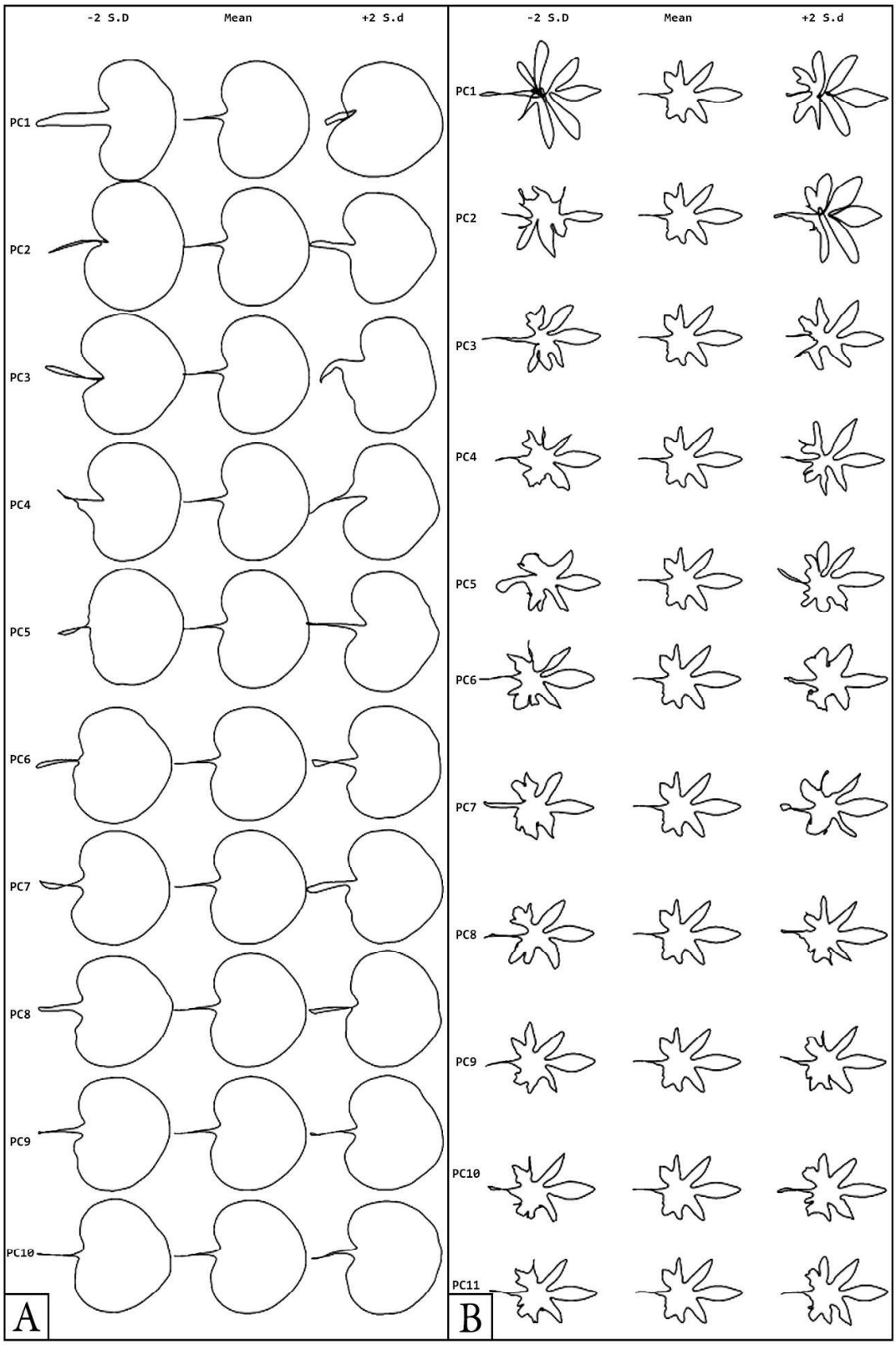

Plate 15 - Processed image showing leaf shape variation (A- A. sharadchandrajii; B- I. tuberculata)

4.2. Genus: *Camonea* Raf.

Camonea Raf., Fl. Tellur. 4: 81. 1838.

Type: *Camonea bifida* (Vahl) Raf.

= *Merremia umbellate* (L.) Hallier f.

4.2.1. General Description of genus Camonea:

Herbaceous twiners or prostrate creepers; leaves entire or angulate-lobed; with two firm outgrowths (paired auricles) at petiole base; corolla with a tuft of hairs at the apex of the mid-petaline bands, otherwise glabrous; anthers longitudinally dehiscing and curved at the apex or spirally dehiscing; pollen hexazonocolpate; fruit a chartaceous four-valved capsule, exocarp not delaminating during dehiscence; seeds pubescent, with long golden hairs either covering the entire surface or concentrated along the edges (Plate – 16A).

Table 11 - Collected species of genus *Camonea*

Sr. No.	Scientific Name
1	*Camonea pilosa* (Houtt.) A.R. Simões & Staples

1. *Camonea pilosa (Houtt.) A.R.Simões & Staples*

Analysis:

Examination of *C. pilosa* leaves resulted in eight effective PCs depicting 97.59% cumulative variance. Major variation of leaf shape was showed by first three PCs. Effects of PC1 was seen as development of petiole and leaf base. It also effected overall shape of the leaf. (Table 12). PC2 was depicted by variation in leaf width and development of petiole. PC3 on the other hand showed ambiguous shape changes towards the leaf base and petiole shape. PC contributed towards the leaf apex shape and development of leaf tip. while PC5 contributed to lanceolate shape of the leaf PC6 contributed towards giving leaf more of an oval shape. PC7 and PC8 were depicted by leaf apex and length to width ratio (Plate – 17B).

Table 12 - Eigen value and PC scores of *C. pilosa*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00911	45.00	45.00
PC2	0.00468	23.12	68.12
PC3	0.00253	12.50	80.63
PC4	0.00150	7.40	88.03
PC5	0.00091	4.50	92.53
PC6	0.00043	2.12	94.65
PC7	0.00034	1.68	96.33
PC8	0.00026	1.26	97.59

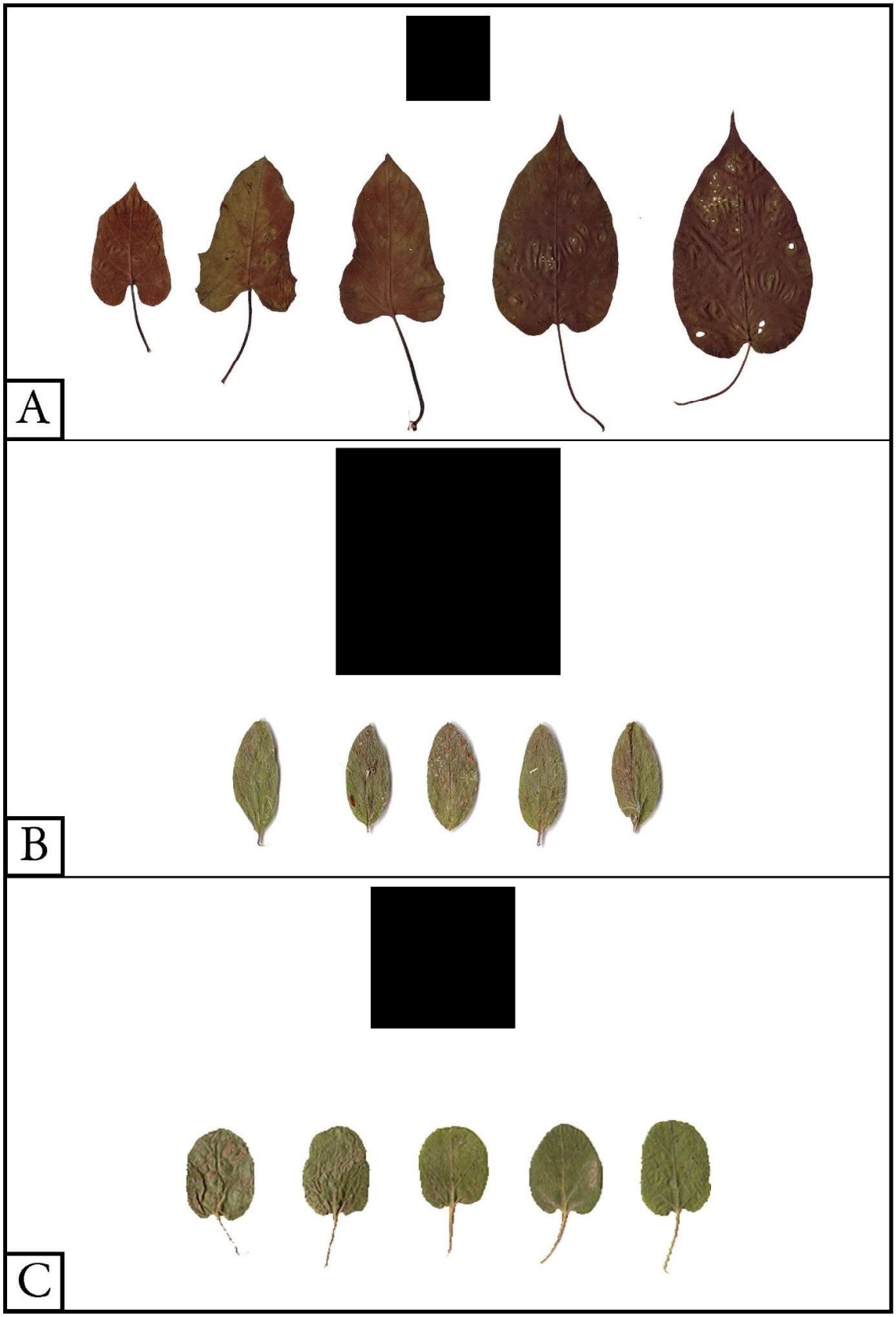

Plate 16 - Leaf sample of Camonea and Evolvulus species (**A**- *C. pilosa*; **B**- *E. alsinoides*; **C**- *E. nummularius*)
(Scale-3 x 3 cm)

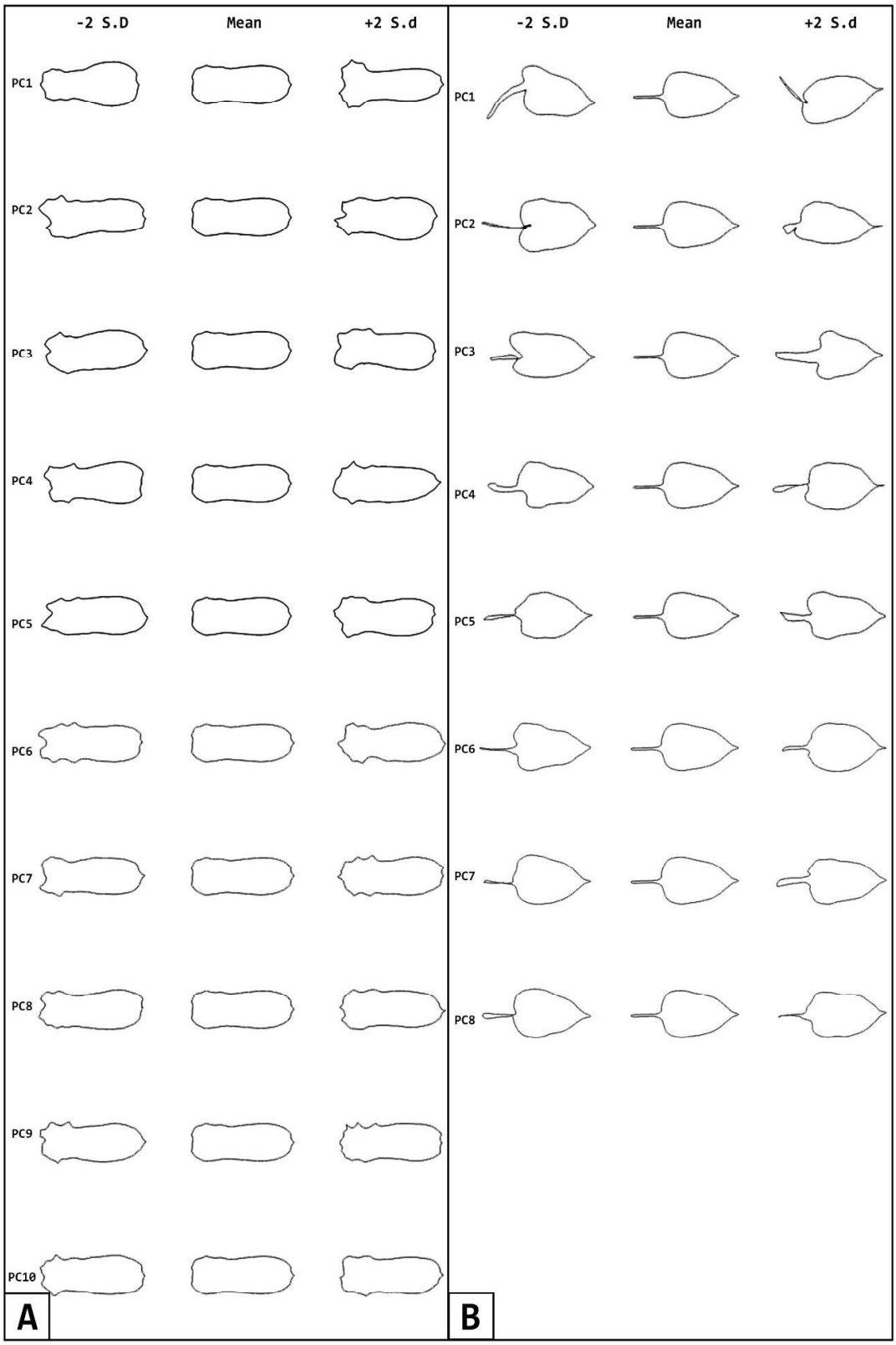

Plate 17 - Processed image showing leaf shape variation (A- *X. tridentata*; B- *C. pilosa*)

4.3. Genus: *Convolvulus*

Convolvulus L., Sp. Pl. 1: 153. 1753. (Linnaeus 1753: 153).

Type: *Convolvulus arvensis* L.

4.3.1. General Description of genus *Convolvulus*:

Spiny or unarmed shrubs or subshrubs or prostrate or erect herbs, stems often twining or trailing. Leaves alternate (rarely subopposite), simple, sessile or petiolate.(Table 13). Flowers variously arranged, solitary or in various kinds of inflorescence, usually cymose in structure although reduced to heads, flower pairs or other arrangements; each flower subtended by a pair of small bracteoles; calyx of 5 free sepals, these usually entire, slightly to very unequal, usually of two similar outer sepals, two similar inner sepals and an asymmetric middle sepal whose two halves are dissimilar; corolla funnel-shaped with a spreading limb and a short glabrous basal tube, the limb with five hirsute external mid-petaline bands which terminate in a tooth or lobe; stamens 5, included, inserted at the top of the basal tube, fi laments unequal, the basal part slightly dilated, glabrous or minutely glandular, the glands sessile or shortly stipitate, anthers equal, oblong to oblong-sagittate, pollen tricolpate, more or less spherical, colpi long and broad, exine thick; ovary usually ovoid, less commonly globose or conical, hirsute or glabrous, the base with a distinct disc, bilocular, each locule with 2 ovules; styles glabrous or hirsute, filiform divided upwards into 2 (rarely 3) arms, stigmas coextensive with style arms (very rarely slightly shorter), linear or, rarely, thickened upwards and ellipsoid or clavate. Capsule bilocular or by abortion unilocular, the dehiscence loculicidal or from the base, 4-seeded or less by abortion; seeds hirsute or glabrous, smooth tuberculate or obscurely ridged, one side convex and the other flat unless capsule is 1-seeded when shape is ellipsoidal. (Plate – 18).

Table 13 - List of collected species of genus Convolvulus

Sr. No.	Scientific Name
1	*Convolvulus arvensis* L.
2	*Convolvulus prostratus* Forssk.
3	*Convolvulus rottlerianus* subsp. *stocksii* (Boiss.) J.R.I. Wood & R.W.Scotland

1. ***Convolvulus arvensis*** L., Sp. Pl. 1: 153. 1753. (Linnaeus 1753: 153)

Analysis:

Examination of *C. arvensis* leaves resulted in 10 effective PCs depicting 93.53% cumulative variance. (Table 14). First four PCs showed most of the variation observed in the leaf shape. Effects of PC1 was major in leaf shape variation showing development of leaf base and petiole giving the leaf its sagittate shape. PC2 was represented by variation in length to width ratio. Effects of PC3 were illustrated by variation in leaf base. PC4 was mainly represented by variation in leaf width. PC5 and PC6 had similar values and showed variation at leaf base development. effects depicted by PC7, PC8 and PC9 were similar showing variation at right proximal part and developing ambiguous shape at leaf base. PC10 was mainly showing variation on overall leaf shape providing leaf its shape (Plate – 19A).

Table 14 - Eigen value and PC scores of *C. arvensis*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00506	28.97	28.97
PC2	0.00333	19.03	47.99
PC3	0.00289	16.53	64.52
PC4	0.00184	10.54	75.06
PC5	0.00087	4.95	80.01
PC6	0.00082	4.71	84.72
PC7	0.00051	2.90	87.62
PC8	0.00048	2.74	90.36
PC9	0.00035	2.00	92.36
PC10	0.00021	1.17	93.53

2. ***Convolvulus prostratus*** Forssk., Fl. Aegypt. -Arab. 203. 1775. (Forsskål 1775: 203)

Analysis:

Examination of *C. prostratus* leaves resulted in 10 effective PCs showing 93.92% cumulative variance (Table - 15). Most of the variation was depicted by first two PCs. Although first PC showed highest accounted variation, there was no visual variation seen in analysed images except for minor variation in petiole orientation. Effects of PC2 were also minor and can be seen as leaf apex variation and variation in length to width ratio. There was no visual differentiation seen by the rest of the PCs in analysed images of *C. prostratus*. This can be a cause of small leaf size and lack of variation in leaf shape (Plate – 19B).

Table 15 - Eigen value and PC scores of *C. prostratus*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00059	45.77	45.77
PC2	0.00024	18.63	64.40
PC3	0.00011	8.75	73.15
PC4	0.00009	6.60	79.75
PC5	0.00006	4.40	84.16
PC6	0.00004	3.15	87.31
PC7	0.00004	3.03	90.34
PC8	0.00002	1.69	92.03
PC9	0.00001	1.01	93.04
PC10	0.00001	0.88	93.92

3. ***Convolvulus rottlerianus* subsp. *stocksii*** (Boiss.) J.R.I. Wood & R.W. Scotland, comb. et stat. nov.

Analysis:

Examination of *Convolvulus rottlerianus* subsp. *stocksii* resulted in seven effective PCs illustrating 98.81% cumulative variance. (Table 16). Most of the variation in leaf shape was depicted by the first three PCs. The effects of PC1 were represented by variation on leaf length and leaf blade shape. PC2 was represented by variation in leaf base and leaf margin along with leaf tip variation. PC3 was depicted by variation in leaf apex and bas development. The rest of the four PCs do not show any visual shape changes in analysed images. (Plate – 20A).

Table 16 - Eigen value and PC scores of *Convolvulus rottlerianus* subsp. *stocksii*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00371	66.96	66.96
PC2	0.00078	14.14	81.11
PC3	0.00062	11.09	92.20
PC4	0.00013	2.41	94.61
PC5	0.00011	2.04	96.64
PC6	0.00007	1.26	97.91
PC7	0.00005	0.90	98.81

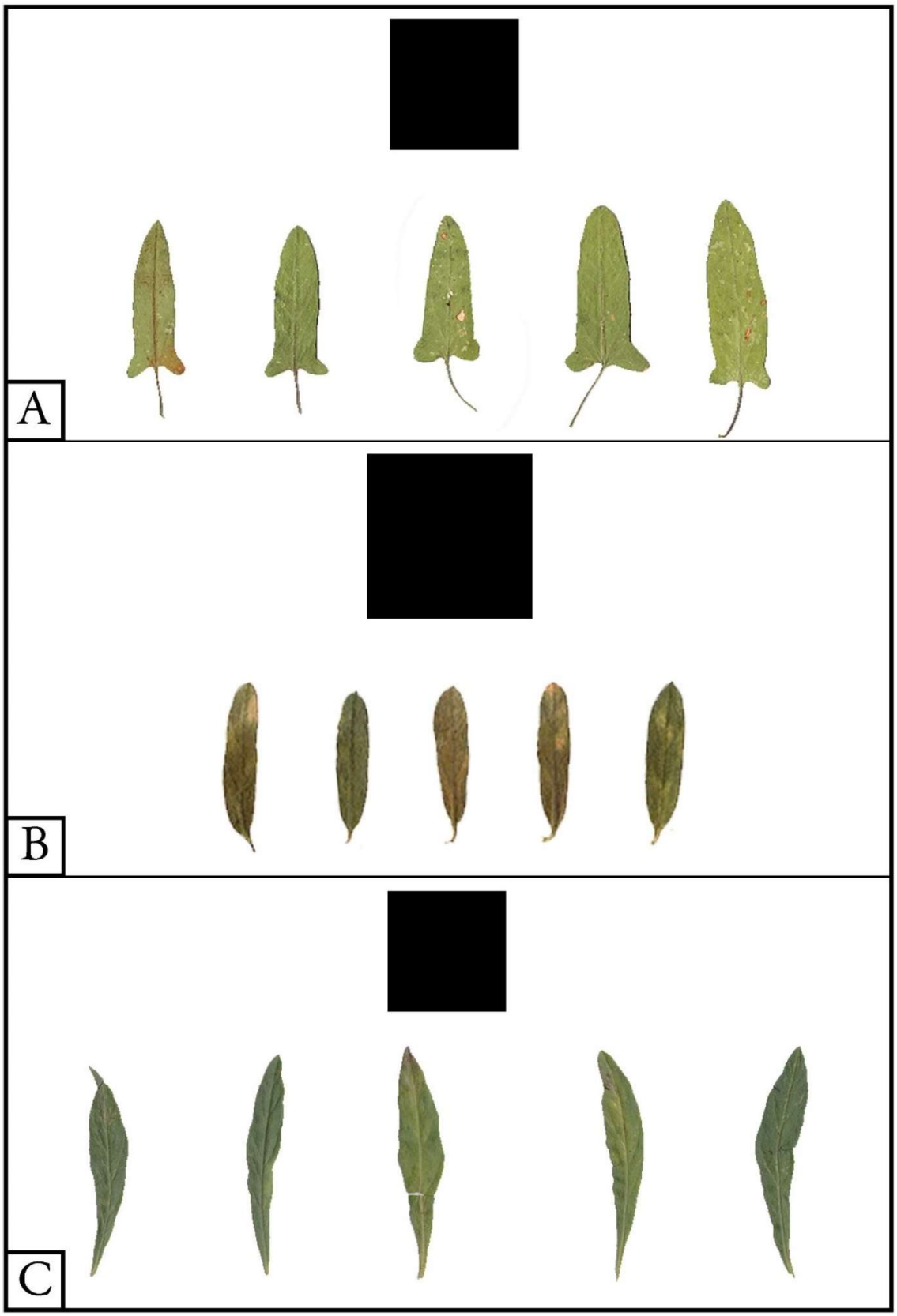

Plate 18 - Leaf sample of *Convolvulus* species (A- *C. arvensis*; B- *C. prostratus*; C- *C. rottlerianus* subsp. *stocksii*) (Scale-3 x 3 cm)

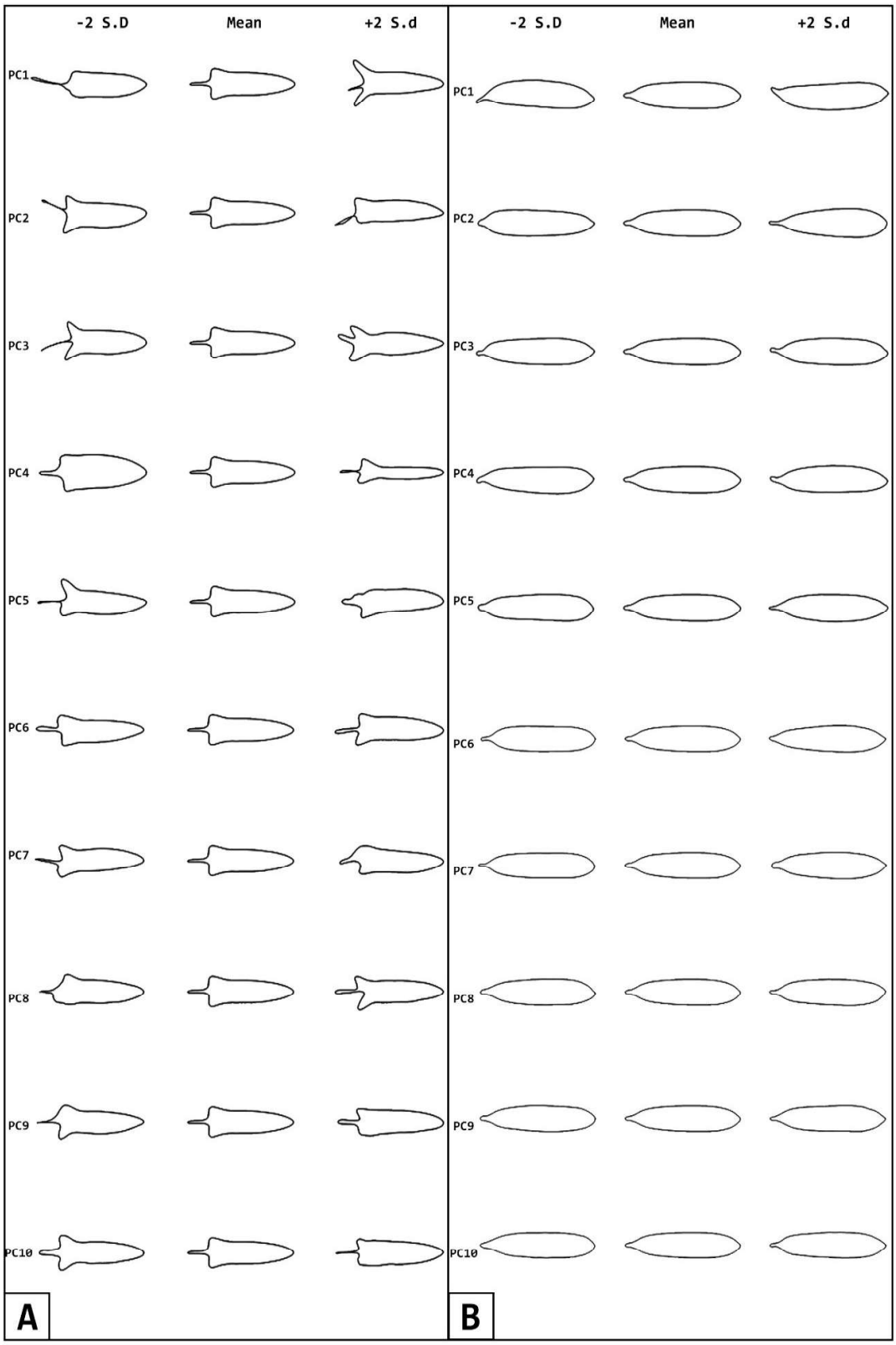

Plate 19 - Processed image showing leaf shape variation (**A**- *C. arvensis*; **B**- *C. prostratus*)

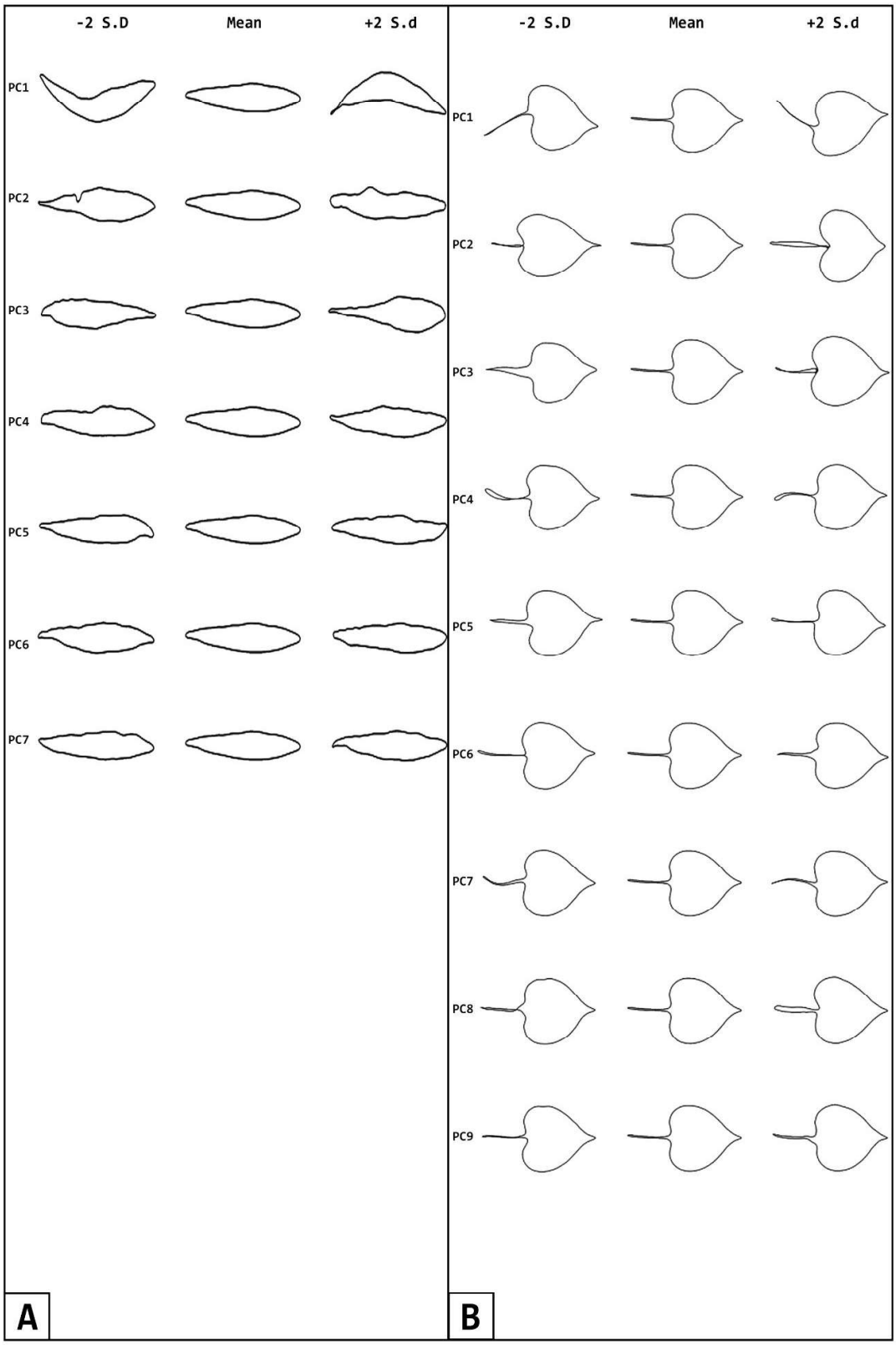

Plate 20 - Processed image showing leaf shape variation (**A**- *C. rottlerianus* subsp. *stocksii*; **B**- *T. corymbosa*)

4.4. Genus: *Distimake* Raf.

Distimake Raf., Fl. Tellur. 4: 82 (1838)

Type: ***Distimake macrocalyx*** (Ruiz & Pav.) A.R. Simões & Staples Bot. J. Linn. Soc. 183: 574 (2017)

4.4.1. General Description of genus *Distimake*:

Distimake is a genus widespread in tropical America and tropical Africa with disjunct species in Asia and northern Australia with 35 species, and more possibly to be described (Simões & Staples 2017). They are robust herbaceous climbers (rarely lianas or erect shrubs); leaves usually five- to seven-palmately lobed or compound (rarely simple or reduced to scales); calyx mostly with flat sepals (not convex) appressed to the corolla tube base, accrescent in fruit; corolla often white or pale yellowish, with or without a dark red centre, entirely glabrous, drying with dark lines in mid-petaline bands; anthers spirally dehiscing; pollen trizonocolpate (12-zonocolpate in *D. tuberosus* and *D. quinatus*) fruit usually a four-valved capsule, calyx greatly accrescent in fruit, later the sepals reflexing; seeds glabrous (less commonly shortly velvety puberulent with dehiscent hairs).(Table 17).

Distimake was separated from *Merremia* s. l. on molecular, morphological, palynological and geographical evidence. The main characters separating *Distimake* from *Merremia* senso stricto are the deeply lobed or compound leaves in *Distimake*, opposed to the entire or shallowly lobed leaves of *Merremia*, and the flat sepals, which are appressed to the corolla tube in *Distimake*, but are moderately convex, and not appressed to the corolla tube, in *Merremia* (Plate – 21; Plate – 49C).

Table 17 - List of collected species of genus *Distimake*

Sr. No.	Scientific name
1	*Distimake dissectus* (Jacq.) A.R. Simões & Staples
2	*Distimake quinquefolius* (L.) A.R. Simões & Staples
3	*Distimake rhyncorhizus* (Dalzell) A.R. Simões & Staples
4	*Distimake vitifolius* (L.) A.R. Simões & Staples

1. ***Distimake dissectus*** (Jacq.) Simões & Staples, Bot. J. Linn. Soc. 183: 574 (2017)

= *Merremia dissecta* (Jacq.) Hallier f. in Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *D. dissectus* leaves resulted in 10 effective PCs showing 90.06% Cumulative variance. (Table 18) Variation depicted by PC1 was highest and showed variation on leaf lobe development and length-to-width ratio. Variation depicted by PC2 was seen as variation in shape and size of petiole. PC3 was depicted by variation in the right distal part of leaf lamina while PC4 depicted the variation I left distal part of the lamina. PC5 was depicted by variation in leaf base and leaf blade lobing. Variation depicted by PC6 and PC7 was mainly on apical lobe shape and development of right distal part. PC8 showed variation along the leaf blade margin and contributed towards trilobed shape. PC9 and PC10 was seen a minor distortion towards the leaf base and apex. (Plate – 22A)

Table 18 - Eigen value and PC scores of *D. dissectus*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02207	27.38	27.38
PC2	0.01306	16.20	43.58
PC3	0.01034	12.84	56.42
PC4	0.00749	9.29	65.70
PC5	0.00455	5.65	71.36
PC6	0.00397	4.93	76.28
PC7	0.00376	4.66	80.94
PC8	0.00282	3.50	84.45
PC9	0.00238	2.95	87.40
PC10	0.00215	2.66	90.06

2. ***Distimake quinquefolius*** (L.) A.R. Simões & Staples, Bot. J. Linn. Soc. 183: 575 (2017)

= *Merremia quinquefolia* (L.) Hallier f. in Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *D. quinquefolius* leaves resulted in seven effective PCs showing 99.74 cumulative variance. (Table 19). PC1 depicted the highest variation among all the PCs, showing variation in overall leaf shape and development of lamina lobes. PC2 was depicted by variation at the basal part and left proximal part. Most visually depicted variation was seen by PC3 showing

variation along the lamina lobes and development of petiole. PC4 was seen as variation along the leaf width and development of left and right lobes. PC5 and PC6 depicted the variation in overall leaf shape and development of lamina lobes. PC7 was represented by least amount of variance and was depicted by variation at the leaf base and apex. (Plate – 22B).

Table 19 - Eigen value and PC scores of *D. quinquefolius*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.03671	46.12	46.12
PC2	0.02109	26.49	72.62
PC3	0.01126	14.15	86.76
PC4	0.00559	7.02	93.78
PC5	0.00239	3.01	96.79
PC6	0.00165	2.07	98.86
PC7	0.00070	0.87	99.74

3. ***Distimake rhyncorhiza*** (Dalzell) A.R.Simões & Staples, Bot. J. Linn. Soc. 183: 575 (2017)

= Merremia rhyncorhiza (Dalzell) Hallier f. in Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *D. rhyncorhiza* leaves resulted in 10 effective PCs showing 93.51% cumulative variance. (Table 20). PC1 was depicted by variation in the overall leaf shape contributing towards the ambiguous shape. PC2 was seen as a development of distal lamina lobes and leaf base. PC3 and PC4 were depicted by petiole development and variation in the leaf apex. Variation depicted by PC5 and PC6 was mainly on the right lamina lobes and leaf base. PC7 and PC8 depicted variation along the distal part of the leaf lamina and left lobes. Variations depicted by PC9 and PC10 were mainly on the leaf lamina shape and development of lobes. (Plate – 23A)

Table 20 - Eigen value and PC scores of *D. rhyncorhiza*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02004	32.43	32.43
PC2	0.01177	19.05	51.47
PC3	0.00676	10.94	62.41
PC4	0.00522	8.45	70.87
PC5	0.00351	5.67	76.54
PC6	0.00312	5.05	81.59
PC7	0.00233	3.78	85.37
PC8	0.00199	3.22	88.59
PC9	0.00174	2.82	91.41
PC10	0.00130	2.10	93.51

4. ***Distimake vitifolius*** (Burm. f.) Pisuttimarn & Petrongari, Bot. J. Linn. Soc. 202: 369–370 (2023)

= *Merremia vitifolia* (Burm.f.) Hallier f. in Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *D. vitifolius* leaves resulted in 10 effective PCs contributing 92.81% cumulative variance. (Table 21). Highest accounted variation was seen by PC1 mainly in the overall leaf shape and development of the petiole. PC2 was depicted by variation at the right middle part of the lamina and the development of lobes at the side. PC3 was seen as variation along the leaf base and development of lamina lobes. PC4 was depicted by leaf apex and base development contributing towards the palmate leaf shape. PC5 and PC6 were depicted by variation at the left middle part of the lamina and development of the petiole. The variation depicted by PC7 was ambiguous and did not provide any visual difference in the leaf shape. PC8, PC9, and PC10 were minor and showed variation along the leaf blade margin and development of overall leaf shape. (Plate – 23B)

Table 21 -Eigen value and PC scores of *D. vitifolius*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01490	29.20	29.20
PC2	0.01202	23.56	52.76
PC3	0.00597	11.70	64.46
PC4	0.00386	7.56	72.02
PC5	0.00277	5.43	77.45
PC6	0.00260	5.09	82.54
PC7	0.00188	3.67	86.21
PC8	0.00128	2.51	88.72
PC9	0.00112	2.20	90.92
PC10	0.00096	1.89	92.81

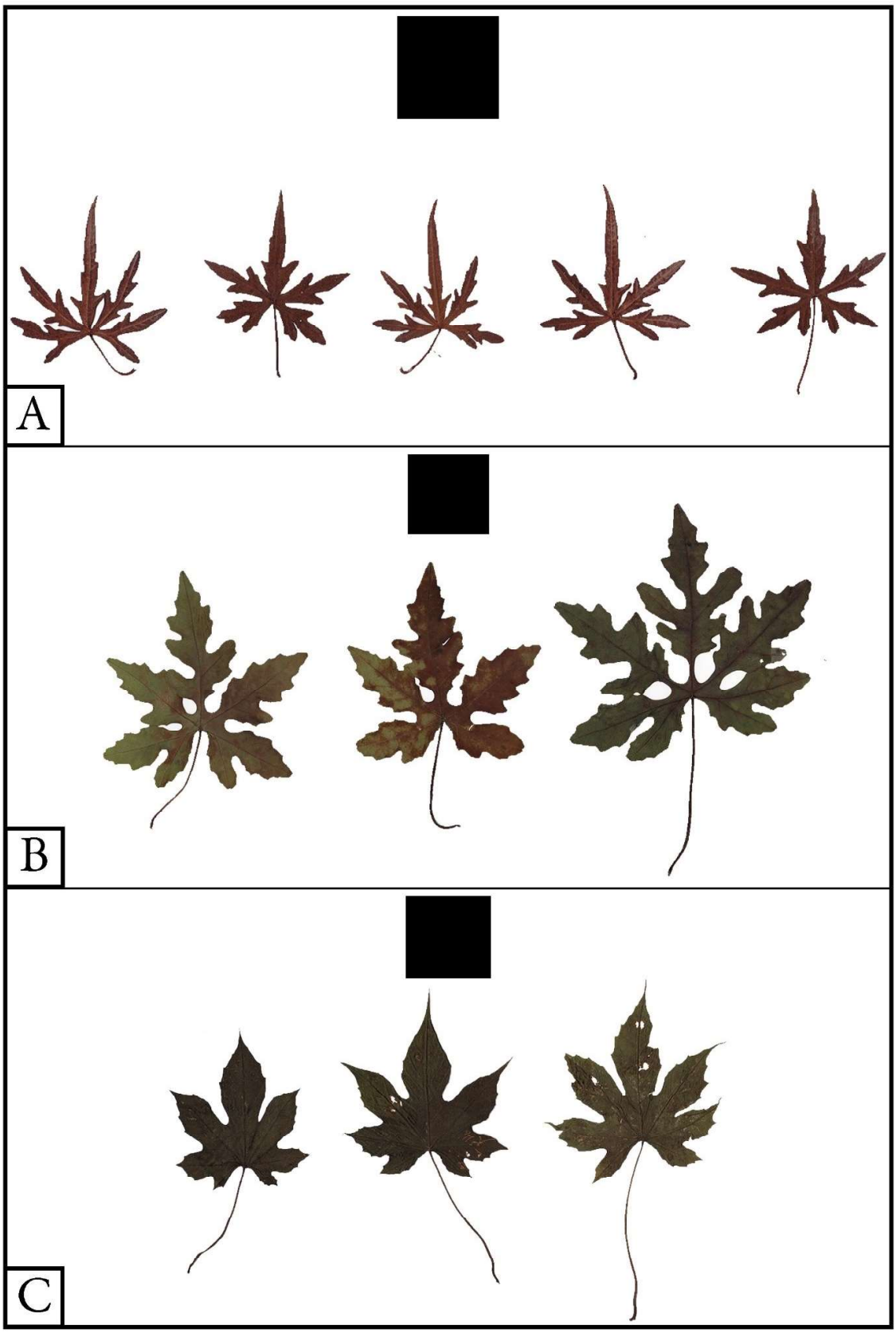

Plate 21 - Leaf sample of Distimake species (**A**- *D. rhyncorhizus*; **B**- *D. dissectus*; **C**- *D. vitifolius*) (Scale-3 x 3 cm)

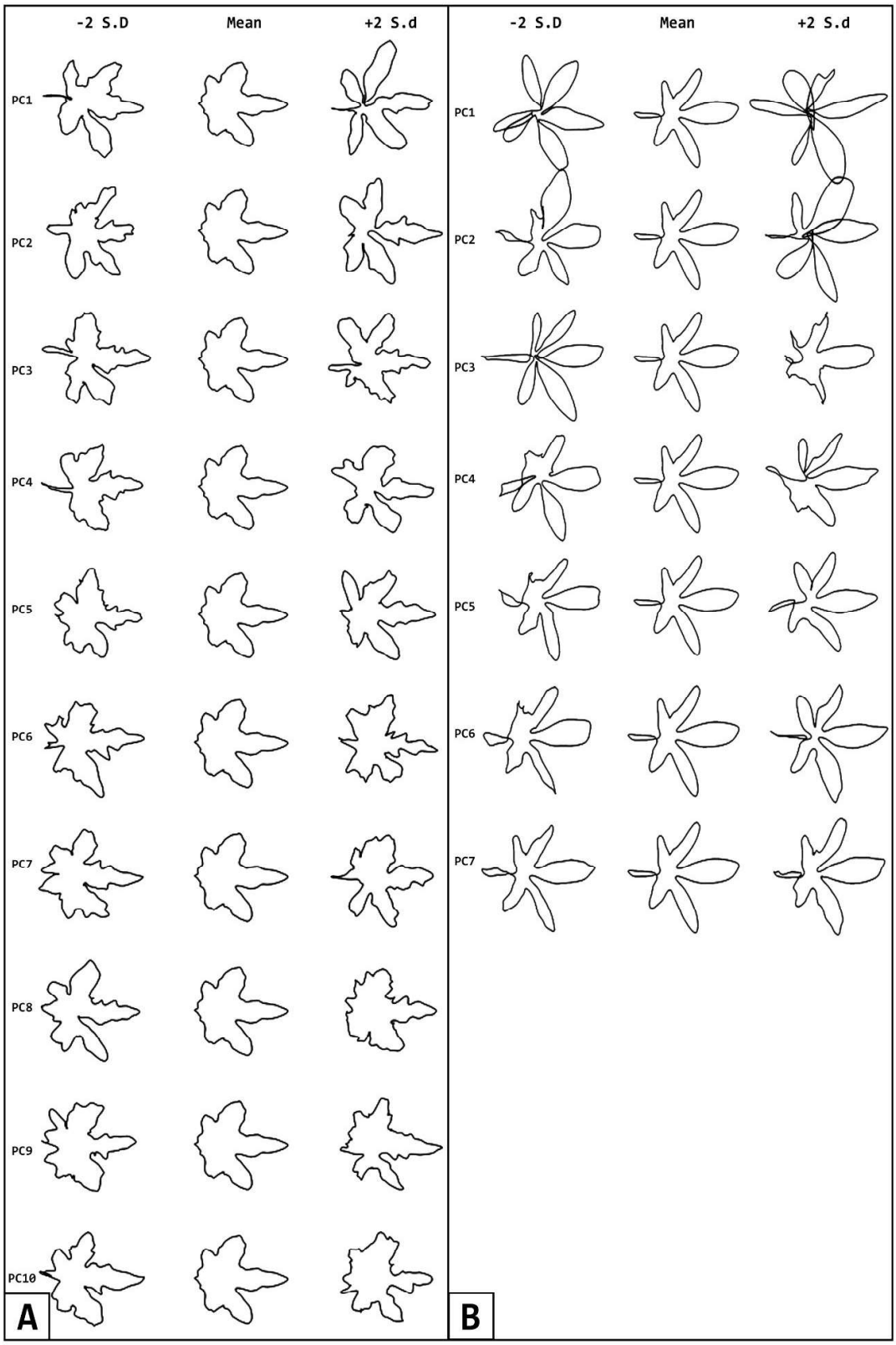

Plate 22 - Processed image showing leaf shape variation (**A**- *D. dissectus*; **B**- *D. quinquefolia*)

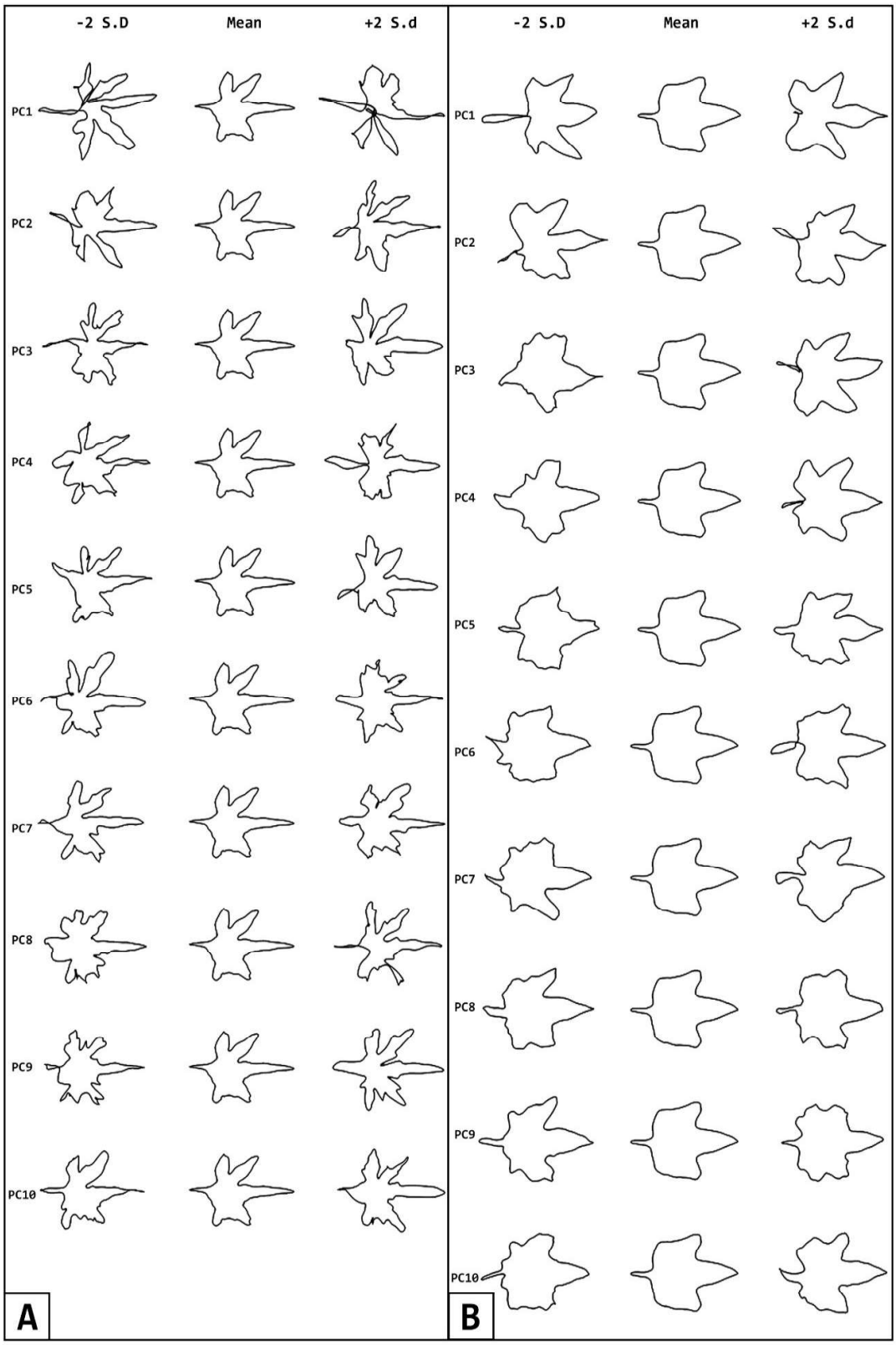

Plate 23 - Processed image showing leaf shape variation (**A**- *D. rhyncorhizus*; **B**- *D. vitifolius*)

4.5. Genus: Evolvulus L.

Evolvulus L. Sp. Pl., ed. 2.: 391 (1762)

Type: *Evolvulus nummularius* L.

4.5.1. General Description of genus *Evolvulus*:

Annual or perennial herbs, under-shrubs, or shrubs: stems prostrate, ascending or erect, never twining. (Table 22). Leaves mostly small, simple, entire. Flowers hermaphroditic, regular, in axillary, pedunculate, several to 1-flowered dichasia or in few-flowered groups or solitary, petiolate or sessile in the leaf-axils, or aggregate at the ends of the stems and the branches in spikes or heads. Sepals 5, free, equal or subequal, acuminate, acute, or obtuse. Corolla rotate, funnel or salver-shaped, generally small purple, blue or white, rarely yellow, the limb plicate, subentire or obscurely to distinctly 5-lobed, the lobes outside with a pilose band. Stamens 5, filaments filiform, inserted on the corolla, at the mouth of the tube, glabrous, occasionally with a tooth at both sides of the base: anthers ovate to oblong or linear. Ovary globular, ovoid, or occasionally cylindrical, glabrous, or occasionally pilose, 2-celled, each cell with 2 ovules, occasionally 1-celled, 4-ovuled: styles 2, slightly united at the base or totally free, each style 2-cleft; stigmas long, terete, filiform or slightly clavate. Capsule globose or ovoid, 4-valved, 4-1-seeded, in the latter case occasionally oblique and 3- or 2-valved. Seeds small, smooth, or minutely verrucose; cotyledons nearly flat, radicle incurved (Plate – 16B,C).

Table 22 - List of collected species of genus Evolvulus

Sr. No.	Scientific Name
1	*Evolvulus alsinoides* (L.) L.
2	*Evolvulus nummularius* (L.) L.

1. *Evolvulus alsinoides* (L.) L., Sp. Pl., ed. 2.: 392 (1762)

Analysis:

Examination of *E. alsinoides* resulted in 10 effective PCs depicting 91.45% cumulative variance. (Table 23). Most of the variation of leaf shape was depicted by first four PCs. Although there are 10 effective PCs there was no visual difference seen in analysed leaf images other than few minor changes like variation in length to width ratio, petiole and leaf apex development. (Plate – 24A).

Table 23 - Eigen value and PC scores of *E. alsinoides*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.000881	38.86	38.86
PC2	0.000450	19.82	58.68
PC3	0.000207	9.11	67.79
PC4	0.000169	7.43	75.23
PC5	0.000095	4.19	79.42
PC6	0.000085	3.76	83.18
PC7	0.000064	2.83	86.01
PC8	0.000052	2.31	88.32
PC9	0.000042	1.84	90.16
PC10	0.000029	1.29	91.45

2. ***Evolvulus nummularius*** (L.) L., Sp. Pl., ed. 2.: 391 (1762)

Analysis:

Examination of *E. nummularius* leaves resulted in 10 effective PCs depicting 93.53% cumulative variance (Table 24). Major variation in leaf shape was depicted by first four PCs. Effects of PC1 was depicted as variation in leaf base development and petiole development. PC2 contributed to the variation in length to width ratio and distal part of the leaf giving the leaf ovoid shape. Effects of PC3 and PC4 were majorly on leaf base shape when positive or negative contributing to ambiguous leaf base and ovoid leaf shape. PC5 and PC6 showed minor variation along the leaf margin and leaf base. The variation depicted by the rest of the four PCs contributed towards the overall leaf shape giving the leaf its ovoid shape. (Plate – 24B)

Table 24 - Eigen value and PC scores of *E. nummularius*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00506	28.97	28.97
PC2	0.00333	19.03	47.99
PC3	0.00289	16.53	64.52
PC4	0.00184	10.54	75.06
PC5	0.00087	4.95	80.01
PC6	0.00082	4.71	84.72
PC7	0.00051	2.90	87.62
PC8	0.00048	2.74	90.36
PC9	0.00035	2.00	92.36
PC10	0.00021	1.17	93.53

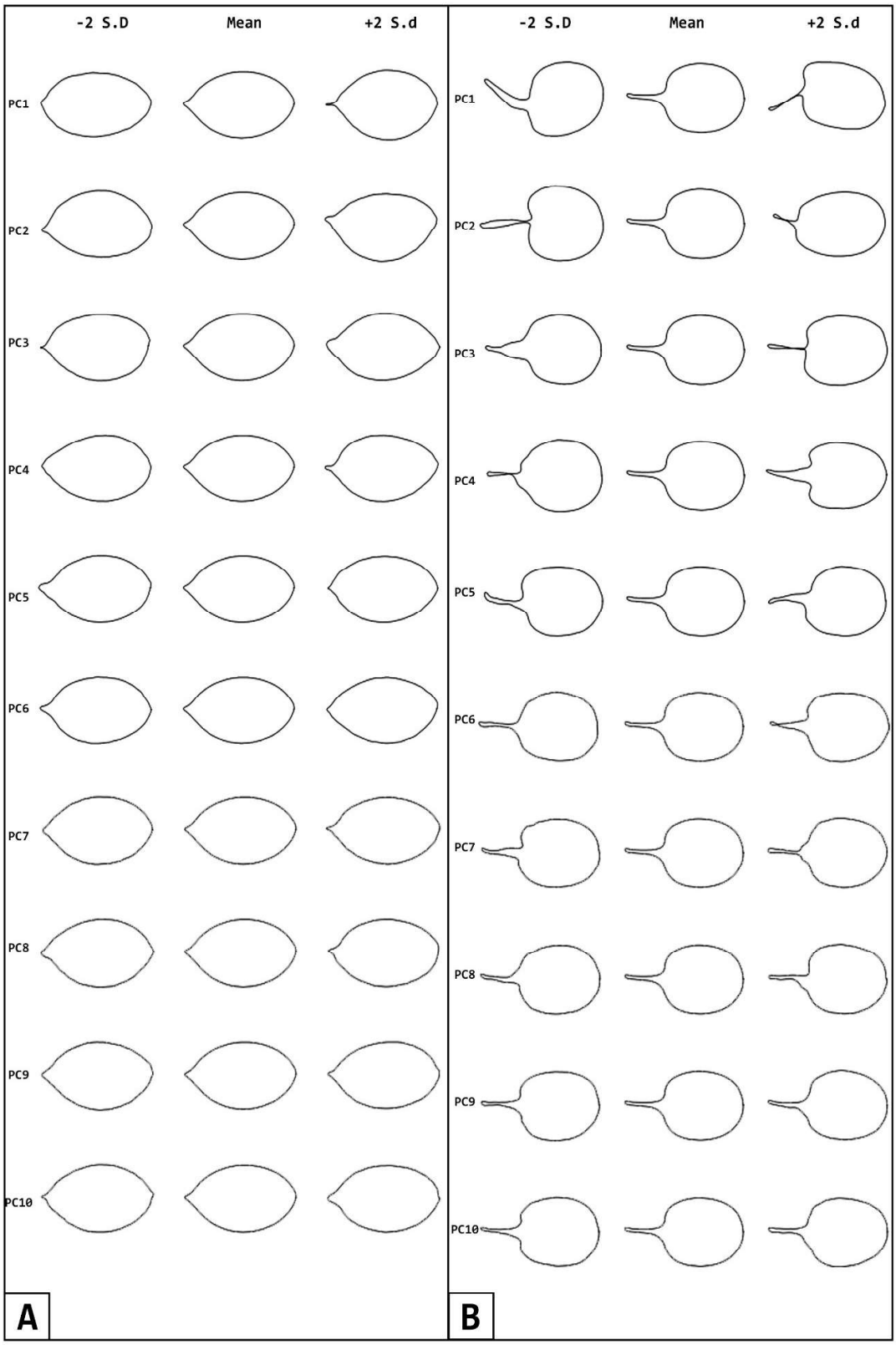

Plate 24 - Processed image showing leaf shape variation (**A**- *E. alsinoides*; **B**- *E. nummularius*)

4.6. Genus: *Ipomoea* L.

Ipomoea L., Sp. Pl.: 159 (1753), nom. cons.

Type: *Ipomoea triloba* L.

4.6.1. General Description of genus *Ipomoea*:

Vines, shrubs, or trees, usually twining, sometimes prostrate or floating. Leaves variable in shape and size, entire, lobed, divided or rarely compound, petiole sometimes with pseudo-stipules. (Table 25). Flowers axillary, 1- few or many flowered cymose or paniculate clusters; bracts various; sepals 5, herbaceous or sub-coriaceous, shape various, ovate to lanceolate, linear or elliptic, apically obtuse or acute to acuminate or shortly to long aristate, equal or unequal ,glabrous or pubescent, persistent or sometimes enlarged in the fruit; corolla regular or slightly zygomorphic, campanulate, funnel-shaped, less often tubular or salverform, mid-petaline bands well defined, white, purple, pink, red or yellow; stamens inserted or exserted; anthers ovate, oblong or linear; filaments filiform or dilated at the base with short to long ciliate, mostly unequal in length; pollen globular, spinulose; ovary usually 2 or 4-celled, rarely 3-celled, 4-ovuled, rarely 6-ovuled; style filiform, inserted or exserted, glabrous, slightly dilated at base; stigma capitate, entire or 2-3 globular. Fruits capsular, globose, or ovoid, mostly 4 or rarely 6-valved, sometimes splitting irregularly or indehiscent; seeds 4(1-6) glabrous or pubescent.

30 species belonging to genus Ipomoea were collected during present investigation from various localities (Table - 1). Members of genus *Ipomoea* shows variable leaf shape. It varies from sub-sessile to long petiolate; glabrous to hairy, mucronate to obtuse etc. Leaf base varies from cordate to rounded to reniform to hastate. Simple leaves of some species have shallow 3 - 5 abrupt lobes while multi-lobed leaves show distinct 3 - 9 lobes. Leaf margin is mostly entire or undulate except serrate in *I. diversifolia* and *I. coptica*. Leaf apex varies from obtuse to acuminate, emarginate to deeply bilobed. Leaves of *I. acanthocarpa* and *I. parasitica* shows purple veins on adaxial surface. Leaves of *I. marginata* are often with purple blotches on adaxial surface. *Ipomoea triloba*, *I. marginata* and *I. pes-tigridis* shows highest degree of leaf variations. (Plate – 25: to Plate – 34).

Table 25 - List of collected species of genus *Ipomoea* L.

Sr. No.	Scientific name
1	*Ipomoea aculeata* Blume
2	*Ipomoea alba* L.
3	*Ipomoea aquatica* Forssk.
4	*Ipomoea biflora* (L.) Pers.
5	*Ipomoea cairica* (L.) Sweet
6	*Ipomoea campanulata* L.
7	*Ipomoea clarkei* Hook.f.
8	*Ipomoea coptica* (L.) Roth.
9	*Ipomoea deccana* D.F. Austin
10	*Ipomoea diversifolia* R.Br.
11	*Ipomoea eriocarpa* R.Br.
12	*Ipomoea hederifolia* L.
13	*Ipomoea horsfalliae* Hook.
14	*Ipomoea indica* (Burm.) Merr.
15	*Ipomoea involucrata* F. Dietr. ex Choisy
16	*Ipomoea kotschyana* Hochst. ex Choisy
17	*Ipomoea laxiflora* H.J. Chowdhery & Debta
18	*Ipomoea marginata* f. *candida* (Naik & Zate) Das & Lakshmin.
19	*Ipomoea marginata* f. *marginata* L.
20	*Ipomoea muricata* (L.) Jacq.
21	*Ipomoea nil* (L.) Roth
22	*Ipomoea obscura* (L.) Ker Gawl.
23	*Ipomoea ochracea* (Lindl.) G. Don
24	*Ipomoea parasitica* (Kunth) G. Don
25	*Ipomoea pes-caprae* (L.) R.Br.
26	*Ipomoea pes-tigridis* L.
27	*Ipomoea quamoclit* L.
28	*Ipomoea sindica* Stapf
29	*Ipomoea staphyllina* Roem. & Schult.
30	*Ipomoea triloba* L.
31	*Ipomoea tuberculata* Ker-Gawl.

1. ***Ipomoea aculeata*** Blume, Bijdr. Fl. Ned. Ind.: 715 (1826)

Analysis:

Analysis of *I. aculeata* leaves generated nine (9) effective principal components (Table 26) showing 96.83 % cumulative variance. The highest accounted variation was seen in PC1 and PC2, both the PCs shows variation among the posterior lobes of the leaves, leaf tip shape and development of cordate leaf base from the mean leaf shape. Initiation of posterior lobes was also seen from these two PCs. Variation depicted by PC3 was showing development of petiole, and broad leaf base rather than the cordate leaf base. PC4, PC5 and PC6 shows variations along the leaf blade, overall leaf shape and ambiguous leaf shape variation respectively. Rest of the remaining PCs (PC7, PC8 and PC9) shows very minor variation. The effect of these PCs is seen as ambiguous leaf base development, and acute leaf tip development. (Plate – 35A)

Table 26 - Eigen values, PCs, and variance of *I. aculeata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.021	29.30	29.30
PC2	0.018	25.24	54.55
PC3	0.011	14.92	69.46
PC4	0.006	8.73	78.19
PC5	0.005	7.14	85.33
PC6	0.003	4.30	89.63
PC7	0.002	2.82	92.44
PC8	0.001	2.23	94.68
PC9	0.001	2.15	96.83

2. ***Ipomoea alba*** L. Sp. Pl.: 161 (1753)

Analysis:

Examination of *I. alba* leaves resulted in eight (8) effective principal components (PCs) depicting 98.79 % cumulative variation. (Table 27). PC1 depicted the highest recorded variation showing development of leaf tip and leaf base affecting the overall leaf shape. PC2 was accounted for 27.37 % variance showing variation along the right distal part of the leaf and leaf base development. PC3 and PC4 was showing variation and development of cordate leaf base and acute leaf tip. PC5 and PC 6 showed minor variation among the leaf margin, leaf tip development and formation of leaf base. PC7 and PC8 shows minor variation affecting the overall shape of the leaf and length-to-width ratio. (Plate – 35B)

Table 27 - Eigen values, PCs, and variance of *I. alba*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.014	45.13	45.13
PC2	0.008	27.37	72.50
PC3	0.003	11.07	83.57
PC4	0.002	7.19	90.76
PC5	0.001	3.65	94.42
PC6	0.001	2.02	96.43
PC7	0.000	1.30	97.73
PC8	0.000	1.06	98.79

3. ***Ipomoea aquatica*** Forssk. Fl. Aegypt. - Arab.: 44 (1775)

Analysis:

Morphometric analysis of *I. aquatica* leaves resulted in nine (9) effective principal components (PCs) showing 96.48 % cumulative variance. (Table 28). Highest accounted variation was seen in PC1 affecting the overall leaf shape from ovate to sagittate, posterior lobe development and length-to-width ratio. Effect of PC2 was mainly on leaf width, and development od distal part of the leaf lamina giving elliptical leaf shape. PC3 and PC4 were affecting the leaf lamina development and giving an ambiguous leaf shape when positive. It also effects the development of posterior lobes which gives leaf its sagittate shape. Effects of PC5 are seen mainly on the leaf base development with minor variation. PC6 and PC7, shows minor distortion towards the leaf base and margin. Effects of PC8 and PC9 is seen as minor variation along the leaf margin and at the leaf base. Overall majority of the PCs shows variation in the development of leaf base and development of posterior lobes giving the leaf its sagittate shape. (Plate – 36A)

Table 28 - Eigen values, PCs, and variance of *I. aquatica*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.019	34.24	34.24
PC2	0.013	23.25	57.50
PC3	0.009	15.66	73.15
PC4	0.006	11.05	84.20
PC5	0.003	4.86	89.06
PC6	0.002	2.78	91.84
PC7	0.001	2.22	94.07
PC8	0.001	1.38	95.44
PC9	0.001	1.04	96.48

4. ***Ipomoea biflora*** (L.) Pers. Syn. Pl. 1: 183 (1805)

Analysis:

Examination of *I. biflora* leaves generated nine (9) effective principal components (PCs) with 96.63 % cumulative variance. PC1 showed the highest accounted variation. (Table 29). Effects of PC1 were seen as development of leaf blade, and leaf base giving leaf its cordate shape. PC2 was showing variation in leaf width, leaf margin development and petiole development. PC3 was accounted for giving leaf its cordate shape and development of leaf apex. PC4 and PC5 were shown to be less effective in depicting any major variation in the leaf shape even with 7.46 % and 4.91 % of variance. Effects depicted by PC6 and PC7 are seen in the development of distal part of the leaf lamina and acute leaf tip. PC8 and PC9 are showing minor variation along the leaf apex and length-to-width ratio. (Plate – 6B)

Table 29 - Eigen values, PCs, and variance of *I. biflora*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.020	38.84	38.84
PC2	0.013	25.50	64.34
PC3	0.006	12.01	76.35
PC4	0.003	7.46	83.81
PC5	0.002	4.92	88.74
PC6	0.001	3.38	92.12
PC7	0.001	2.05	94.17
PC8	0.0007	1.46	95.63
PC9	0.0005	1.01	96.63

5. ***Ipomoea cairica*** (L.) Sweet Hort. Brit.: 287 (1826)

Analysis:

Examination of *I. cairica* leaves resulted in six effective PCs exhibiting 100 % cumulative variance. (Table 30). PC1 depicted the highest accounted variation among all resulted PCs. Effects of PC1 was majorly seen on overall leaf shape. As PC1 is showing major variation of all the PCs showing ambiguous shape development of the leaf when positive or negative. PC2 on the other hand provides more useful and visually comprehensible leaf shape development variation than PC1. Effects of PC2 can be seen as development of anterior and posterior lobes. PC3 was depicted by the development of petiole and two small sub-lobes of the proximal lobes. PC4 depicted the variation of lobe development contributing towards the palmate shape of the leaf. PC5 on the other hand

showed variation along the posterior lobes developing ambiguous shape of the leaf. PC6 depicted minor variation along the left part of the leaf. Overall resulted PCs are not enough to properly depict the leaf shape variation of *I. cairica*. (Plate – 37A)

Table 30 - Eigen values, PCs, and variance of *I. cairica*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.03006	39.30	39.30
PC2	0.02077	27.15	66.45
PC3	0.00963	12.59	79.05
PC4	0.00835	10.92	89.96
PC5	0.00545	7.13	97.10
PC6	0.00222	2.90	100.00

6. *Ipomoea campanulata* L. Sp. Pl.: 160 (1753)

Analysis:

Examination of *I. campanulata* leaves resulted in seven effective principal components (PCs) showing 97.31 % overall variance. (Table 31). The highest accounted variation was depicted by PC1. Major effect of the PC1 is seen as development of cordate leaf base and on overall leaf shape development. Variation depicted by PC2 was affecting the petiole shape and development, and leaf tip development. Variation accounted for PC3 was, showing leaf lamina development of distal part. Effects of PC4 and PC5 were mainly seen on leaf apex and leaf tip development. Effects depicted by PC6 and PC7 were minor, showing distortions along the leaf blade and petiole. Overall leaf shape of *I. campanulata* was mainly affected by first five PCs and rest of the PCs can be described as minor distortions in the leaf shape development. (Plate – 37B)

Table 31 - Eigen values, PCs, and variance of *I. campanulata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00861	39.59	39.59
PC2	0.00572	26.28	65.87
PC3	0.00373	17.14	83.01
PC4	0.00123	5.63	88.64
PC5	0.00084	3.84	92.49
PC6	0.00059	2.72	95.20
PC7	0.00046	2.11	97.31

7. ***Ipomoea clarkei*** Hook. f., Fl. Brit. India 4: 734 (1885)

Analysis:

Examination of *I. clarkei* leaves ensued in total of nine (9) effective principal components depicting 97.24 % total variance. (Table 32). Effects of first PC was seen on overall leaf shape development, leaf apex development, leaf tip development, and cordate leaf base. PC2 was showing ambiguous leaf shape when positive. It also shows development of leaf tip and base. Effects of PC3 and PC4 were seen as leaf margin distortions on distal right part of the leaf and petiole development. PC5 was showing shape changes at proximal part of the leaf and leaf base. The variation accounted by PC6 was depicted by changes in leaf base shape and overall leaf shape from cordate to sagittate. PC7 was accounted for 2.70 % of total variance showing leaf apex development when positive or negative effecting the direction of leaf tip. Variations depicted by PC8 and PC9 were minor distortions on the leaf margin forming a wavy pattern. (Plate – 38A)

Table 32 - Eigen values, PCs, and variance of *I. clarkei*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.015	31.91	31.91
PC2	0.010	20.91	52.82
PC3	0.007	15.83	68.65
PC4	0.006	13.11	81.76
PC5	0.003	6.14	87.90
PC6	0.002	3.66	91.56
PC7	0.001	2.70	94.25
PC8	0.001	1.79	96.04
PC9	0.001	1.20	97.24

8. ***Ipomoea coptica*** (L.) Roth. J. J. Roemer & J. A. Schultes, Syst. Veg., ed. 15[bis]. 4: 208 (1819)

Analysis:

Examination of *I. coptica* leaves resulted in 11 effective principal components (PCs) depicting 99.86 % cumulative variance. PC1 showed the highest accounted variation among all the. (Table 33). Effects depicted by PC1 were not visually informative and generated an ambiguous shape of leaf. Effects depicted by PC2 on the other hand were informative and contributed towards the more visually acceptable leaf shape near to the actual leaf shape. Variation depicted by PC2 were mainly on development of anterior lobes. Variation depicted by PC3 were majorly seen as anterior lobes differentiation and development. PC4 and PC5 were seen as development of right and left proximal parts of the leaf respectively and contributed towards the lobed leaf shape. Rest of the PCs

showed minor variation along the same plane of the development contributing ambiguous shape and visually uninformative. Although there were only eight effective PCs defined here but, the were not enough to visually explain the development and variation happening in the leaf shape of *I. coptica*. (Plate – 38B)

Table 33 - Eigen values, PCs, and variance of I. coptica

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02533	28.97	28.97
PC2	0.02222	25.41	54.38
PC3	0.01829	20.91	75.29
PC4	0.01021	11.67	86.97
PC5	0.00602	6.89	93.85
PC6	0.00273	3.12	96.97
PC7	0.00205	2.35	99.32
PC8	0.00047	0.54	99.86

9. ***Ipomoea deccana*** D.F. Austin., M. D. Dassanayake & al. (eds.), Revis. Handb. Fl. Ceylon 1: 324 (1980)

Analysis:

Analysis of *I. deccana* leaves resulted in ten (10) effective principal components showing 98.16 % cumulative variance. (Table 34). The highest accounted variation was depicted by PC1. Effects of PC1 was mainly seen on the development of right posterior lobe and petiole development. Variation depicted by PC2 mainly effects development of left posterior lobe and petiole. Variation depicted by PC3 and PC4 was mainly on leaf apex development and ambiguous leaf base development. Effects of PC 5 and PC6 were seen on leaf lobing and margin of the leaf base. PC7 and PC8 shows variation along the leaf base margin and giving the leaf apex an ovate shape. Variation depicted by last two PCs (PC9 and PC10) were minor showing leaf base development and giving the leaf its overall tri lobed shape. (Plate – 39A)

Table 34 - Eigen values, PCs, and variance of *I. deccana*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0478	38.17	38.17
PC2	0.0344	27.49	65.66
PC3	0.0127	10.16	75.82
PC4	0.0089	7.09	82.91
PC5	0.0067	5.38	88.29
PC6	0.0041	3.26	91.55
PC7	0.0034	2.70	94.25
PC8	0.0023	1.84	96.09
PC9	0.0014	1.13	97.22
PC10	0.0012	0.95	98.17

10. *Ipomoea diversifolia* R.Br. Prodr. Fl. Nov. Holland.: 487 (1810)

Analysis:

Examination of *I. diversifolia* leaves resulted in 10 effective principal components exhibiting 92.17 % cumulative variance. (Table 35). Highest variation was seen in PC1 which effects the overall leaf shape and leaf lobe development. PC2 was accounted for showing variation on developing leaf lobes when positive and no lobing when negative. PC3 and PC4 effects the right distal part of the leaf contributing towards palmate leaf shape. PC5 depicted variation on overall leaf shape developing and ambiguous leaf shape. PC6, PC7 and PC8 exhibit almost similar values (3.99 %, 3.49 % and 3.12 %) and effects on the leaf shape of these three PCs are also almost similar, showing development of right distal lobes and petiole development. PC9 and PC10 shows overall palmate leaf shape, development of petiole and leaf lobing. (Plate – 39B)

Table 35 - Eigen values, PCs, and variance of *I. diversifolia*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.127	33.68	33.68
PC2	0.072	19.10	52.79
PC3	0.039	10.31	63.09
PC4	0.032	8.42	71.52
PC5	0.018	4.79	76.30
PC6	0.015	3.99	80.30
PC7	0.013	3.49	83.78
PC8	0.012	3.12	86.90
PC9	0.010	2.71	89.60
PC10	0.010	2.57	92.17

11. ***Ipomoea eriocarpa*** R.Br. Prodr. Fl. Nov. Holland.: 484 (1810)

Analysis:

Examination of *I. eriocarpa* leaves resulted in six (6) effective principal components depicting 98.65 % cumulative variance. (Table 36). PC1 depicted the highest calculated variance. It mainly effects length-to-width ratio of leaves and development of leaf base. PC2 depicted by the variation at distal part of the leaf, development of leaf apex and petiole. Effects of PC3 were majorly on leaf base development giving leaf its cordate-sagittate shape and acute apex. Variation depicted by PC4 was mainly on right proximal part of the leaf forming an ambiguous shape towards the base. PC5 and PC6 depicted very minor variations towards the leaf base and petiole development. (Plate – 40A)

Table 36 - Eigen values, PCs, and variance of *I. eriocarpa*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.008	44.51	44.51
PC2	0.005	27.64	72.14
PC3	0.003	18.97	91.11
PC4	0.0008	4.80	95.91
PC5	0.0003	1.51	97.42
PC6	0.0002	1.22	98.65

12. ***Ipomoea hederifolia*** L., Syst. Nat., ed. 10. 2: 925 (1759)

Analysis:

Examination of *I. hederifolia* leaves produced 10 effective principal components (PCs) showing 95.94 % of total variance. (Table 37). PC1 showed the highest accounted variation among all the PCs. Effects of PC1 were seen on overall leaf shape development, leaf length-to-width ratio, and leaf tip development giving the leaf its shape. PC2 and PC3 were depicting variations at leaf base and leaf tip development. Effects depicted by PC4, PC5 and PC6 were mainly on lobing of posterior lobes, development of acute leaf tip and petiole development. Effects shown by PC7 and PC8 were mainly on the leaf lamina and overall shape of the leaf blade giving the leaf acute leaf apex and broad leaf base. Effects of PC9 and PC10 were not depicted by any major changes in the shape other than deformations on leaf margin. (Plate – 40B)

Table 37 - Eigen values, PCs, and variance of *I. hederifolia*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0277	39.86	39.86
PC2	0.0133	19.16	59.02
PC3	0.0113	16.18	75.20
PC4	0.0031	4.52	79.72
PC5	0.0025	3.55	83.28
PC6	0.0022	3.15	86.43
PC7	0.0020	2.88	89.31
PC8	0.0014	2.03	91.34
PC9	0.0011	1.63	92.97
PC10	0.0007	1.05	94.01

13. *Ipomoea horsfalliae* Hook. Bot. Mag. 61: t. 3315 (1834)

Analysis:

Examination of *I. horsfalliae* leaves resulted in seven effective principal components (PCs) showing 92.72 % of cumulative variance which summarizes all the variation that can occur. (Table 38). Highest variation was seen in PC1, mainly effecting leaf lobing development. Effects depicted by PC2 and PC3 were seen as development of distal middle lobe and ambiguous shape at right distal part of leaf lamina. PC4, PC5, PC6 and PC7 were accounted for less variance. Although the analysis resulted in seven effective PCs, the visual interpretation of development of the leaf shape of *I. horsfalliae* proved to be difficult. As seen in the analysed image, no significant conclusion can be drawn based on ambiguous shape. (Plate – 40C)

Table 38 - Eigen values, PCs, and variance of *I. horsfalliae*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.2103	39.02	39.02
PC2	0.0837	15.53	54.55
PC3	0.0688	12.76	67.31
PC4	0.0453	8.40	75.71
PC5	0.0348	6.46	82.17
PC6	0.0321	5.95	88.12
PC7	0.0248	4.60	92.72

14. ***Ipomoea indica*** (Burm.) Merr. Interpr. Herb. Amboin.: 445 (1917)

Analysis:

Investigation of *I. indica* leaves resulted in nine effective principal components depicting 99.18 % cumulative variance. (Table 39). PC1 showed highest variation. Effects of PC1 can be seen on overall leaf shape development, posterior lobe development giving the leaf its tri lobed leaf shape. Variation depicted by PC2 was mainly on the leaf apex and petiole development when positive or negative giving the leaf acute to caudate apex. Variation depicted by PC3 was on development of posterior lobes. PC4 and PC5 depicted variation among the right posterior lobe and development of left posterior lobe. PC6 and PC7 contributed towards the leaf apex and base shape variation showing tapering towards the apex when negative. Variation depicted by PC8 and PC9 was seen as variation in leaf base and posterior lobes shape. (Plate – 41A)

Table 39 - Eigen values, PCs and variance of I. indica

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0249	40.24	40.24
PC2	0.0164	26.41	66.65
PC3	0.0057	9.22	75.87
PC4	0.0043	7.01	82.88
PC5	0.0033	5.31	88.19
PC6	0.0030	4.87	93.06
PC7	0.0018	2.93	95.99
PC8	0.0011	1.71	97.71
PC9	0.0009	1.47	99.18

15. ***Ipomoea involucrata*** P.Beauv. Fl. Oware 2: 52, t. 89 (1816)

Analysis:

Examination of *I. involucrata* leaves resulted in eight principal components depicting 97.04 % cumulative variance. (Table 40). Highest variation of 50.30 % was seen in first PC. Effects of PC1 were mainly seen on the length-to-width ratio, leaf base development, and providing leaf its overall shape. PC2 was accounted for 23.17 % of total variance depicting variation along the leaf margin and posterior lobes differentiation. PC3 and PC4 shows variation at the leaf apex and ambiguous shape at the leaf base with 7.31 % and 6.72 % of total variance respectively. PC5 and PC6 does not

show much variation as compared to the former PC variables depicting minor variations at the leaf base. PC7 and PC8 shows minor variation at the leaf apex. (Plate – 41B)

Table 40 - Eigen values, PCs, and variance of *I. involucrata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0259	50.30	50.30
PC2	0.0122	23.71	74.01
PC3	0.0038	7.31	81.32
PC4	0.0034	6.72	88.04
PC5	0.0016	3.00	91.04
PC6	0.0015	2.92	93.96
PC7	0.0010	2.01	95.96
PC8	0.0005	1.08	97.04

16. ***Ipomoea kotschyana*** Hochst. ex Choisy A.P.de Candolle, Prodr. 9: 354 (1845)

Analysis:

Examination of *I. kotschyana* leaves resulted in 15 effective principal components showing 94.95 % cumulative variance. (Table 41). Highest accounted variation was seen in PC1 depicting variation on overall leaf shape and lobing development. PC2 shows development of leaf lobes. Variation depicted by PC3 was on posterior lobes development whereas PC4 and PC5 depicts development of distal lobes of the leaves. PC6 and PC7 shows development of left and right part of the leaves contributing in the lobe development when positive or negative. Rest of the PCs (PC7 to PC15) does not show any major variation and develops ambiguous leaf shape. (Plate – 47B)

Table 41 - Eigen values, PCs, and variance of *I. kotschyana*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02774	22.67	22.67
PC2	0.01836	15.00	37.67
PC3	0.01565	12.79	50.46
PC4	0.01191	9.74	60.20
PC5	0.00810	6.62	66.81
PC6	0.00741	6.05	72.87
PC7	0.00533	4.36	77.22
PC8	0.00487	3.98	81.21
PC9	0.00387	3.17	84.37
PC10	0.00335	2.73	87.11

17. ***Ipomoea laxiflora*** H.J. Chowdhery & Debta Indian J. Forest. 32: 120 (2009)

Analysis:

Examination of leaves of *I. laxiflora* resulted in nine effective principal components showing 98.82 % cumulative variance. (Table 42). PC1, PC2 and PC3 showed highest accounted variation among all resulted PCs. These three PCs show significant variation on the leaf shape compared to remaining PCs. Effects of the PC1 includes posterior lobe development, variation in length-to-width ration and overall leaf area. Although value of PC2 was less than PC1, visual variation in leaf shape was depicted by PC2 effecting the overall leaf shape and leaf lobing. Effects depicted by PC4 was ambiguous and does not conclude any specific leaf shape variation. Effects depicted by PC5 and PC6 were majorly on differentiation of posterior lobes giving the leaf its trilobed shape. PC7, PC8 and PC9 shows minor variation along the leaf margin and leaf apex development. (Plate – 42A)

Table 42 - Eigen values, PCs, and variance of *I. laxiflora*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0509	36.21	36.21
PC2	0.0396	28.16	64.37
PC3	0.0211	15.01	79.38
PC4	0.0082	5.86	85.24
PC5	0.0071	5.03	90.26
PC6	0.0045	3.23	93.49
PC7	0.0035	2.48	95.97
PC8	0.0024	1.69	97.66
PC9	0.0016	1.16	98.82

18. ***Ipomoea marginata*** L. (Desr.) Manitz, Feddes Repert. 85: 638 (1974)

Analysis:

Examination of *I. marginata* leaves resulted in ten effective PCs depicting 98.04 % cumulative variance. (Table 20). PC1 and PC2 shows the highest accounted variation among all the PCs. Effects of these PCs were seen on the development of posterior lobes and petiole showing the lobe differentiation. PC3 shows minor variation at the leaf base and petiole insertion point. Effects of PC4 and PC5 were seen on the distal part of the leaf, depicting variation on leaf apex and overall leaf width. Rest of the PCs (PC6, PC7, PC8, PC9, PC10) depicted the similar effect on the leaf shape showing minor variation towards the leaf apex and base. (Plate – 43A)

Table 43 - Eigen values, PCs, and variance of *I. marginata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01352	45.36	45.36
PC2	0.00928	31.13	76.49
PC3	0.00232	7.79	84.29
PC4	0.00129	4.33	88.62
PC5	0.00090	3.02	91.64
PC6	0.00078	2.62	94.26
PC7	0.00050	1.68	95.93
PC8	0.00024	0.82	96.75
PC9	0.00023	0.76	97.51
PC10	0.00016	0.53	98.04

19. *Ipomoea marginata* f. *candida* (Naik & Zate) Das & Lakshmin. J. Econ. Taxon. Bot. 24: 449 (2000)

Analysis:

Examination of *I. marginata* f. *candida* leaves resulted in ten effective PCs showing 98.24 % cumulative variance. (Table 44). PC1 was accounted for highest variation depicting variation in overall leaf shape, length-to-width ratio, and petiole development. It also depicts change at the posterior lobes' development. PC2 depicts changes at distal part of the leaf and leaf apex. PC3 shows variation along the leaf margin and ambiguous petiole shape. PC4 depicts variation at the leaf base showing posterior lobe development and leaf tip development. PC5 and PC6 describes development of right proximal part of the leaf base and distal part of the leaf contributing towards the oval shape of the leaf blade. PC7 shows minor variation towards the petiole-blade junction. PC8, PC9 and PC10 depicts variation towards the leaf apex giving the leaf acute leaf tip and broad leaf base. (Plate – 43B)

Table 44 - Eigen values, PCs, and variance of *I. marginata* f. *candida*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01985	43.02	43.02
PC2	0.01148	24.89	67.91
PC3	0.00525	11.38	79.29
PC4	0.00320	6.93	86.22
PC5	0.00174	3.78	90.00
PC6	0.00138	3.00	92.99
PC7	0.00101	2.20	95.19
PC8	0.00060	1.30	96.49
PC9	0.00054	1.16	97.66
PC10	0.00027	0.59	98.24

20. ***Ipomoea muricata*** (L.) Jacq. Pl. Hort. Schoenbr. 3: 40 (1798)

Analysis:

Examination of *I. muricata* leaves resulted in nine effective PCs showing 96.29 cumulative variance. (Table 45). Highest variation was seen in PC1 depicting variation in overall leaf shape, posterior lobe development and resulted in ambiguous shape. Effects of PC2 and PC3 were majorly seen on development of petiole and posterior lobe differentiation. PC4 and PC5 showed variation at distal part of the leaf and contributed towards the leaf apex development. Variation depicted by PC6 was majorly on leaf base and posterior lobes differentiation. PC7, PC8 and PC9 were accounted for vary minor variation towards the leaf apex. (Plate – 44A)

Table 45 - Eigen values, PCs, and variance of *I. muricata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0443	47.93	47.93
PC2	0.0160	17.31	65.24
PC3	0.0118	12.83	78.07
PC4	0.0067	7.27	85.34
PC5	0.0038	4.16	89.50
PC6	0.0028	3.04	92.54
PC7	0.0013	1.41	93.95
PC8	0.0013	1.35	95.31
PC9	0.0009	0.99	96.29

21. *Ipomoea nil* (L.) Roth Catal. Bot. 1: 36 (1797)

Analysis:

Examination of *I. nil* leaves resulted in ten effective principal components with 95.77 % cumulative variance. (Table 46). Highest variation was seen in PC1 showing posterior lobes differentiation and development and length-to-width ratio, contributing towards the variation in overall leaf shape. PC2 depicted variation in leaf width and development of lobes when positive. PC3, PC4 and PC5 combined showed variation along distal part of the leaf, leaf apex giving the leaf acute apex. PC6 showed the variation of petiole development and giving leaf more sagittate shape. Rest of the four PCs (PC7 – PC10) showed the development of leaf base and petiole insertion point. All PCs contribute towards the trilobed leaf shape. (Plate – 44B)

Table 46 - Eigen values, PCs, and variance of *I. nil*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01633	43.95	43.95
PC2	0.00605	16.30	60.25
PC3	0.00364	9.80	70.04
PC4	0.00313	8.43	78.48
PC5	0.00292	7.85	86.32
PC6	0.00132	3.54	89.87
PC7	0.00072	1.95	91.81
PC8	0.00062	1.67	93.48
PC9	0.00050	1.34	94.82
PC10	0.00035	0.96	95.77

22. *Ipomoea obscura* (L.) Ker Gawl. Bot. Reg. 3: t. 239 (1817)

Analysis:

Examination of *I. obscura* leaves resulted in eight effective PCs depicting 98.16 % cumulative variance. (Table 47). PC1 showed the highest accounted variation in among all the resulted PCs. As the variation depicted by PC1 was more than 50% it showed the major variation in the leaf shape. From posterior lobe development to the overall cordate leaf shape, PC1 depicted major variations seen in the leaves. PC2 and PC3 showed the variation along the distal part of the leaf developing leaf apex and forming ambiguous shape at the base. PC4 and PC5depicted variation at the petiole development and insertion point with minor variations at leaf base. Although all the

eight PCs are considered as effective in depicting shape variation, values of rest of the PCs were much smaller and variation depicted by them were not visually determinant. (Plate – 45A)

Table 47 - Eigen values, PCs, and variance of *I. obscura*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.04624	60.30	60.30
PC2	0.01517	19.79	80.09
PC3	0.00639	8.34	88.43
PC4	0.00221	2.89	91.31
PC5	0.00217	2.83	94.14
PC6	0.00142	1.85	95.99
PC7	0.00089	1.16	97.15
PC8	0.00078	1.01	98.16

23. *Ipomoea ochracea* (Lindl.) Sweet Hort. Brit., ed. 2: 371 (1830)

Analysis:

Examination of *I. ochracea* leaves resulted in eight effective PCs depicting 97 % cumulative variance. (Table 48). Highest variation was seen in PC1 depicting variation at leaf apex development giving the lead acute apex and cordate base. PC2 and PC3 depicted variation at the leaf base and petiole. PC4 and PC5 contributed towards the development of cordate leaf base, increasing overall leaf width. PC6, PC7 and PC8 showed variation along the leaf apex, giving the lead acute leaf tip and giving the lead its overall cordate shape. (Plate – 45B)

Table 48 - Eigen values, PCs, and variance of *I. ochracea*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.0229	47.04	47.04
PC2	0.0105	21.52	68.56
PC3	0.0063	12.89	81.45
PC4	0.0026	5.41	86.86
PC5	0.0021	4.35	91.22
PC6	0.0012	2.52	93.73
PC7	0.0010	2.05	95.78
PC8	0.0006	1.22	97.00

24. *Ipomoea parasitica* (Kunth) G. Don Gen. Hist. 4: 275 (1837)

Analysis:

Examination of *I. parasitica* leaves surprisingly resulted in only four PCs showing 100 % cumulative variance. (Table 49). The highest accounted variation was depicted by PC1 resulting in visually depicted variation in overall leaf shape, petiole development and length-to-width ratio. Compared to PC1 variation depicted by other three PCs were smaller and not much visually explained. PC2 showed minor variation along the leaf margin and leaf base. PC3 depicted variation in the leaf blade and leaf apex. PC4 showed the distortions at the leaf base. (Plate – 46A)

Table 49 - Eigen values, PCs, and variance of *I. parasitica*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02838	84.33	84.33
PC2	0.00340	10.11	94.44
PC3	0.00134	3.97	98.42
PC4	0.00053	1.58	100.00

25. *Ipomoea pes-caprae* (L.) R.Br. J.H.Tuckey, Narr. Exped. Zaire: 477 (1818)

Analysis:

Examination of *I. pes-caprae* leaves resulted in six effective PCs depicting 98.74 % cumulative variance. (Table 50). PC1depicted more than 50% variance showing variation on the distal part of the leaf and development of apical notch contributing towards the bi-lobed leaf shape. PC2 depicted variation on the development of lobes contributing towards the overall leaf width. Variation depicted by PC3 was on petiole shape and petiole insertion point. PC4, PC5 and PC6 showed very less visually comprehensible variation which was mainly on overall leaf shape and distal lobed differentiation. (Plate – 46B)

Table 50 - Eigen values, PCs, and variance of *I. pes-caprae*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00786	56.57	56.57
PC2	0.00359	25.82	82.39
PC3	0.00114	8.22	90.61
PC4	0.00061	4.40	95.01
PC5	0.00036	2.57	97.59
PC6	0.00016	1.15	98.74

26. *Ipomoea pes-tigridis* L. Sp. Pl.: 162 (1753).

Analysis:

Examination of *I. pes-tigridis* leaves resulted in 11 effective PCs depicting 97.50 % cumulative variance. (Table 51). PC1 depicted the highest variation among all the other PCs. Effects of PC1 were seen on the development of petiole and differentiation of leaf lobes from the mean leaf shape. PC2 and PC3 were showed variation in lobe differentiation from positive to negative depicting lobe development and contributing towards the palmate leaf shape. PC4 and PC5 contributed to the differentiation of two proximal lobes of the leaf. PC6 and PC7 were almost similar in the values depicted minor variation in leaf shape and form an ambiguous leaf shape when positive. Remaining four PCs showed minor variation in the apical lobe shape, proximal lobe shape and ambiguous leaf shape at the right distal part. (Plate – 46C)

Table 51 - Eigen values, PCs, and variance of *I. pes-tigridis*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02449	25.69	25.69
PC2	0.01845	19.35	45.04
PC3	0.01520	15.95	60.99
PC4	0.00948	9.95	70.94
PC5	0.00737	7.73	78.67
PC6	0.00544	5.70	84.38
PC7	0.00476	5.00	89.37
PC8	0.00331	3.47	92.85
PC9	0.00241	2.53	95.38
PC10	0.00119	1.25	96.63
PC11	0.00083	0.87	97.50

27. *Ipomoea quamoclit* L. Sp. Pl.: 159 (1753)

Analysis:

Examination of *I. quamoclit* leaves resulted in 20 effective PCs depicting 99.45% cumulative variance (Table 52). Although the number of PCs were higher than the all the other analysed species there was no visual difference seen in the processed image of the *I. quamoclit.* Hence it can be said that due to the highly dissected leaf it is not possible to record leaf shape variation (Plate 24C, Plate – 47A).

Table 52 - Eigen values, PCs, and variance of *I. quamoclit*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02826	17.41	17.41
PC2	0.02436	15.01	32.41
PC3	0.01800	11.09	43.50
PC4	0.01627	10.02	53.52
PC5	0.01357	8.36	61.88
PC6	0.00916	5.64	67.52
PC7	0.00804	4.95	72.47
PC8	0.00758	4.67	77.14
PC9	0.00730	4.49	81.63
PC10	0.00495	3.05	84.68
PC11	0.00385	2.37	87.05
PC12	0.00359	2.21	89.26
PC13	0.00317	1.95	91.21
PC14	0.00281	1.73	92.95
PC15	0.00263	1.62	94.56
PC16	0.00251	1.54	96.11
PC17	0.00184	1.13	97.24
PC18	0.00148	0.91	98.15
PC19	0.00114	0.70	98.86
PC20	0.00097	0.59	99.45
PC21	0.00089	0.55	100.00

28. *Ipomoea sindica* Stapf Bull. Misc. Inform. Kew 1894: 346 (1894)

Analysis:

Examination of *I. sindica* leaves resulted in six effective PCs contributing 97.17 % cumulative variance. (Table 53). Effects of PC1 were highest on the leaf shape depicting variation in length-to-width ratio effecting overall leaf shape. PC2 was also the major contributor towards the shape variation depicting expansion of right proximal lobe and leaf apex. Effects of PC3 were mainly on the development of leaf base contributing towards the cordate leaf base and giving the leaf sagittate shape. PC4 showed variation at the leaf apex forming an acute leaf tip. PC5 and PC6 were depicted by lower values but visually the showed variation along the leaf base and petiole insertion point. (Plate – 48A)

Table 53 - Eigen values, PCs, and variance of *I. sindica*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02376	44.81	44.81
PC2	0.01638	30.89	75.71
PC3	0.00718	13.53	89.24
PC4	0.00234	4.40	93.65
PC5	0.00135	2.55	96.20
PC6	0.00051	0.97	97.17

29. *Ipomoea staphyllina* Roem. & Schult. Syst. Veg., ed. 15[bis]. 4: 249 (1819)

Analysis:

Examination of *I. staphyllina* leaves resulted in eight effective PCs with 96.90 % cumulative variance. (Table 54). PC1 was the highest accounted variable among all depicting variation on length-to-width ratio. PC2 was depicted by variation on overall leaf shape contributing towards the ovate leaf shape. PC3 and PC4 showed similar variation when positive or negative, along the leaf margin and depicting development of leaf base and petiole. PC5 and PC6 showed minor variation in overall leaf shape and leaf apex development. PC7 and PC8 contributed towards the acute leaf apex and broader base of the leaf. (Plate – 48B)

Table 54 - Eigen values, PCs, and variance of I. staphyllina

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00655	51.36	51.36
PC2	0.00322	25.26	76.61
PC3	0.00102	8.03	84.65
PC4	0.00049	3.88	88.52
PC5	0.00037	2.90	91.42
PC6	0.00033	2.57	93.98
PC7	0.00021	1.64	95.62
PC8	0.00016	1.28	96.90

30. ***Ipomoea triloba*** L. Sp. Pl.: 161 (1753)

Analysis:

Examination of *I. triloba* leaves resulted in ten effective PCs depicting 96.44 % cumulative variance. (Table 55). PC1 was the highest accounted for variation among all the resulted PCs. Effected of PC1 was depicted by overall leaf shape change from simple to trilobed when positive to negative. PC2 was depicted by variation at the posterior lobes' differentiation and development. Effects of PC3 was depicted by variation in length to width ratio of leaf showing more longer apical part than the posterior lobes. PC4 contributed towards shape variation of leaf base and petiole development. PC5 and PC6 were accounted for nearly similar values but visual representation of these two varies while PC5 showed variation towards the leaf base, PC6 showed variation over the leaf apex. PC7 showed minor variation along the posterior lobes shape and development. Last three PCs, although nearly similar in the values showed minor variation in the leaf shape contributing towards the trilobed leaf shape. (Plate – 42B)

Table 55 - Eigen values, PCs, and variance of I. triloba

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01894	33.47	33.47
PC2	0.01401	24.76	58.24
PC3	0.00876	15.49	73.73
PC4	0.00447	7.90	81.63
PC5	0.00249	4.41	86.03
PC6	0.00228	4.03	90.07
PC7	0.00122	2.15	92.21
PC8	0.00102	1.79	94.01
PC9	0.00072	1.28	95.29
PC10	0.00065	1.16	96.44

31. ***Ipomoea tuberculata*** Ker-Gawl. Bot. Reg. 1: t. 86 (1816)

Analysis:

Examination of *I. tuberculata* leaves resulted in 11 effective PCs with 99.53 % cumulative variance. Different PCs depicted variation on the leaf shape. PC1 was the major variable PC depicting the variation in overall leaf shape and development of lobes of the leaves and differentiation of upper and lower three lobes. PC2 was depicted by ambiguous shape development

at the leaf base and right proximal part of the leaf. PC3 showed variation in posterior lobe differentiation and development while PC4 depicted variation in posterior and anterior lobes development as well as differentiation. PC5, PC6 and PC7 were close with each other and showed variation in development of posterior lobes and development of two small lobes at leaf base. PC8 and PC9 depicted variation at the distal part of the leaf and showed the differentiation of lobes. PC10 and PC11 were represented by small values hence apart from minor variation at the leaf base they do not depict any visually extinguishable variations. (Plate – 15B)

Table 56 - Eigen values, PCs, and variance of I. tuberculata

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02969	45.08	45.08
PC2	0.01304	19.81	64.89
PC3	0.00775	11.76	76.66
PC4	0.00370	5.62	82.28
PC5	0.00282	4.28	86.56
PC6	0.00267	4.05	90.61
PC7	0.00229	3.48	94.09
PC8	0.00163	2.47	96.56
PC9	0.00095	1.44	98.00
PC10	0.00063	0.95	98.96
PC11	0.00038	0.57	99.53

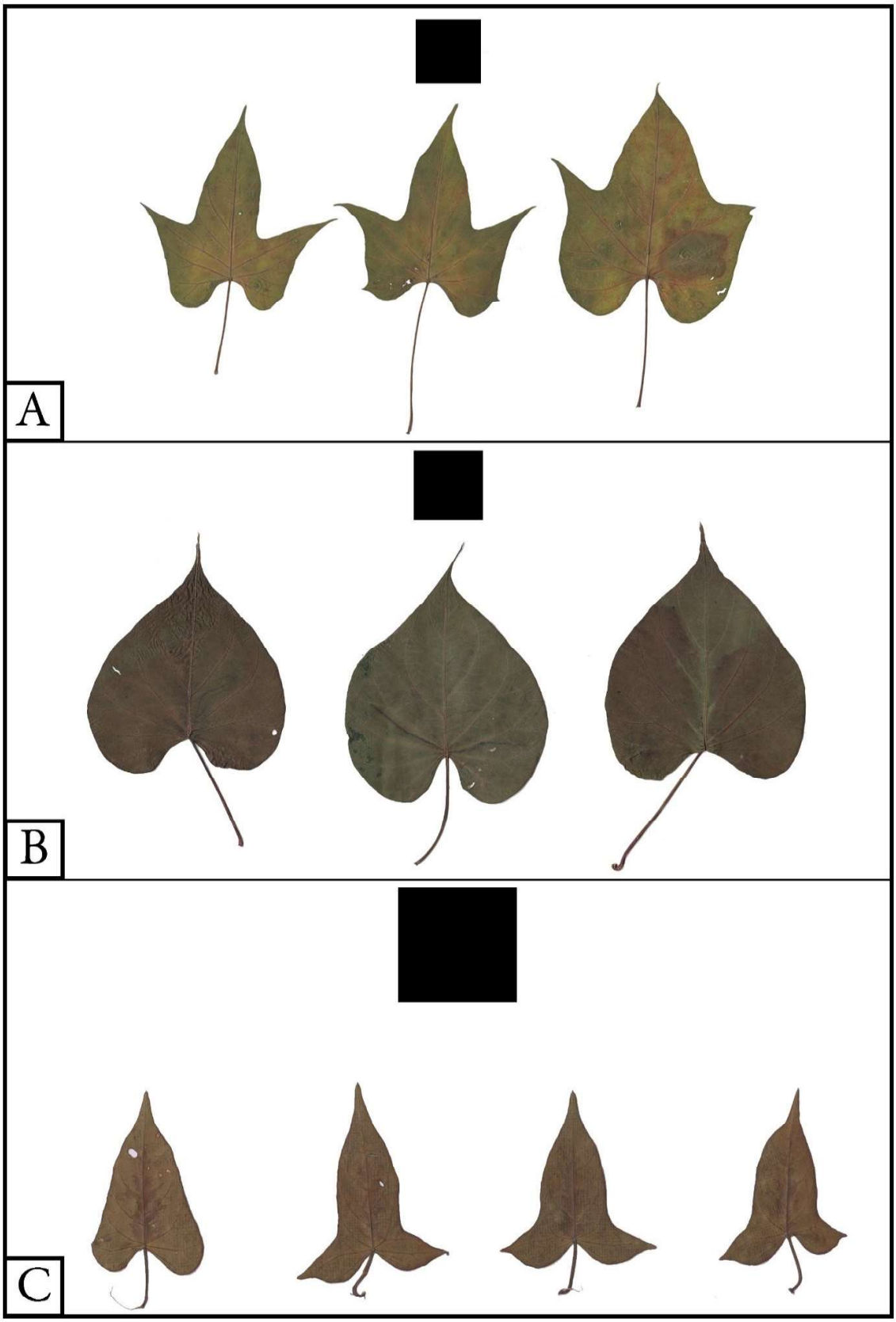

Plate 25 - Leaf samples of Ipomoea species (**A**- *I. aculeata*; **B**- *I. alba*; **C**- *I aquatica*) (Scale - 3 X 3 cm)

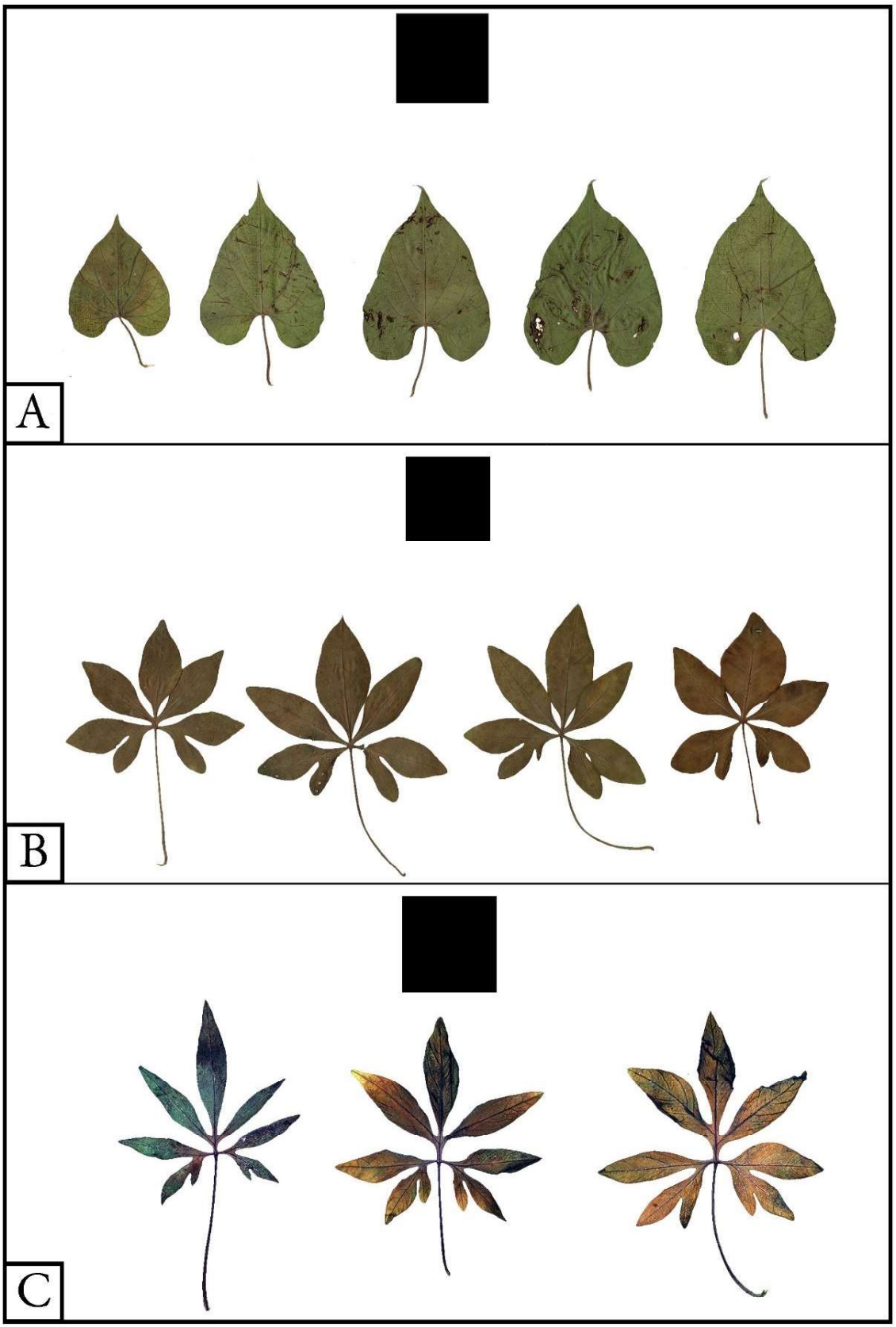

Plate 26 - Leaf samples of Ipomoea species (A- I. biflora; B- I. cairica, C- I. tuberculata) (Scale - 3 X 3 cm)

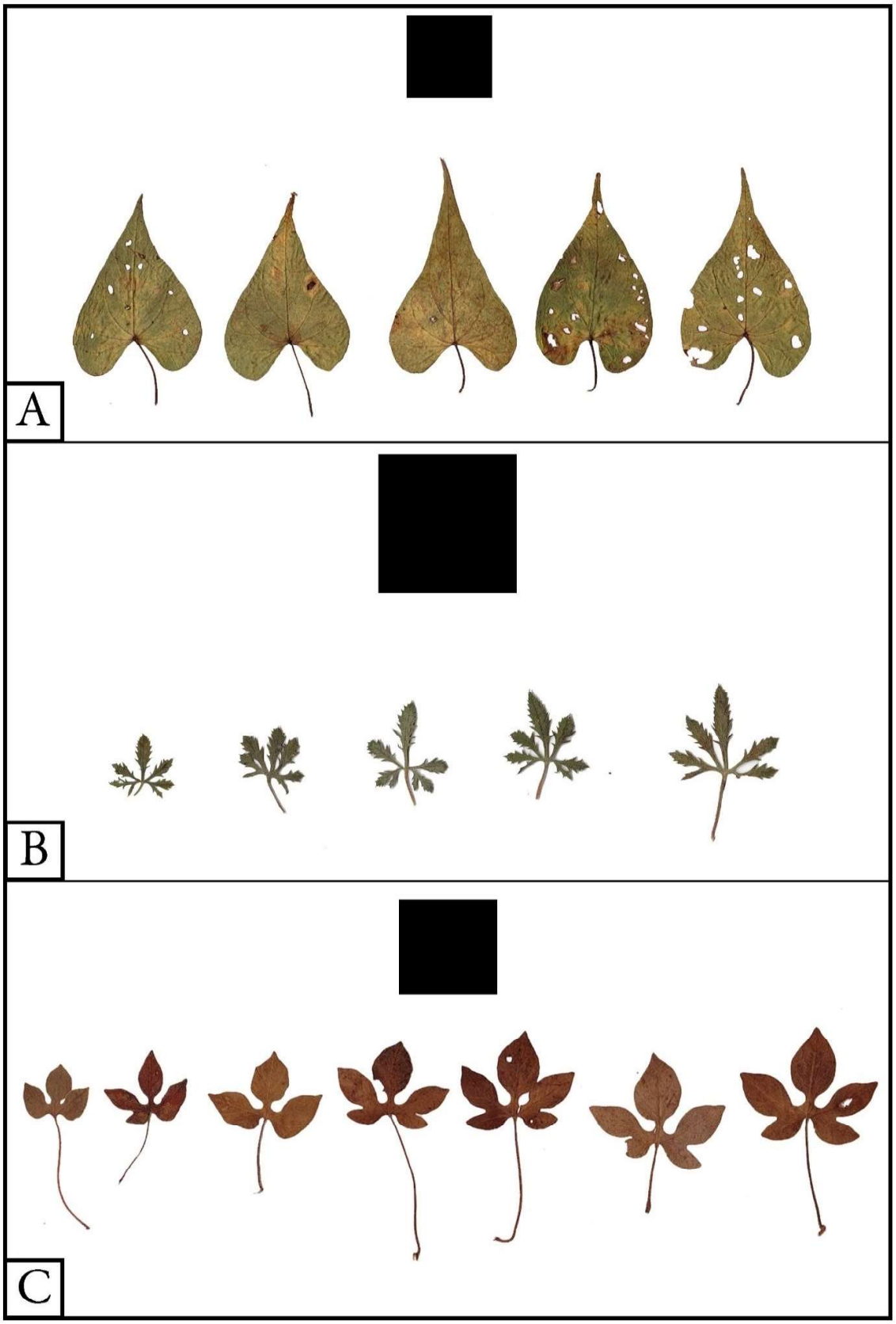

Plate 27 - Leaf samples of Ipomoea species (**A**- *I. clarkei*; **B**- *I. coptica*; **C**- *I. deccana*) (Scale - 3 X 3 cm)

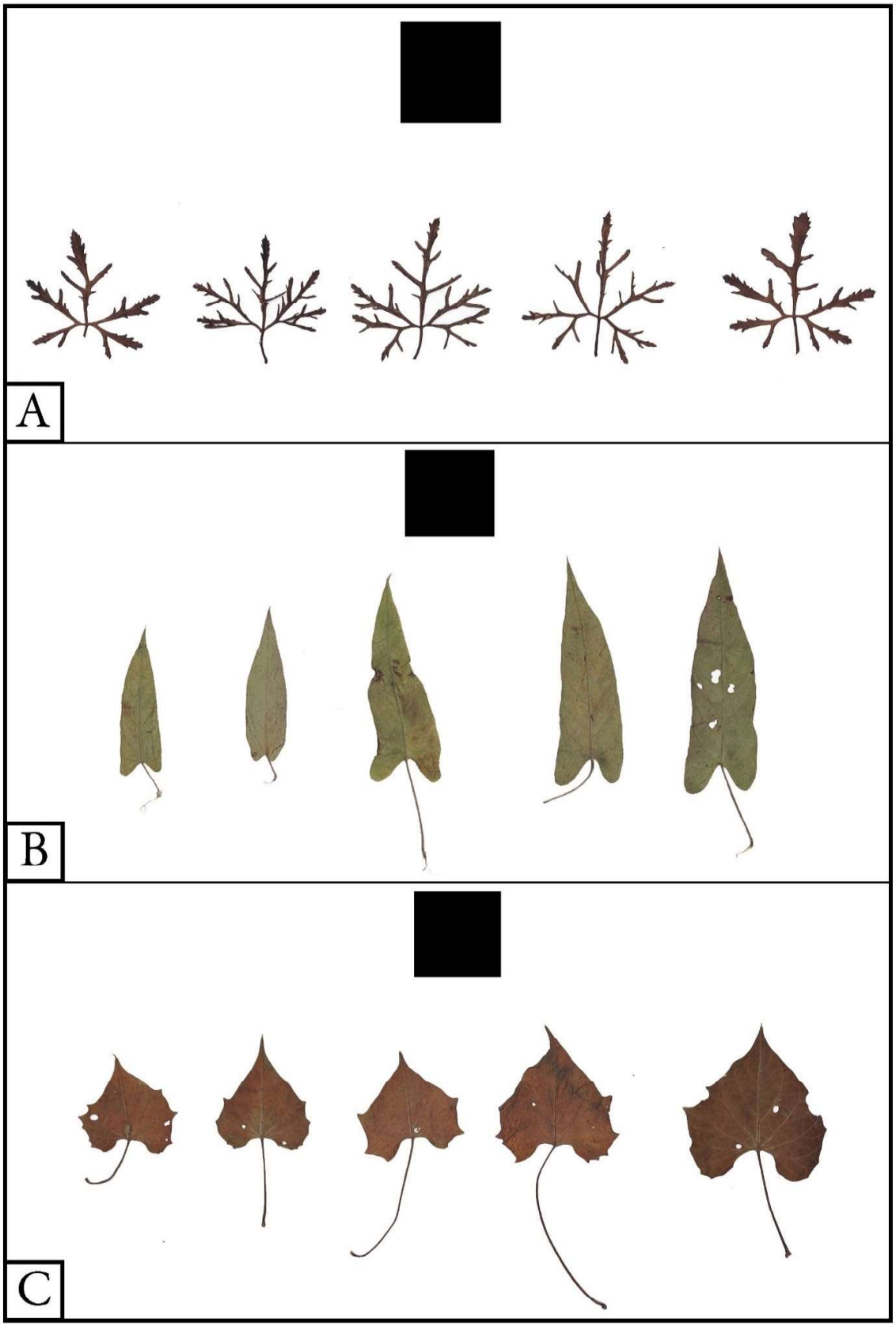

Plate 28 - Leaf samples of Ipomoea species (**A**- *I. diversifolia*; **B**- *I. eriocarpa*; **C**- *I. hederifolia*) (Scale - 3 X 3 cm)

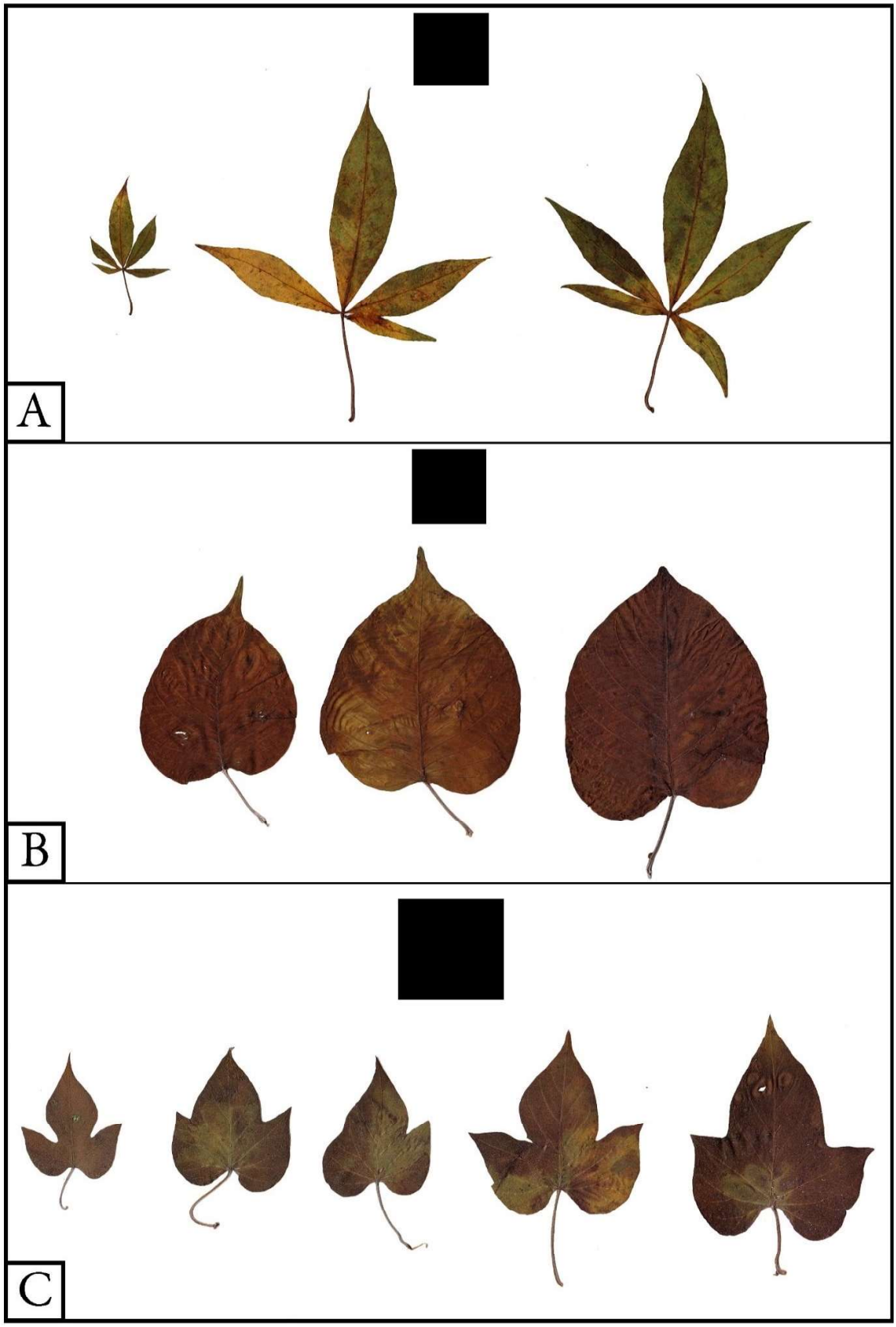

Plate 29 - Leaf samples of Ipomoea species (**A**- *I. horsfalliae*; **B**- *I. campanulata*; **C**- *I. indica*) (Scale - 3 X 3 cm)

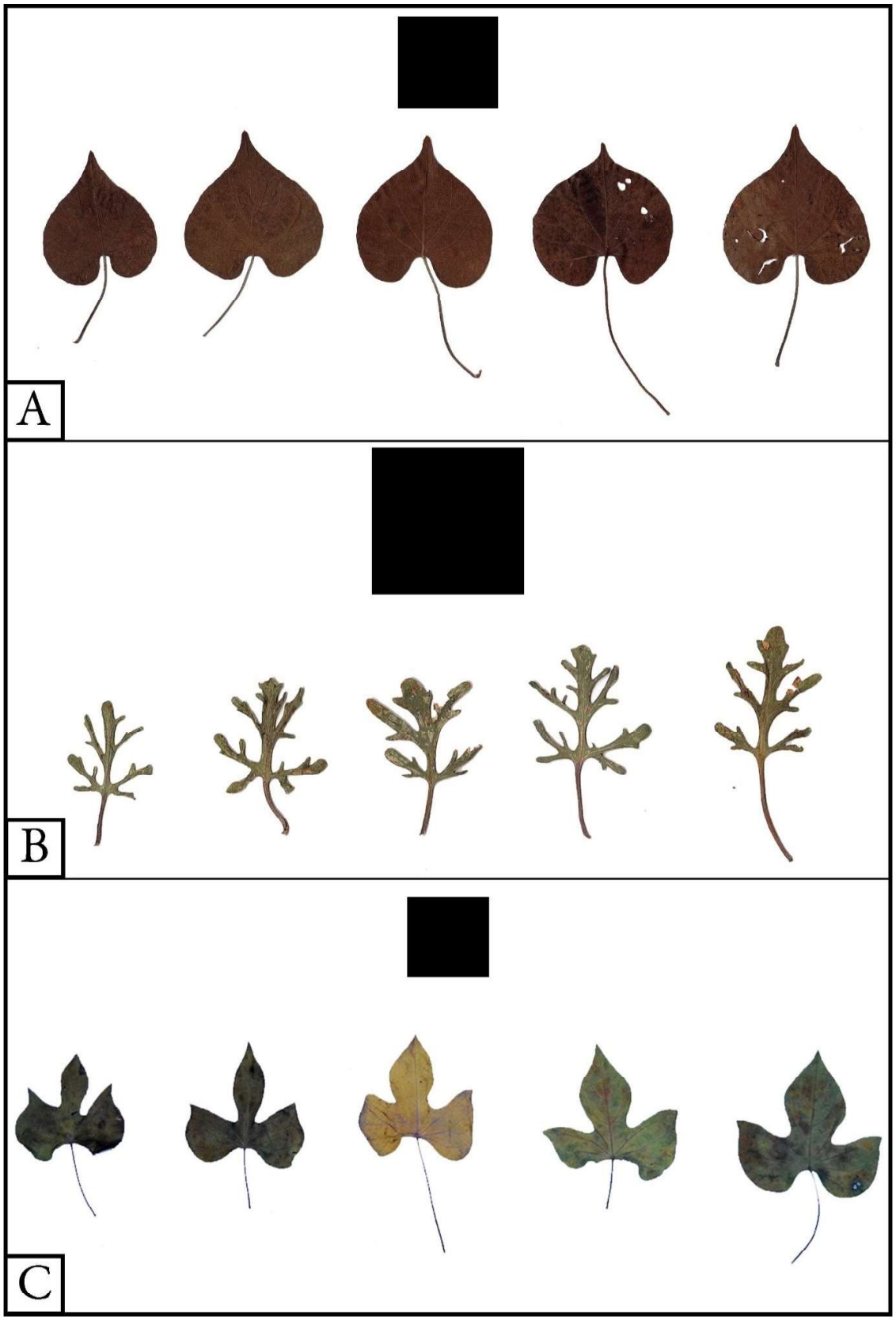

Plate 30 - Leaf samples of Ipomoea species (A- I. involucrata; B- I. kotschyana; C- I. laxiflora) (Scale - 3 X 3 cm)

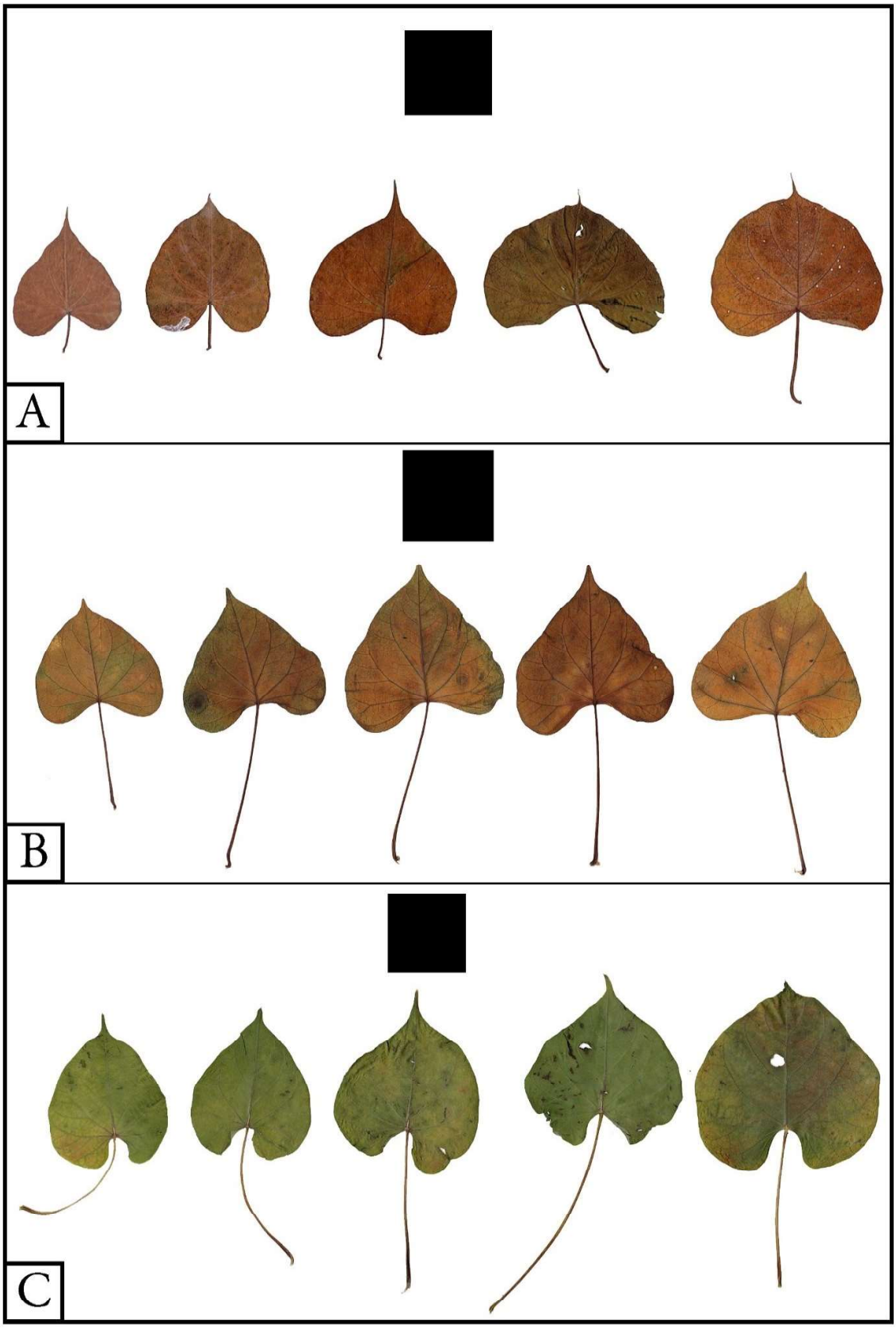

Plate 31 - Leaf samples of Ipomoea species (**A**- *I. marginata* f. *candida*; **B**- *I. marginata*; C- *I. muricata*) (Scale - 3 X 3 cm)

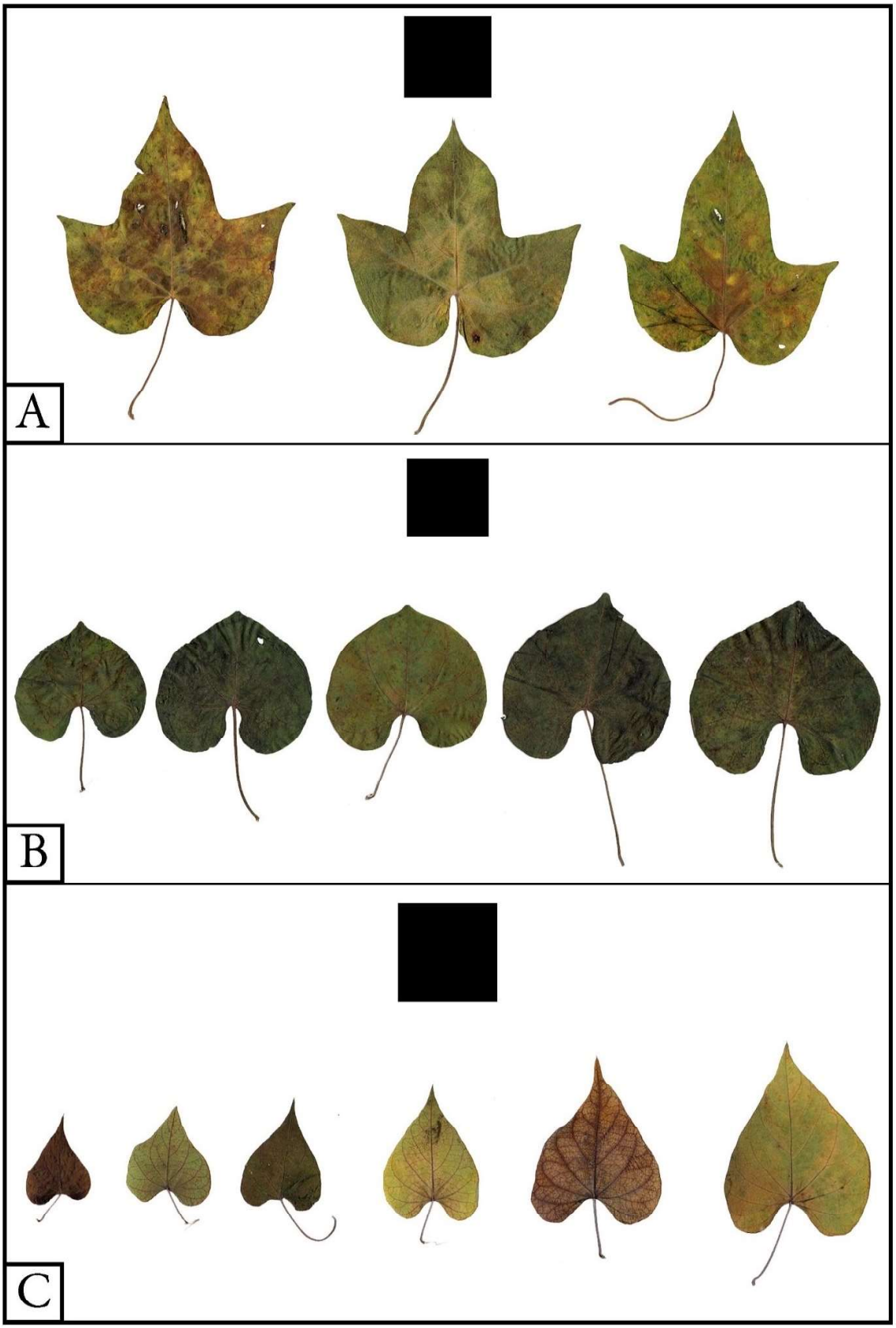

Plate 32 - Leaf samples of Ipomoea species (**A**- *I. nil*; **B**- *I. obscura*; **C**- *I. ochracea*) (Scale - 3 X 3 cm)

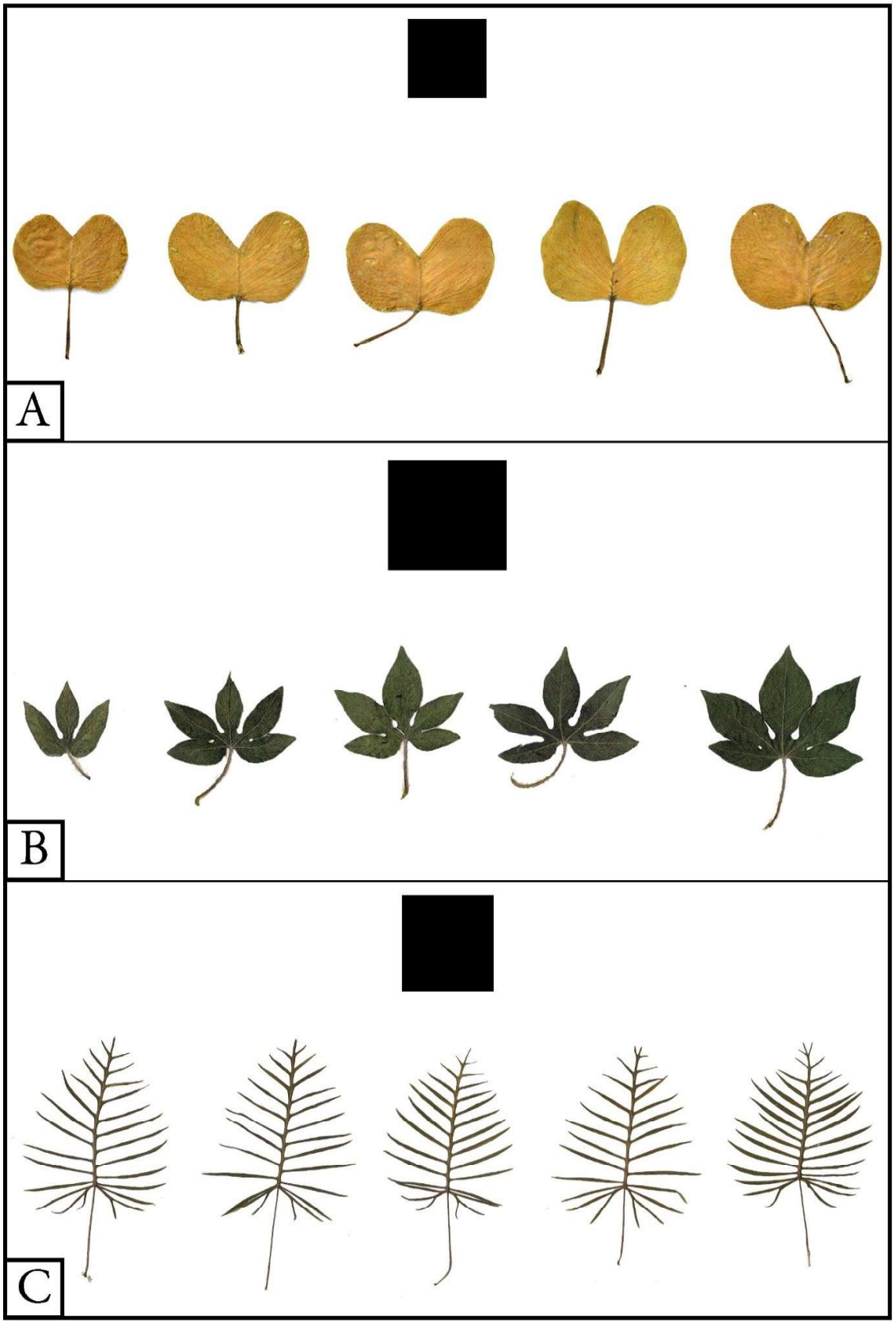

Plate 33 - Leaf samples of Ipomoea species (**A**- *I. pes-caprae*; **B**- *I. pes-tigridis*; **C**- *I. quamoclit*) (Scale - 3 X 3 cm)

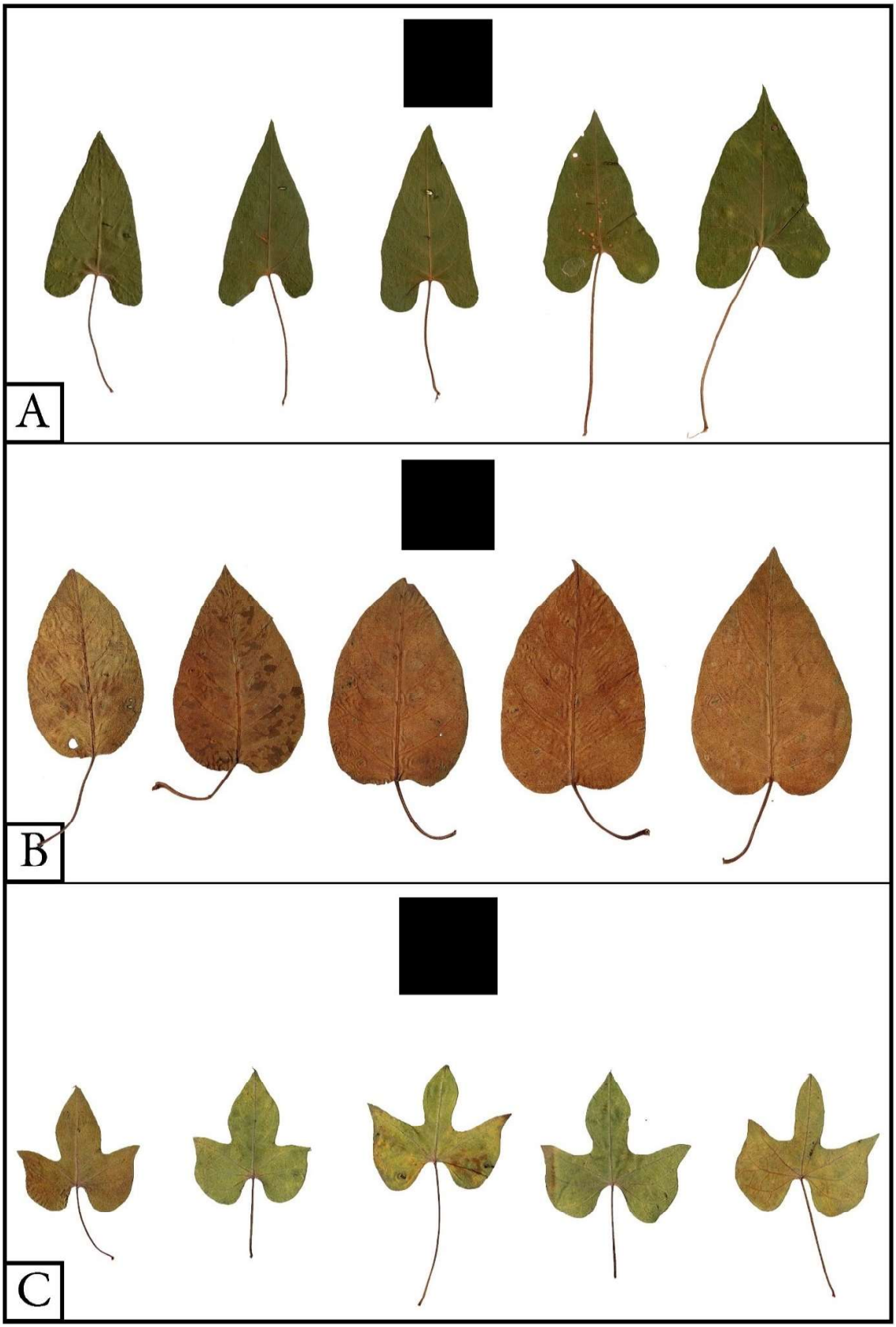

Plate 34 - Leaf samples of Ipomoea species (**A**- *I. sindica*; **B**- *I. staphyllina*; **C**- *I. triloba*) (Scale - 3 X 3 cm)

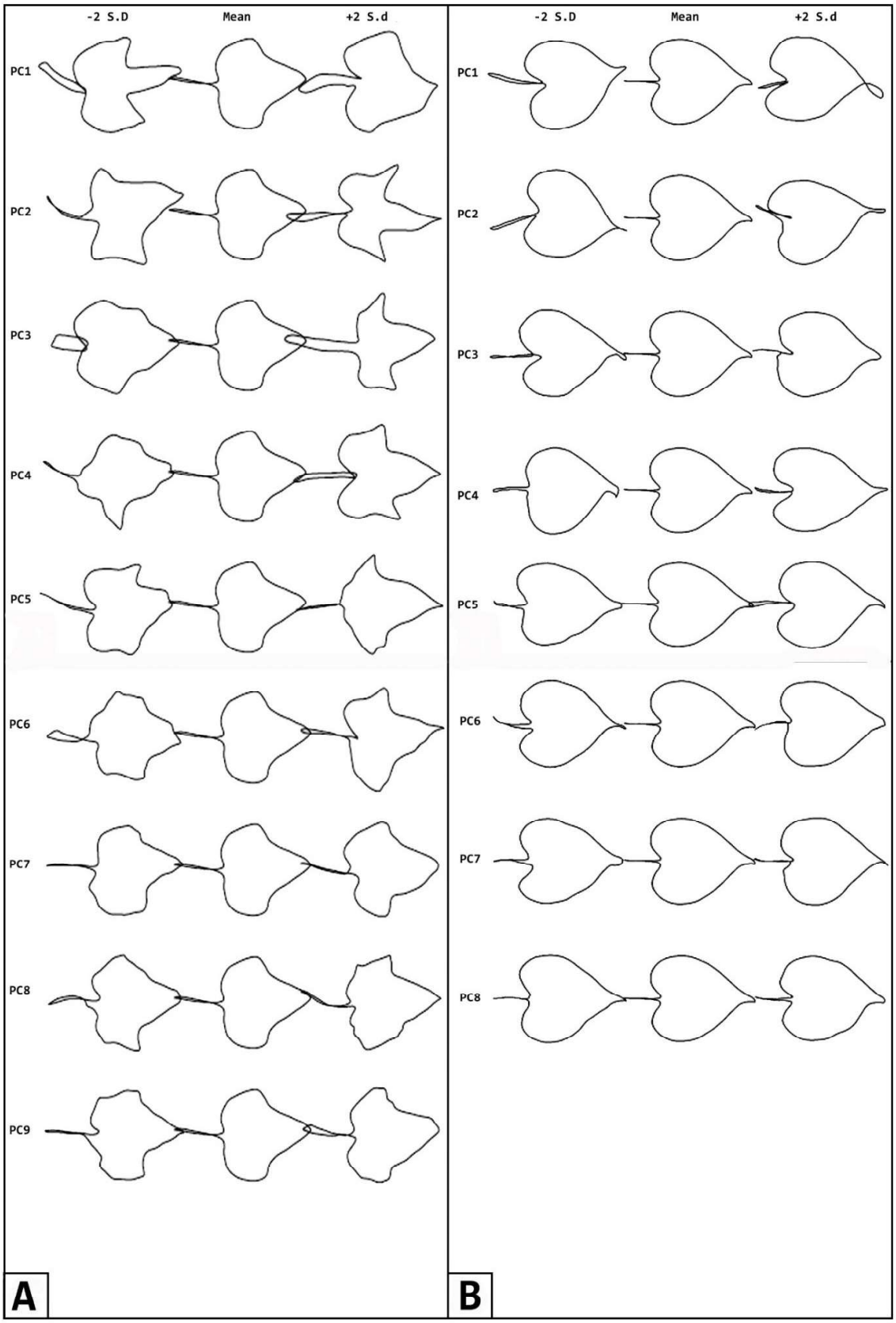

Plate 35 - Processed image showing leaf shape variation (**A**- *I. aculeata*; **B**- *I. alba*)

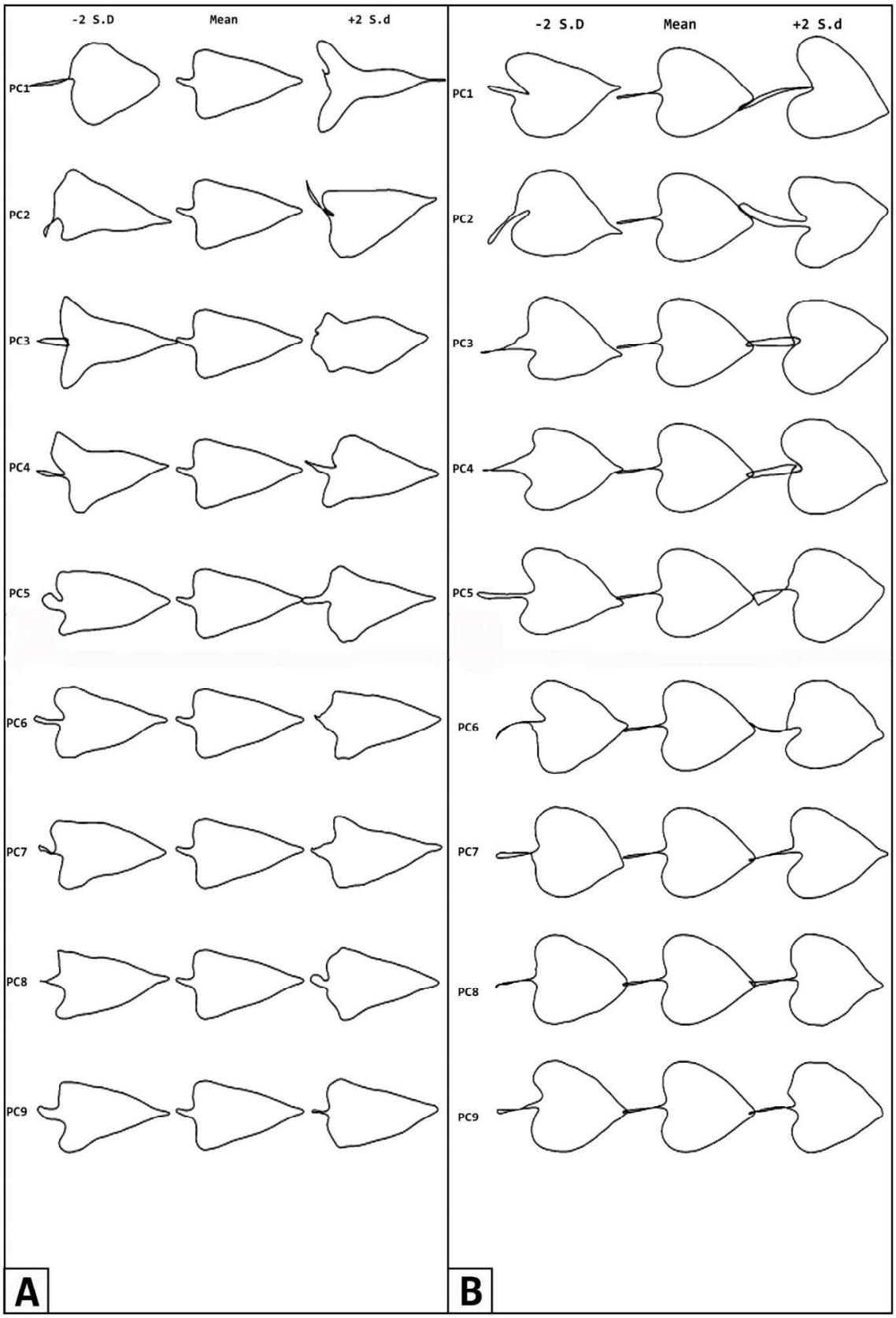

Plate 36 - Processed image showing leaf shape variation (**A**- *I. aquatica*; **B**- *I. biflora*)

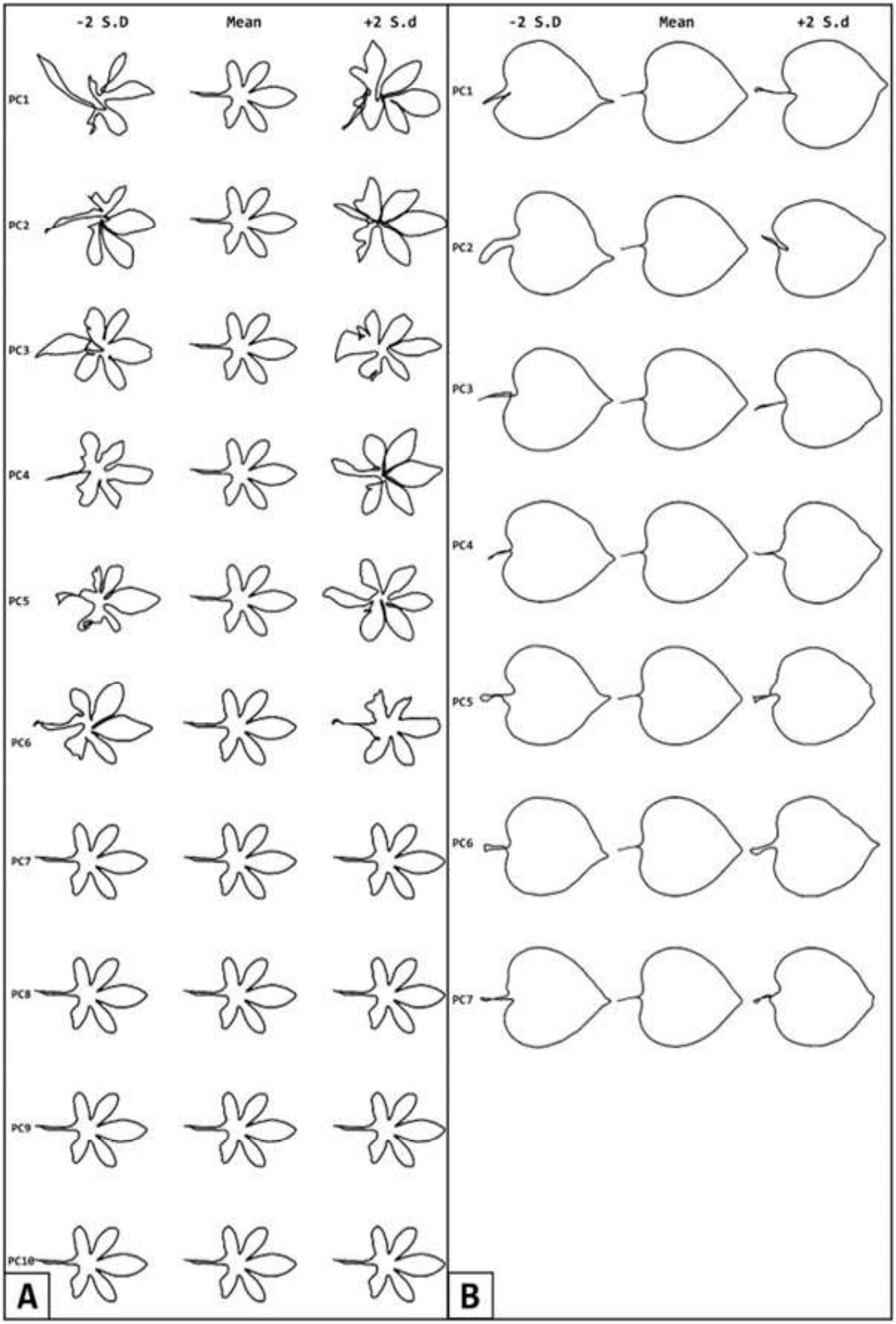

Plate 37 - Processed image showing leaf shape variation (**A**- *I. cairica*; **B**- *I. campanulata*)

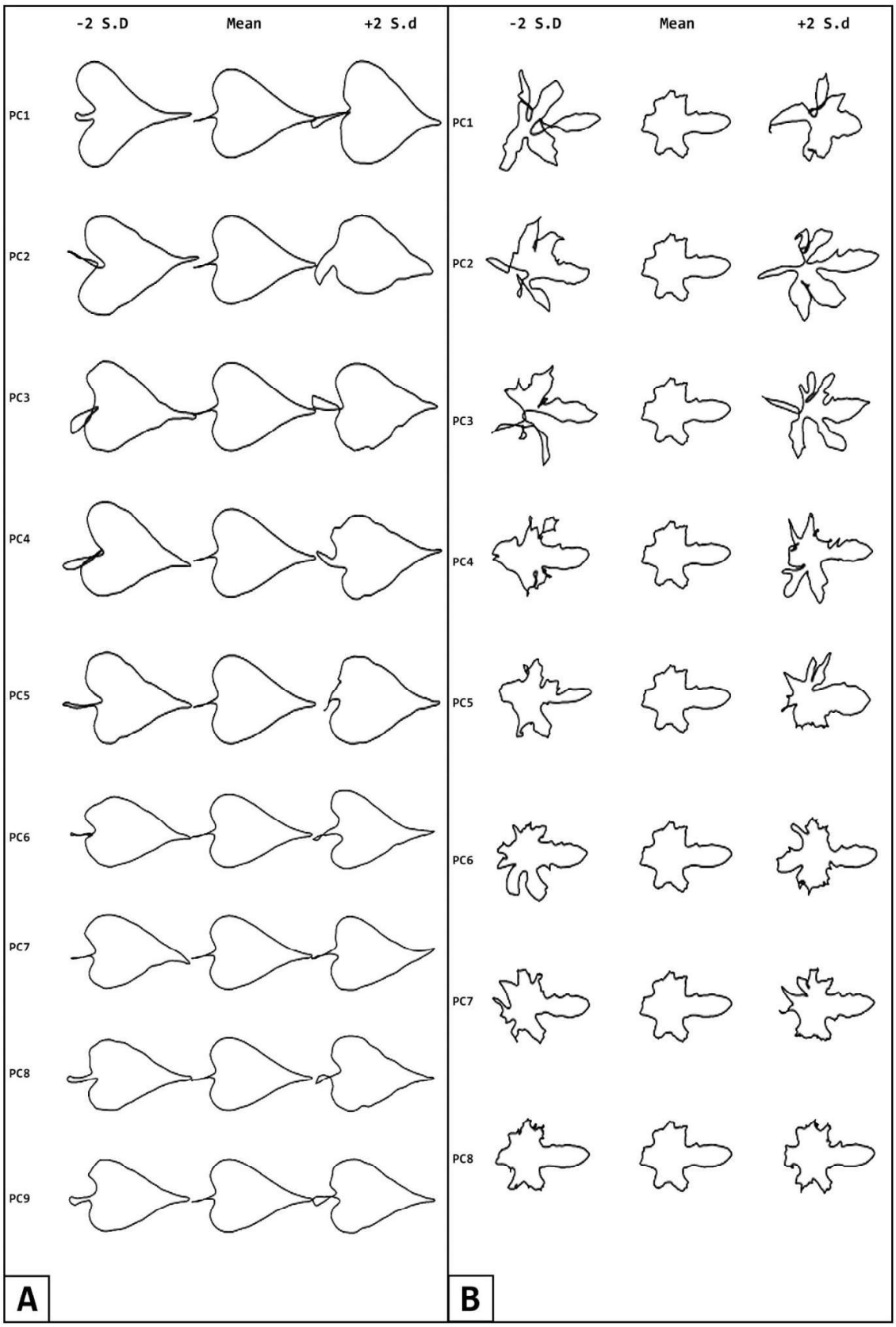

Plate 38 - Processed image showing leaf shape variation (**A**- *I. clarkei*; **B**- *I. coptica*)

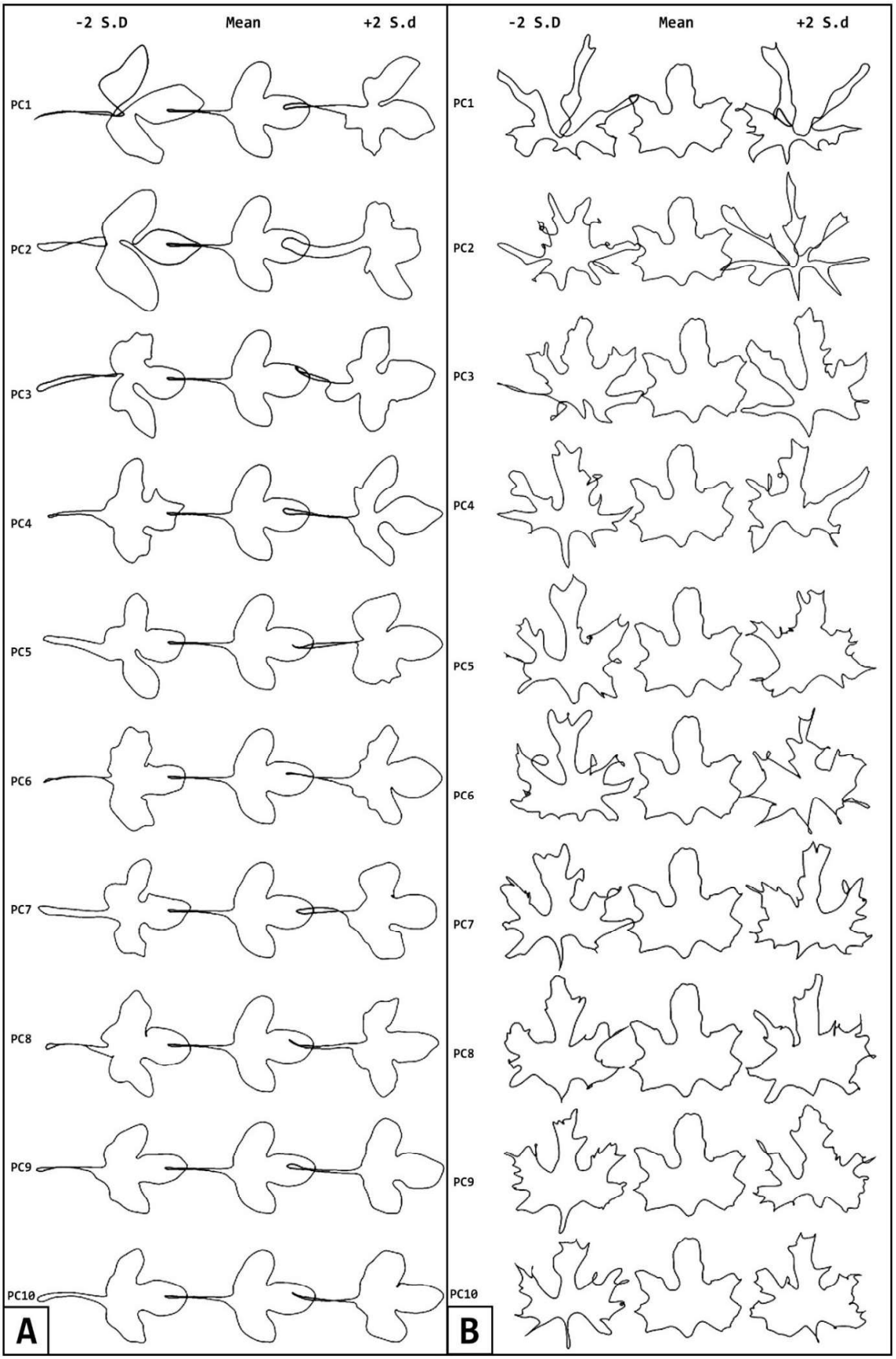

Plate 39 - Processed image showing leaf shape variation (**A**- *I. deccana*; **B**- *I. diversifolia*)

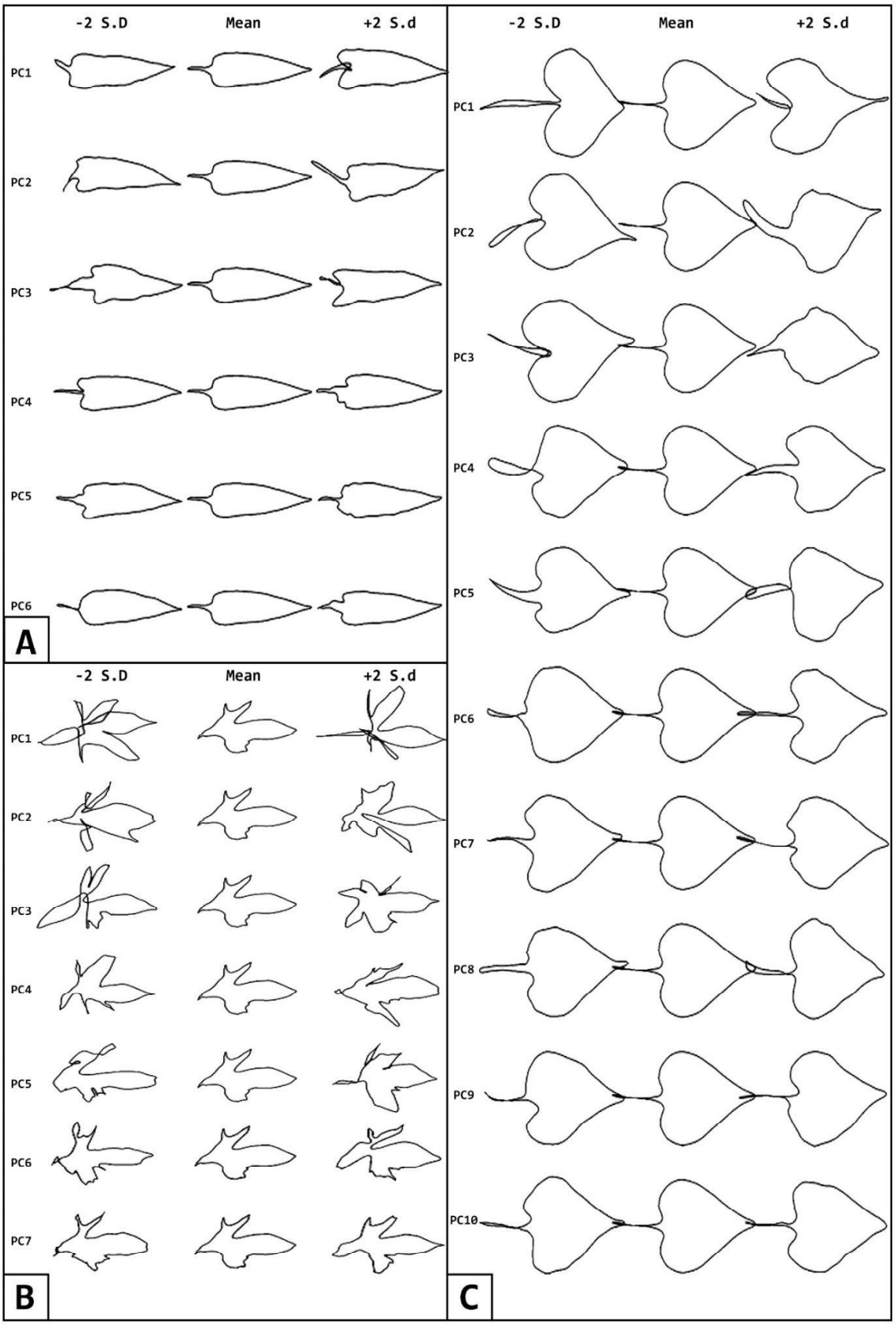

Plate 40 - Processed image showing leaf shape variation (**A**- *I. eriocarpa*; **B**- *I. horsfalliae*; **C**- *hederifolia*)

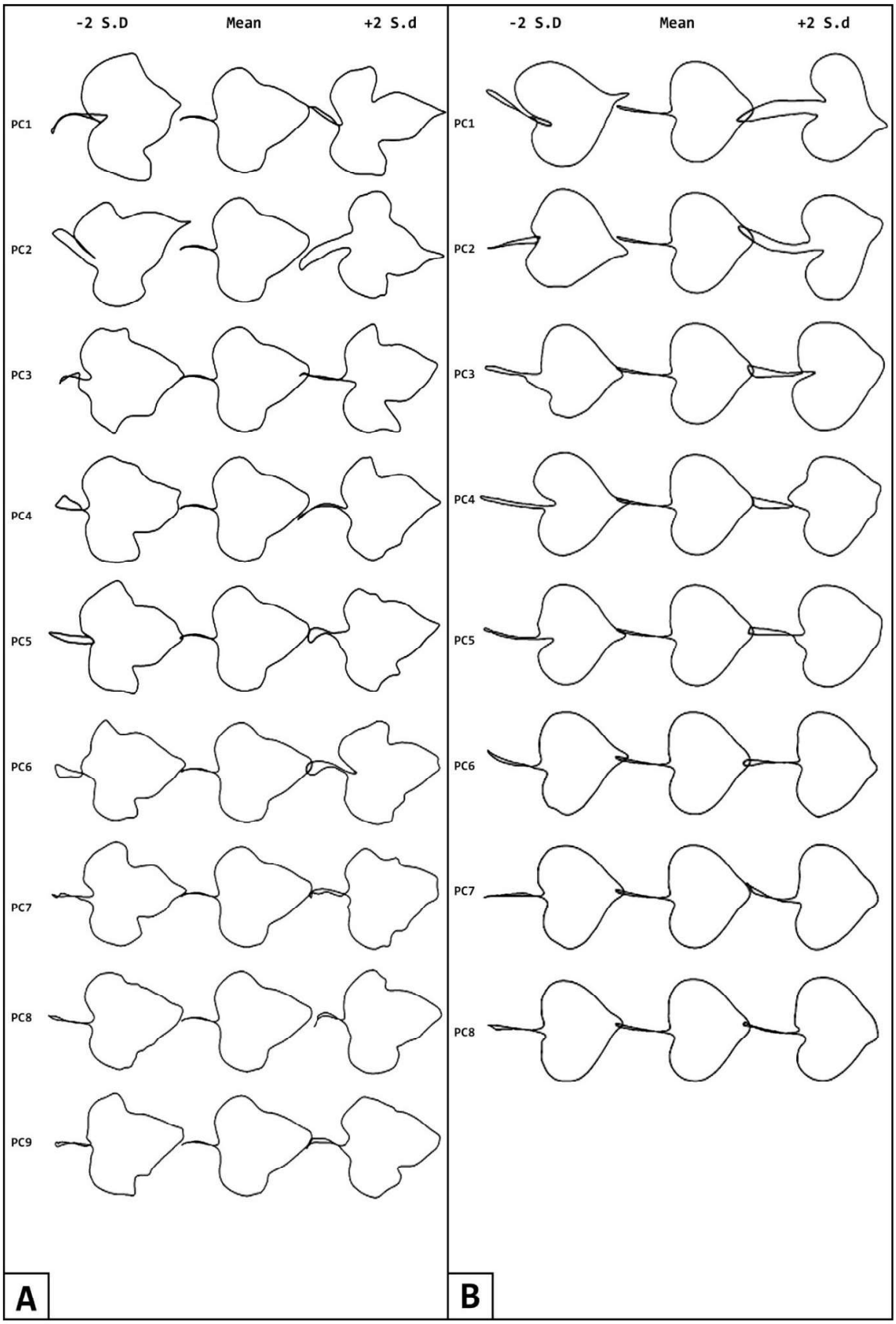

Plate 41 - Processed image showing leaf shape variation (A- I. indica; B- I. involucrata)

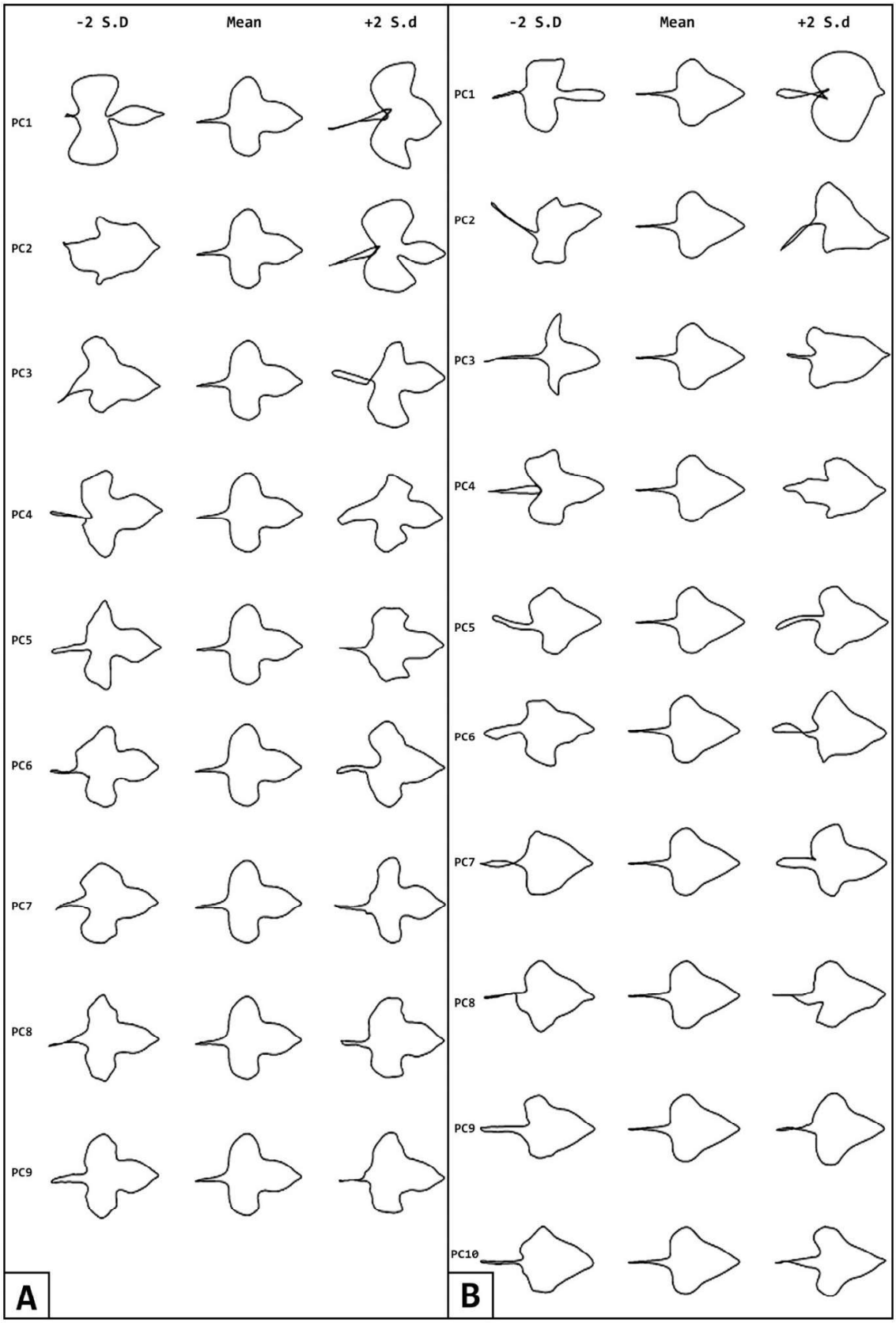

Plate 42 - Processed image showing leaf shape variation (**A**- *I. laxiflora*; **B**- *I. triloba*)

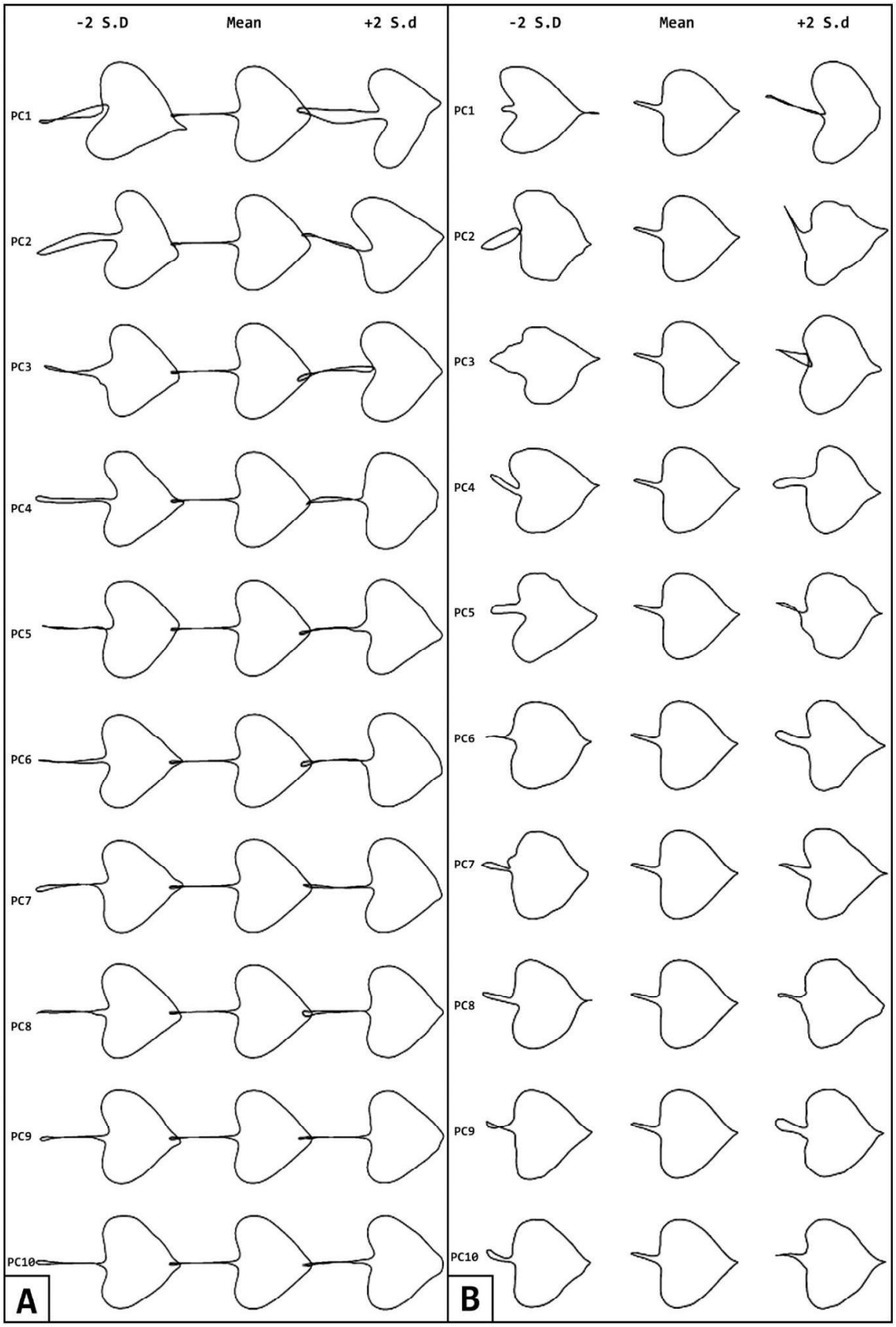

Plate 43 - Processed image showing leaf shape variation (**A**- *I. marginata*; **B**- *I. marginata* **f.** *candida*)

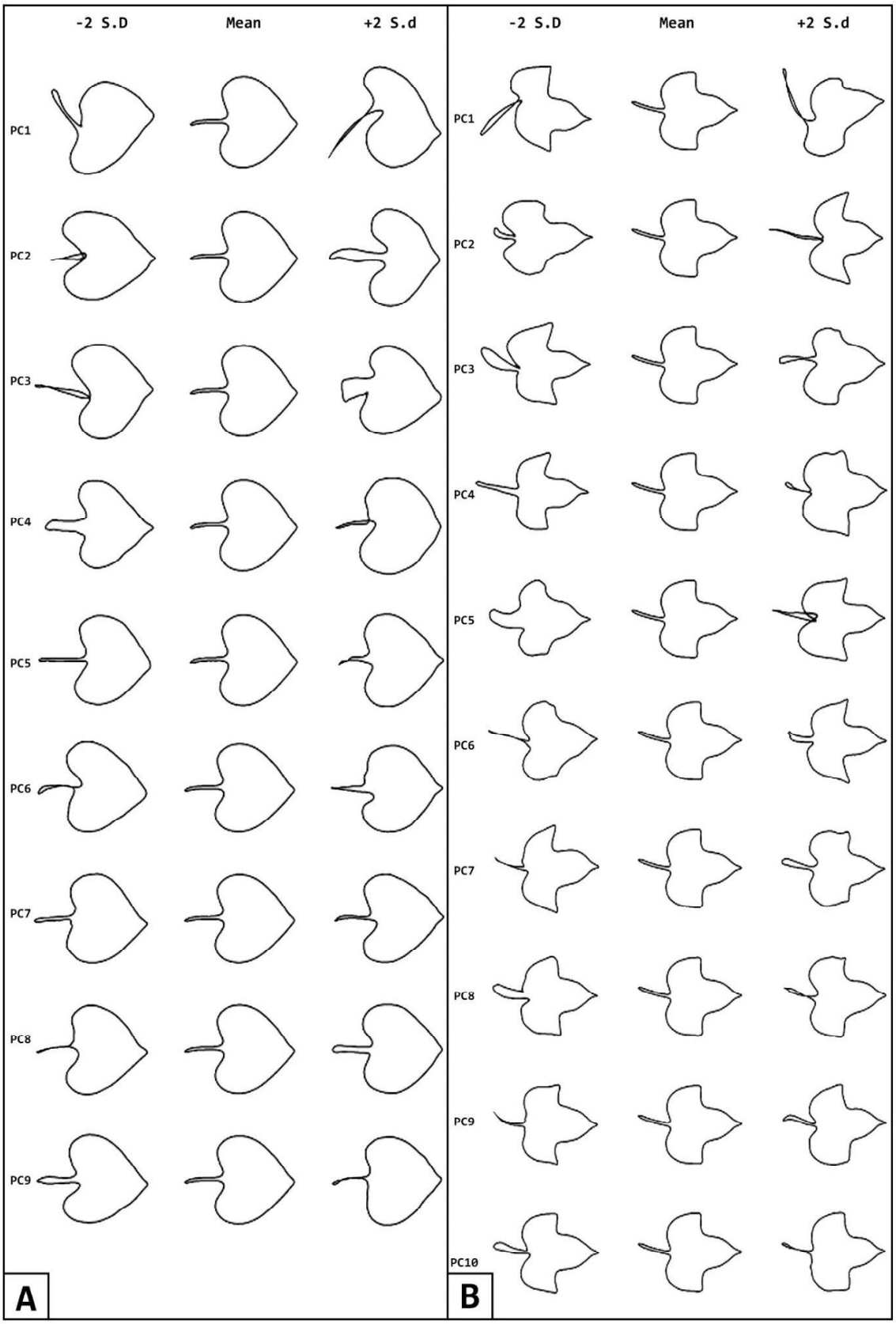

Plate 44 - Processed image showing leaf shape variation (**A**- *I. muricata*; **B**- *I. nil*)

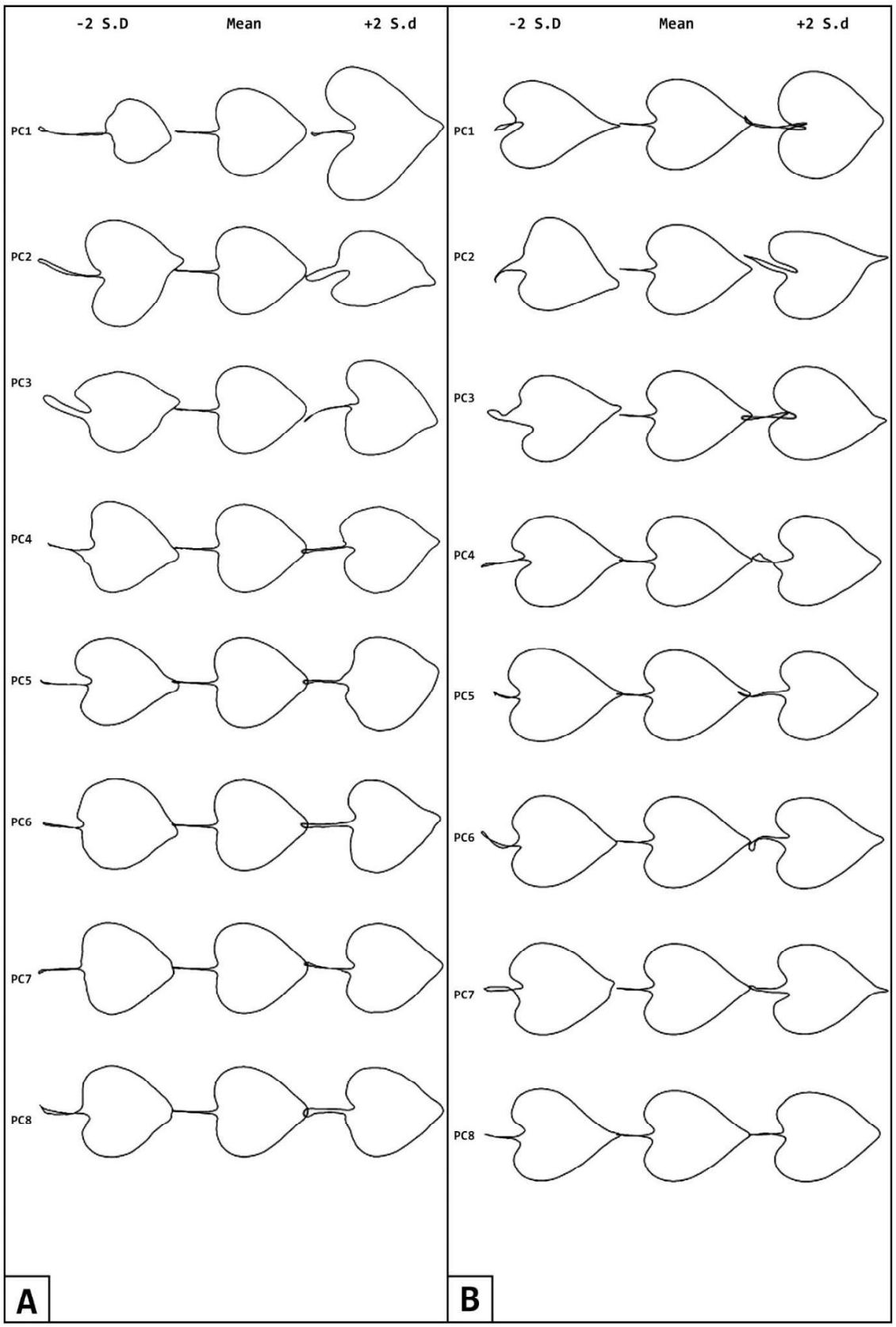

Plate 45 - Processed image showing leaf shape variation (**A**- *I. obscura*; **B**- *I. ochracea*)

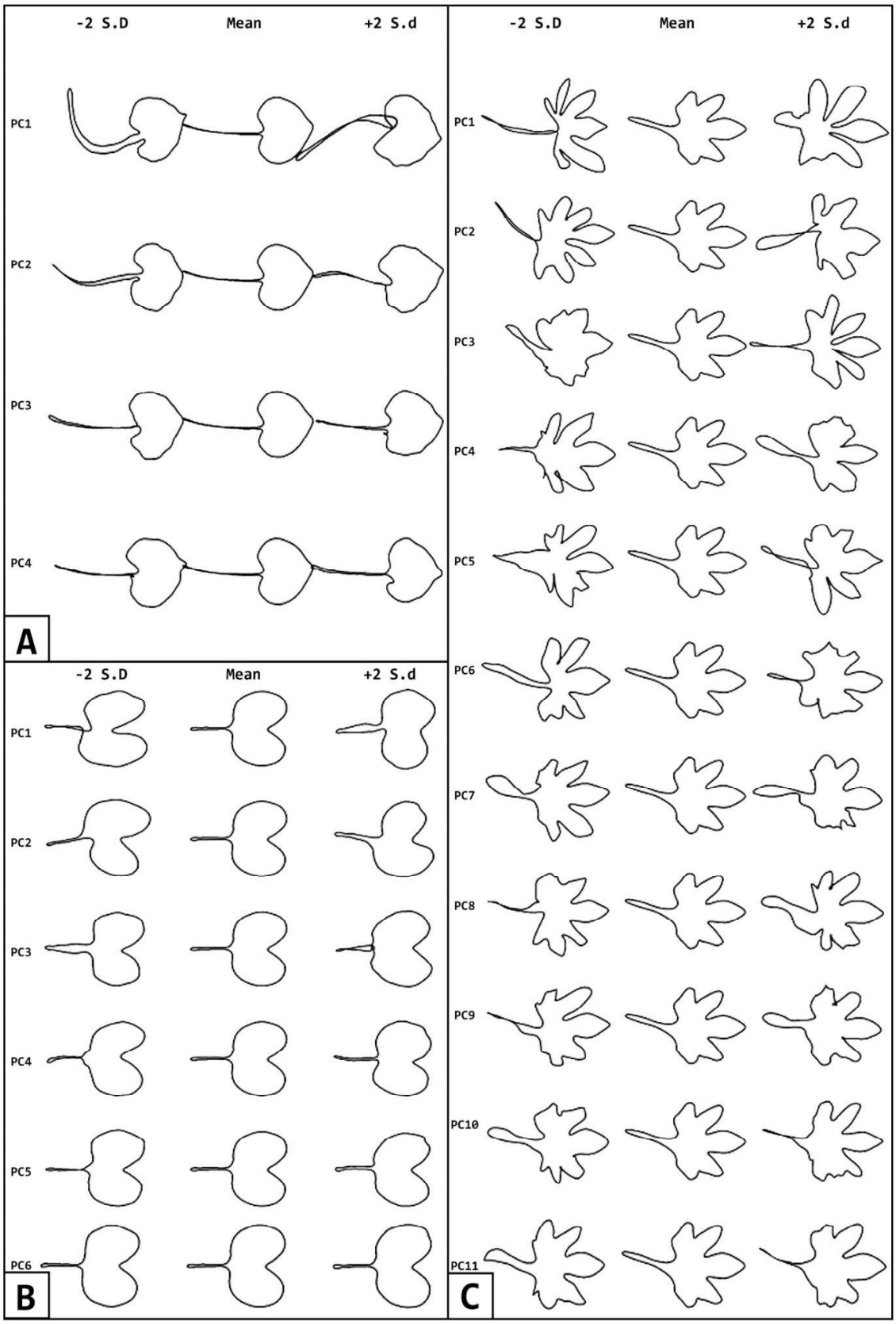

Plate 46 - Processed image showing leaf shape variation (**A**- *I. parasitica*; **B**- *I. pes-caprae*; **C**- I. *pes-tigridis*)

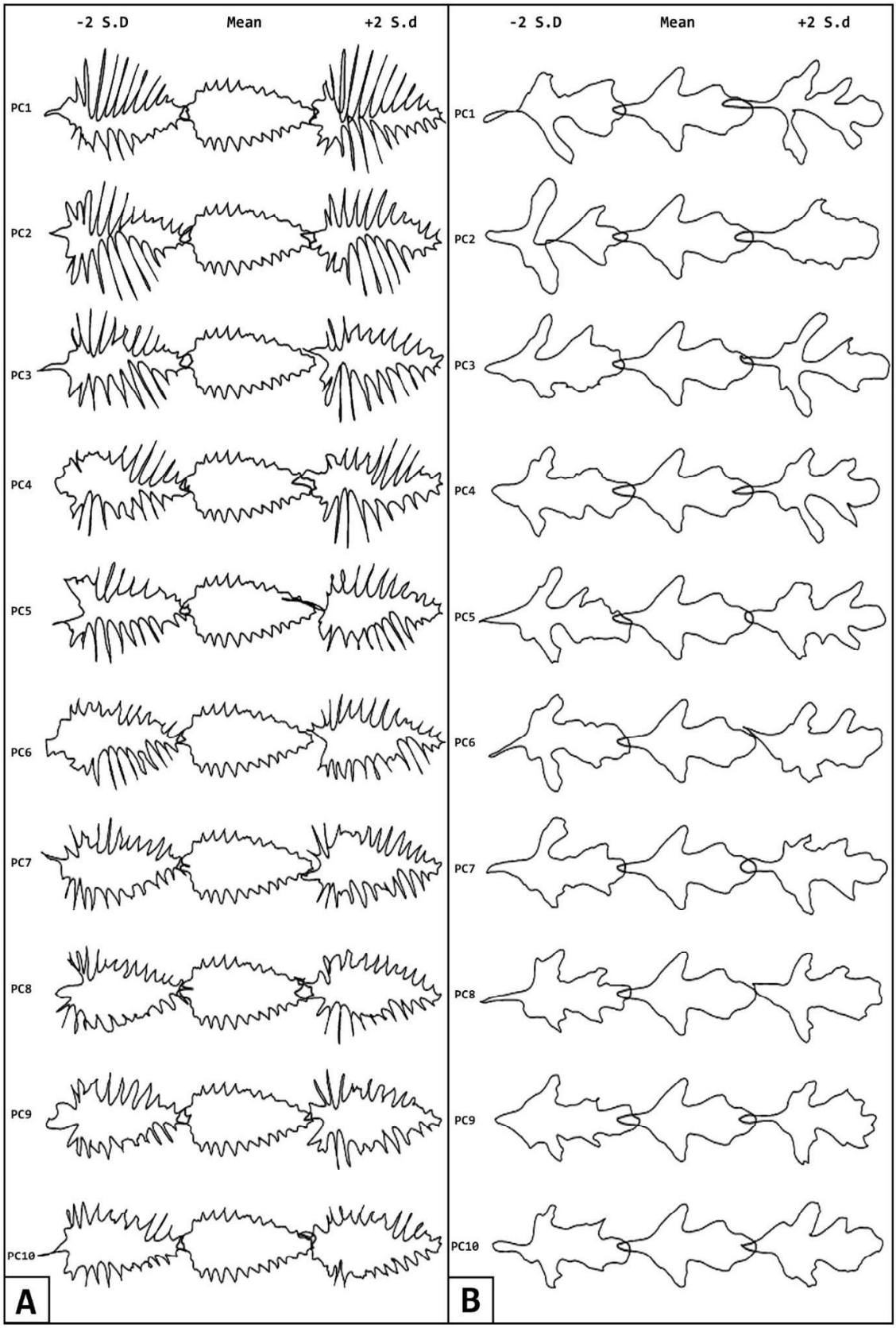

Plate 47 - Processed image showing leaf shape variation (**A**- *I. quamoclit*; **B**- *I. kotschyana*)

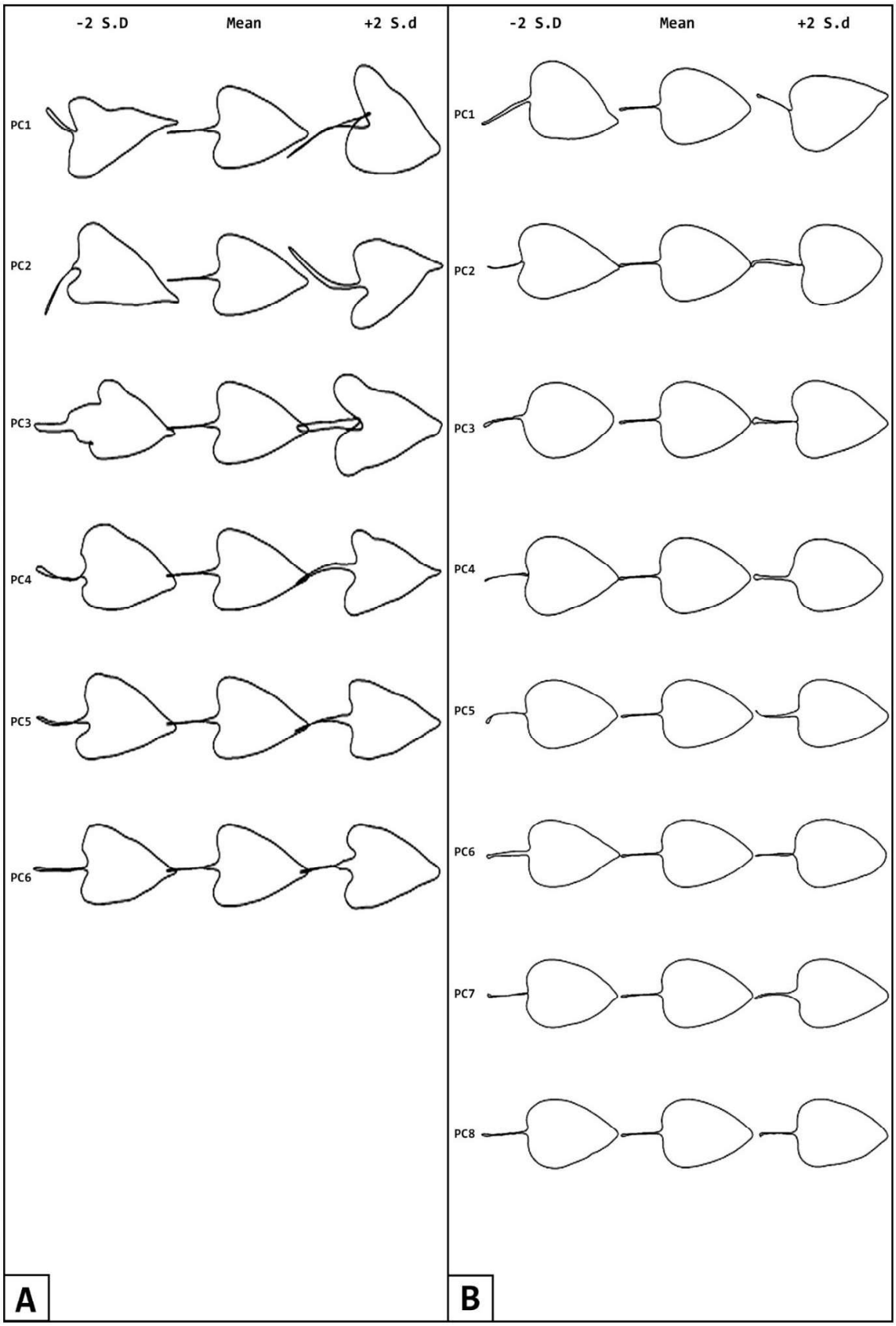

Plate 48 - Processed image showing leaf shape variation (**A**- *I. sindica*; **B**- *I. staphyllina*)

4.7. Genus: Jacquemontia Choicy

Jacquemontia Choisy Mém. Soc. Phys. Genève 6: 476 (1833 publ. 1834) [Conv. Or.: 94]

Type: *Convolvulus pentanthos* Jacquin = *J. pentanthos* (Jacquin) G. Don.

4.7.1. General Characters of genus *Jacquemontia*:

Herbs or sub-shrubs, perennial; stems trailing, decumbent, twining, or erect; indumentum commonly of branched hairs. (Table 57). Leaves entire, oblong to ovate; inflorescence usually cymose but often contracted and sub-capitate; sometimes racemose or loosely paniculate; calyx of five free sepals, sepals subequal or unequal, the two outer differing from the two innermost. Corolla blue or white (rarely pale pink), broadly funnel-shaped, glabrous on the exterior; stamens 5, included or very shortly exserted, white; pollen mostly pantocolpate, rarely tricolpate; style 1; stigmas 2, ellipsoid to oblong, straight or bent, somewhat flattened, exceeding anthers; ovary bilocular, 4-ovulate. Capsule usually 4 – 8-valved, subglobose, glabrous; seeds glabrous, often verruculose, occasionally weakly winged. (Plate – 49A,B)

Table 57 - list of collected species of genus *Jacquemontia* Choisy

Sr. No.	Scientific Name
1	*Jacquemontia paniculata* (Burm. f.) Hallier f.
2	*Jacquemontia pentanthos* (Jacq.) G. Don

1. ***Jacquemontia paniculata*** (Burm. f.) Hallier f. Bot. Jahrb. Syst. 18: 95 (1893)

Analysis:

Examination of *J. paniculata* leaves resulted in eight effective PCs covering 96.26% cumulative variance. (Table 58). Almost half of the variation was depicted by PC1 showing variation in overall leaf shape, length-to-width ratio and petiole. PC2 depicted variation at leaf base and proximal part of the leaf lamina. PC3 showed variation along the leaf width and ambiguous shape at petiole development. PC4 and PC5 depicted variation at distal end of the lamina and leaf apex. The variation depicted by PC6 was mainly on leaf apex contributing towards acute leaf tip. PC7 and PC8 depicted minor variation along the leaf margin and leaf base giving leaf its overall shape. (Plate – 50A)

Table 58 - Eigen value, PCs and Variance of J. paniculata

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01105	49.09	49.09
PC2	0.00588	26.14	75.23
PC3	0.00200	8.88	84.11
PC4	0.00088	3.90	88.01
PC5	0.00072	3.21	91.22
PC6	0.00056	2.48	93.70
PC7	0.00032	1.41	95.11
PC8	0.00026	1.15	96.26

2. ***Jacquemontia pentanthos*** (Jacq.) G. Don Gen. Hist. 4: 283 (1837)

Analysis:

Examination of *J. pentanthos* leaves resulted in nine effective PCs showing 96.22% cumulative variance. (Table 59). PC1 depicted the highest accounted variation among all the calculated PCs. Effects of PC1 was seen as variation in length-to-width ratio and petiole development. PC2 was depicted by variation at the right middle part of the leaf lamina and leaf apex. Effects of PC3 were depicted by development of petiole and round leaf base. PC4 was seen as variation at leaf apex. Variation depicted by PC5 was not visually differentiated. Rest of the four PCs (PC6, PC7, PC8, and PC9) showed minor variation along the leaf margin and at the leaf base. (Plate – 50B)

Table 59 - Eigen value, PCs and Variance of J. pentanthos

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00880	53.49	53.49
PC2	0.00333	20.23	73.72
PC3	0.00143	8.67	82.39
PC4	0.00084	5.12	87.51
PC5	0.00055	3.31	90.82
PC6	0.00027	1.66	92.48
PC7	0.00025	1.49	93.97
PC8	0.00021	1.28	95.25
PC9	0.00016	0.97	96.22

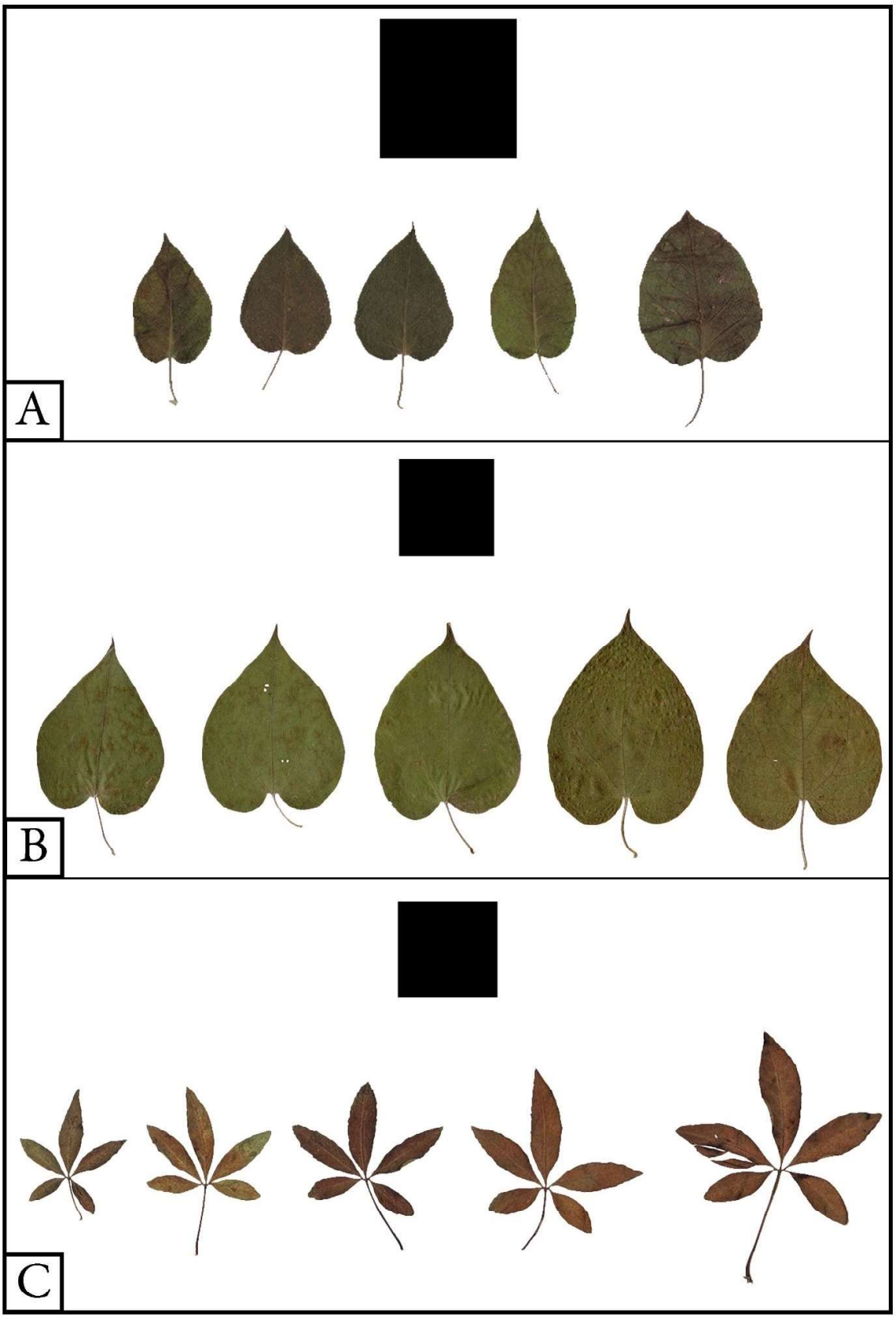

Plate 49 - Leaf samples of Jacquemontia and Distimake (**A**- *J. paniculata*; **B**- *J. pentanthos*; **C**- *D. quinquefolia*)
(Scale - 3 X 3 cm)

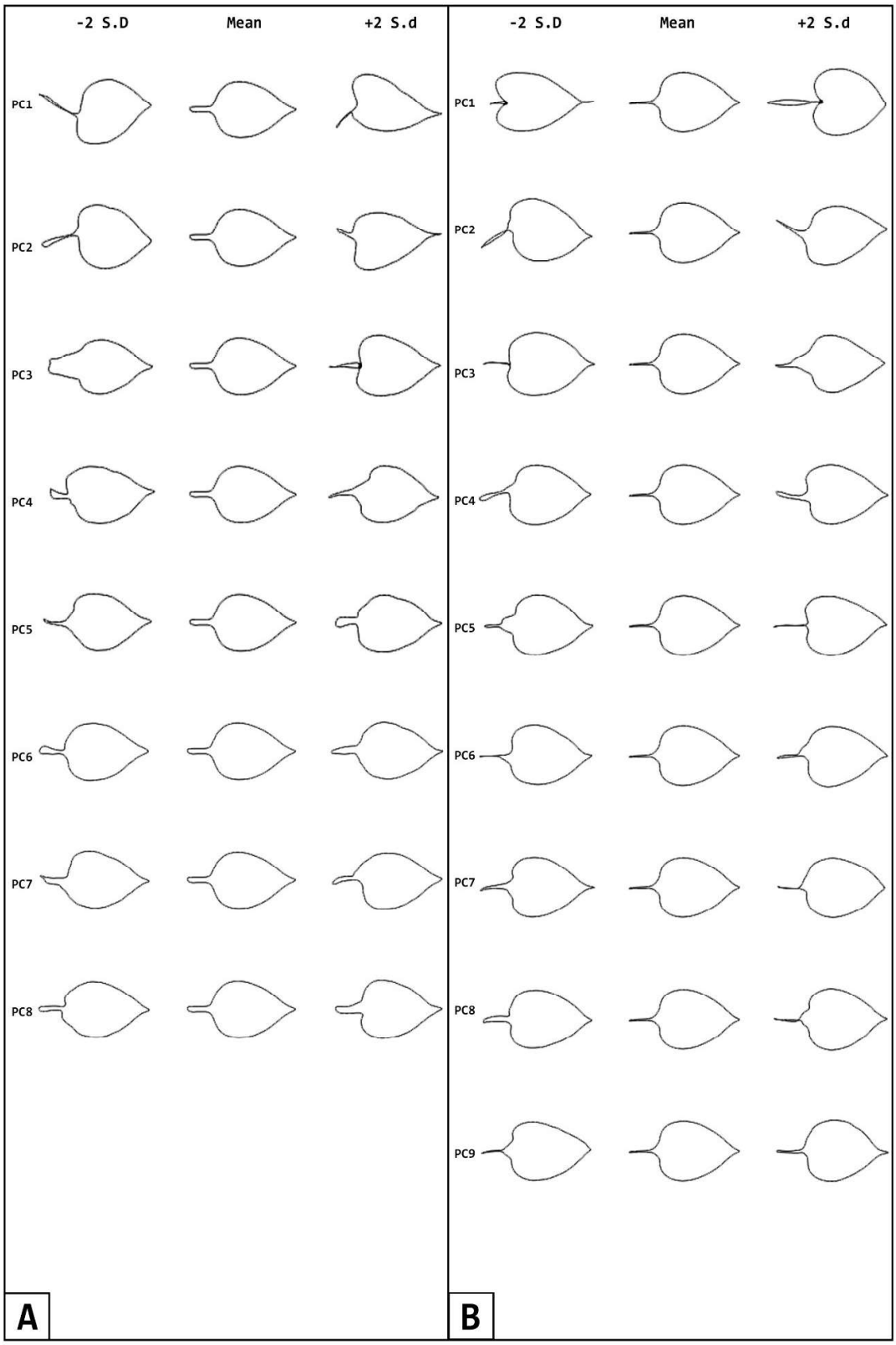

Plate 50 - Processed image showing leaf shape variation (**A**- *J. paniculata*; **B**- *J. pentanthos*)

4.8. Genus: *Merremia* Dennst. ex Endl.

Merremia Dennst. ex Endl., Gen. Pl. Suppl. 1: 1403. 1841. nom. cons., sensu stricto.

Type: *Merremia hederacea* (Burm. f.) Hallier f

4.8.1. General Description of genus *Merremia*:

Prostrate or twining herbs; leaves simple, entire or shallowly three-lobed or three angled, often variable in shape; flowers small, corolla campanulate, often gibbous on one side, glabrous outside, drying with dark veins in the mid-petaline bands; anthers longitudinally dehiscing with the apex slightly curving or spirally dehiscing; ovary glabrous (in some species pubescent); fruit a chartaceous four valved capsule, calyx not accrescent in fruit, exocarp not delaminating; seeds trigonous, pollen tricolpate, glabrous or puberulent. (Plate – 51A,B)

Table 60 - List of collected species of genus *Merremia*

Sr. No.	Scientific name
1	*Merremia emarginata* (Burm.f.) Hallier f.
2	*Merremia hederacea* (Burm.f.) Hallier f.

1. *Merremia emarginata* (Burm.f.) Hallier f., Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *M. emarginata* leaves resulted in seven effective PCs depicting 96.72 % cumulative variance. (Table 61). PC1 was the highest contributor towards the leaf shape changes with 50 % variance accounted for. It was depicted by variation in petiole shape and leaf blade shape. It also showed the developmental direction of petiole. Variation depicted by PC2 was mainly of petiole size and development of posterior lobes. PC3 was depicted by variation in leaf width and over all length-to-width ratio. PC4 and PC5 represented minor variation towards the leaf base developing ambiguous shape while PC6 and PC7 showed variation towards the leaf apex developing circular leaf apex. (Plate – 52A)

Table 61 - Eigen value, PCs and Variance of *M. emarginata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.02284	50.02	50.02
PC2	0.01248	27.33	77.34
PC3	0.00324	7.09	84.43
PC4	0.00194	4.25	88.69
PC5	0.00163	3.57	92.25
PC6	0.00125	2.74	94.99
PC7	0.00079	1.73	96.72

2. ***Merremia hederacea*** (Burm.f.) Hallier f., Bot. Jahrb. Syst. 18: 118 (1893)

Analysis:

Examination of M. hederacea leaves resulted in nine effective PCs, depicting 95.30 % cumulative variance. (Table 62). Variation depicted by PC1 was seen mainly on leaf base and leaf width. PC2 showed variation towards the leaf apex contributing towards acute apex. PC3 was depicted by variation in petiole shape and leaf length. PC4 was depicted by variation in length-to-width ration. Variation at the posterior lobes was depict by PC5 and PC6 was showed minor variation in overall leaf lamina shape. PC7, PC8 and PC9 were depicted by lower values and effects of these PCs were depicted by distortion towards the leaf base, posterior lobe development and petiole shape. (Plate – 52B)

Table 62 - Eigen value, PCs and Variance of M. hederacea

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00753	37.10	37.10
PC2	0.00488	24.06	61.16
PC3	0.00309	15.23	76.40
PC4	0.00143	7.03	83.42
PC5	0.00084	4.16	87.59
PC6	0.00060	2.95	90.54
PC7	0.00040	1.96	92.49
PC8	0.00036	1.76	94.26
PC9	0.00021	1.04	95.30

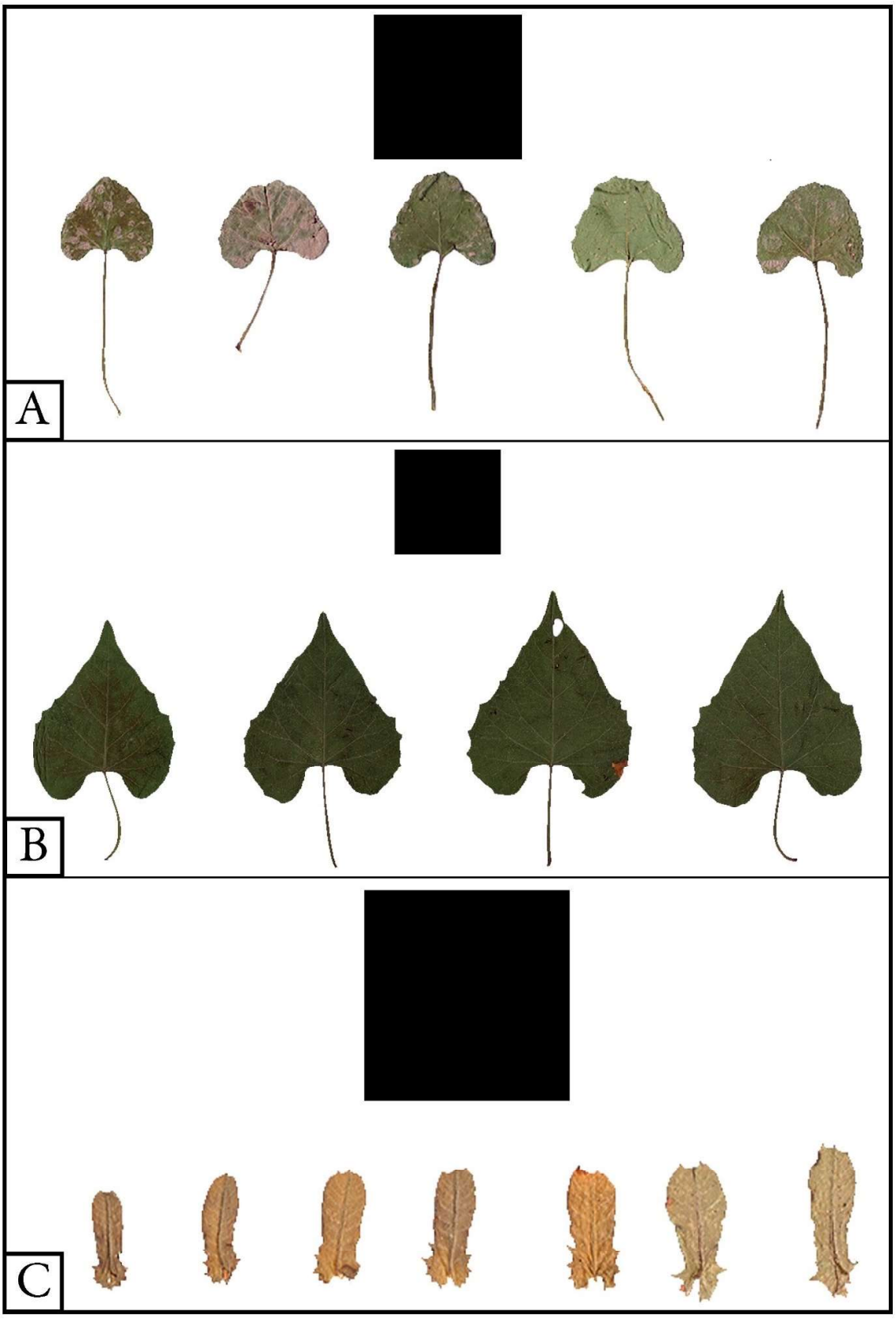

Plate 51 - Leaf samples of *Merremia* and *Xenostegia* (**A**- *M. emarginata*; **B**- *M. hederacea*; **C**- *X. tridentata*)
(Scale – 3 X 3 cm)

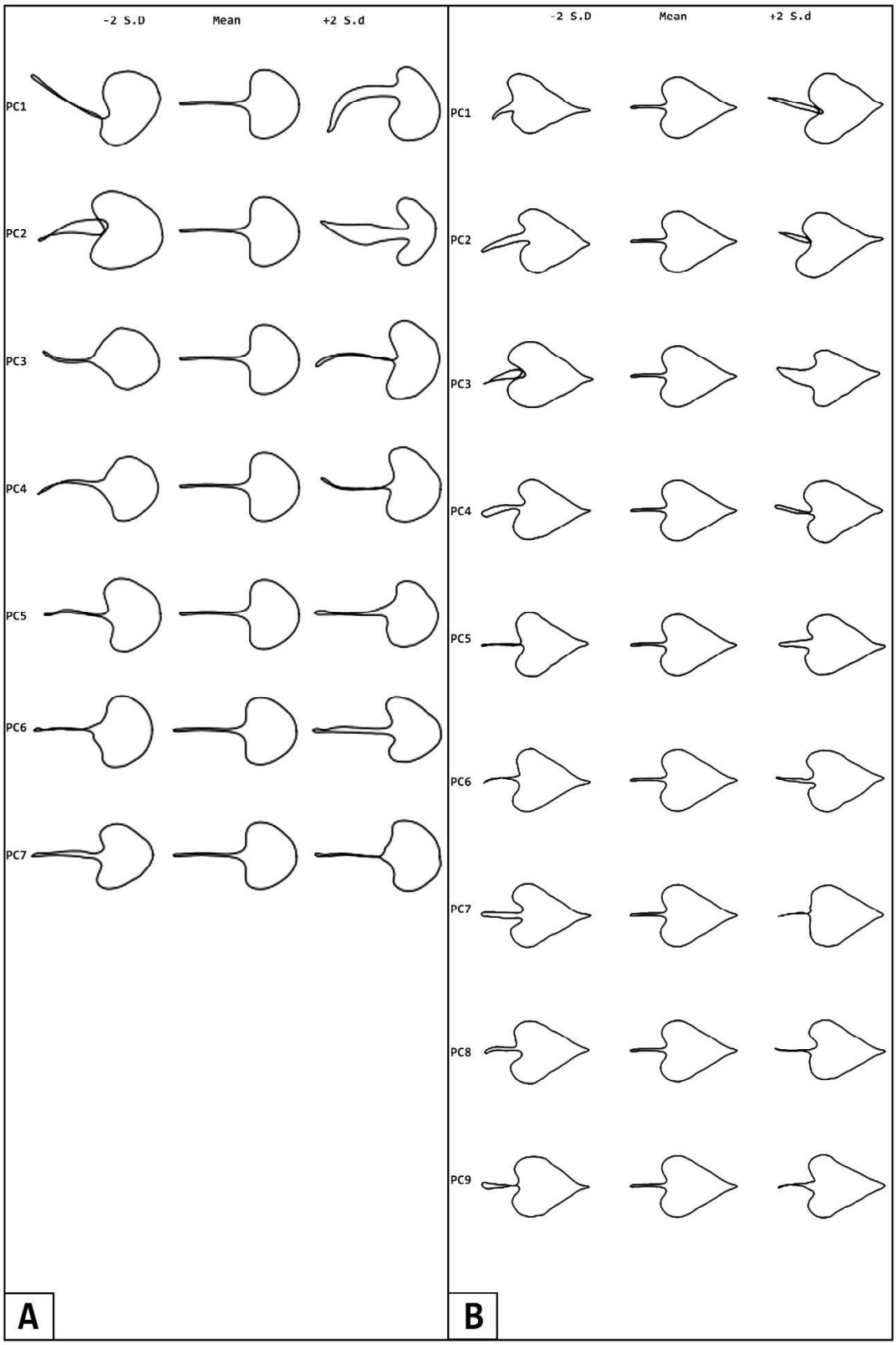

Plate 52 - Processed image showing leaf shape variation (**A**- *M. emarginata*; **B**- *M. hederacea*)

4.9. Genus: *Operculina* Silva Manso.

Operculina Silva Manso, Enum. Subst. Braz.: 16, 49. 1836.

Type: *Operculina turpethum* (L.) Silva Manso.

4.9.1. General Description of genus *Operculina*:

Herbaceous twiners or lianas. Stems twining or prostrate; axial parts (stems, petioles, peduncles, pedicels) often winged, angled, or ribbed. Indumentum of 3 distinct types: simple unicellular trichomes; sessile glandular trichomes; elongate glandular trichomes. (Table 63). Leaves simple, entire, pinnately 5- to 9-lobed or palmately parted into 5 or 7 entire lobes, petioles stout or slender, terete or sulcate adaxially, base often swollen. Inflorescences cymose, or reduced to a solitary flower, or the cymes aggregated into panicles with up to 12 flowers; peduncles shorter than subtending petiole and stout, or elongate, slender, longer than subtending petiole; bracts small, deciduous, or foliose and persistent. Flowers usually medium to large, diurna, odorless. Calyx ventricose (pear-shaped), broader at base, tapering upward and appressed to corolla, persistent and accrescent in fruit, cupping the mature fruit or the sepals may reflex away and downward, margins often eroding. Corolla campanulate or broadly funnelform, midpetaline bands on the exterior of the corolla pilose, sericeous, or shaggy with long hirsute hairs, sometimes only sparsely so (*O. turpethum, O. ventricosa*), sometimes dotted with tiny golden glands, limb erect or spreading, entire or ruffled, rarely lobed. Stamens included, filaments basally flattened, broadly dnate to corolla tube for 1/4 to 1/2 their length, free and filamentous above insertion point, glabrous except for trichomes on and around insertion point, anthers spirally coiled at dehiscence. Pollen 3-zonocolpate to sometimes 6-pantocolpate, micro-echinate to microgranulate. Pistil included; ovary superior, 2-locular, each locule 2-ovulate, glabrous or hirsute; style terminal, filamentous, glabrous or basally hirsute or rarely whitish tomentose almost to middle (*O. ventricosa*); stigmas 2, terminal, deeply lobed, lobes elongate, densely covered in filiform or bulbous papillae. Fruit an operculate capsule: apical fruit wall (operculum, exocarp) fleshy at first, drying leathery and dehiscing circumscissily. Seeds 4 or fewer, ovoid trigonous and carinate or subglobose, dull, blackish or brown, completely glabrous or with trichomes along the angles only (Plate – 53)

Table 63 - List of Collected species of Genus *Operculina*

Sr. No.	Scientific Name
1	*Operculina turpethum* (L.) Silva Manso.
2	*Operculina ventricosa* (Bertero) Peter

1. ***Operculina turpethum*** (L.) Silva Manso, Enum. Subst. Braz.: 16 (1836)

Analysis:

Examination of *O. turpethum* leaves resulted in nine effective PCs depicting 95.90 % cumulative variance. (Table 64). PC1 was the highest contributor towards the shape changes. Most of the variation was depicted by first three PCs. Effects depicted by PC1 was mainly on leaf base and leaf apex development when positive or negative affecting overall leaf shape. PC2 and PC3 mainly effected leaf blade shape developing different leaf shape. It also effects development of petiole to some extent. PC4 and PC5 showed variation in length-to-width ratio. Rest of the four PCs showed minor variations in leaf shape i.e., petiole shape, leaf blade margin etc. (Plate – 54B)

Table 64 - Eigen value, PCs and Variance of *O. turpethum*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00810	47.05	47.05
PC2	0.00335	19.44	66.50
PC3	0.00287	16.66	83.15
PC4	0.00074	4.32	87.47
PC5	0.00047	2.72	90.20
PC6	0.00030	1.75	91.95
PC7	0.00027	1.57	93.51
PC8	0.00025	1.43	94.94
PC9	0.00016	0.96	95.90

2. ***Operculina ventricosa*** (Bertero) Peter, H.G.A.Engler & K.A.E.Prantl, Nat. Pflanzenfam. 4(3a): 32 (1891)

   = *Operculina tansaensis* Santapau & Patel, Trans. Bose Res. Inst. Calcutta 22: 33 (1958)

Analysis:

Investigation of *O. ventricose* leaves resulted in seven effective PCs depicting 97.93 % cumulative variance. (Table 65). Major variation was depicted by first three PCs. Effects of PC1 was

the major shape changes on the leaf showing variation in leaf blade shape, length to width ratio and leaf base development. PC2 showed variation along the leaf base and petiole development while PC3 depicted variation along the leaf apex and leaf blade. PC4 depicted variation in leaf width and petiole development. Rest of the four PCs showed minor and ambiguous variation of leaf shape. (Plate – 54A)

Table 65 - Eigen value, PCs and Variance of *O. ventricosa*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00753	49.32	49.32
PC2	0.00346	22.65	71.97
PC3	0.00191	12.52	84.49
PC4	0.00117	7.69	92.18
PC5	0.00038	2.47	94.66
PC6	0.00034	2.20	96.86
PC7	0.00016	1.08	97.93

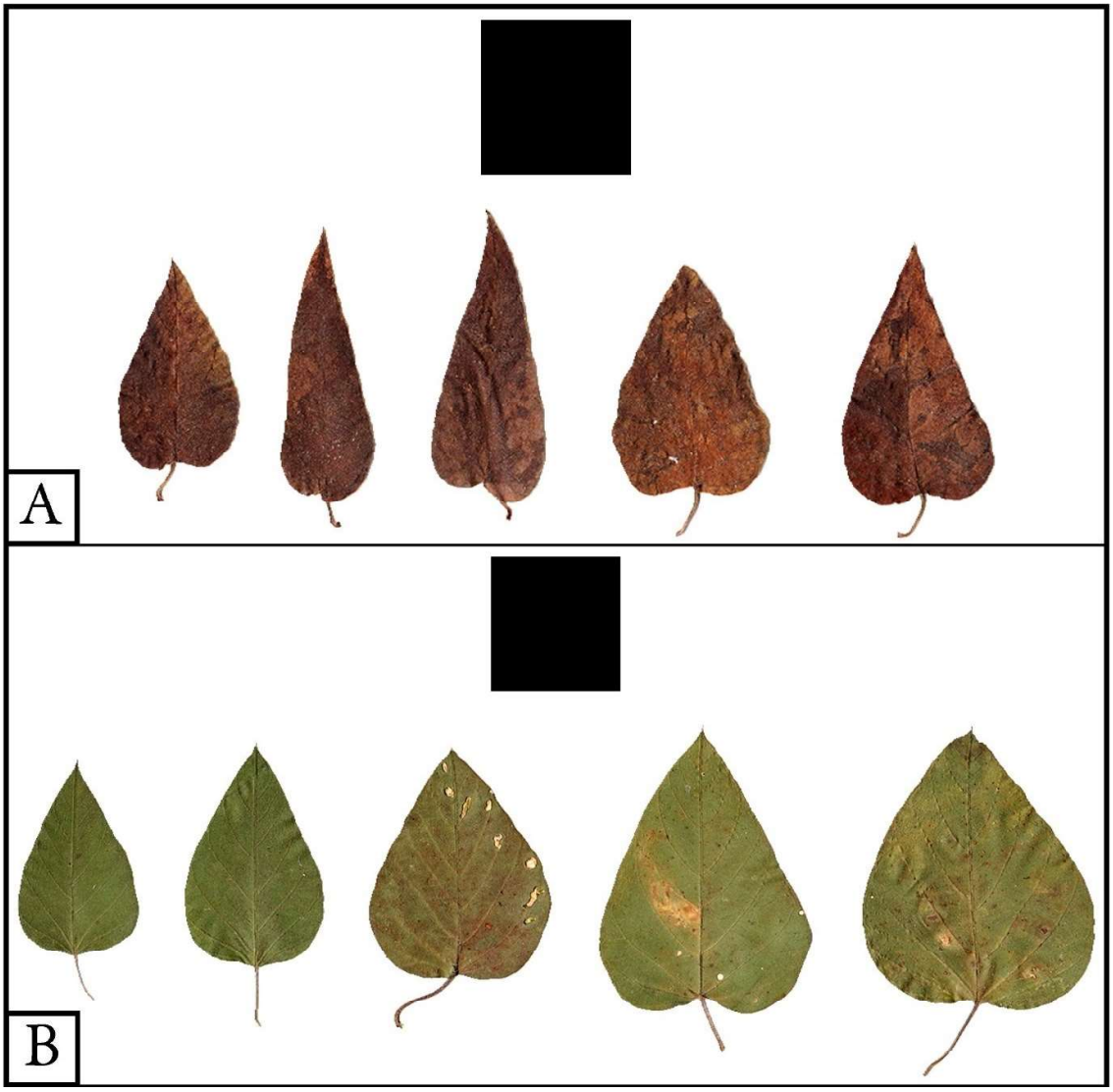

Plate 53 - Leaf samples of Ipomoea species (**A**- *O. ventricosa*; **B**- *O. turpethum*) (Scale – 3 X 3 cm)

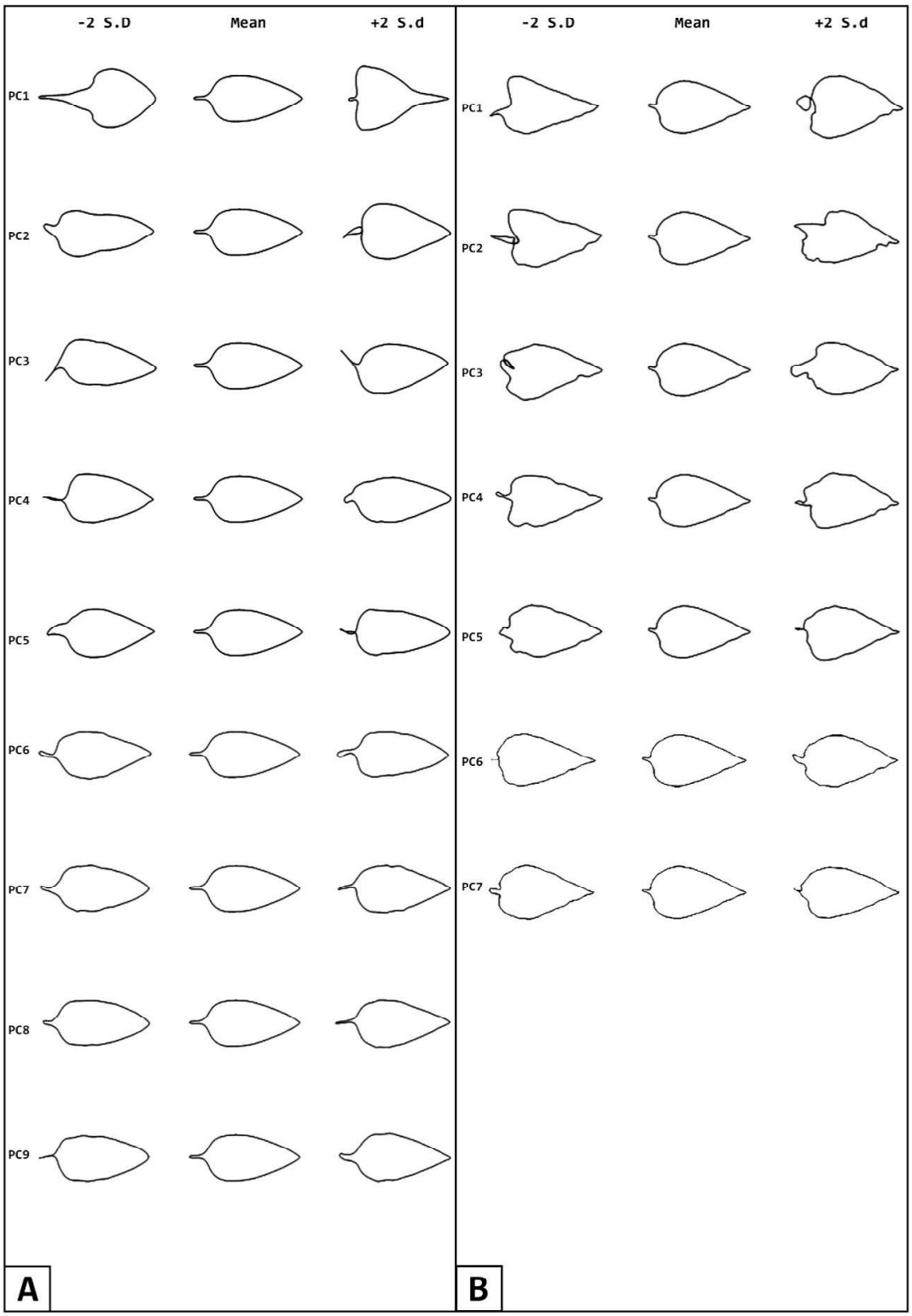

Plate 54 - Processed image showing leaf shape variation (**A**- *O. ventricosa*; **B**- *O. turpethum*)

4.10. Genus: *Rivea* Choicy

Rivea Choisy, Mém. Soc. Phys. Genève 6: 407 (1833 publ. 1834) [Conv. Or.: 25]

Type: *Rivea hypocrateriformis* (Desr.) Choisy, Mém. Soc. Phys. Genève 6: 408

4.10.1. General Description of genus *Rivea*:

Climbing shrubs. Leaves cordate, usually silky beneath (at least when young); petiole long. (Table 66). Peduncles axillary, 1-3 (sometimes 7) -flowered; bracts 2-3, narrow. Sepals 5, ovate or lanceolate oblong, subequal. Corolla large, hypocrateriform; tube narrow, cylindric; lobes of the limb broad, rounded, plicate. Disk annular. Stamens 5 included, anthers narrow, oblong, not finally twisting. Ovary 4-celled; ovules 4: style filiform; stigmas 2, linear-oblong. Pruit a subglobose dry woody berry, or an irregularly opening capsule often 1-celled from the absorption of the septa. Seeds 1-4, glabrous, surrounded by mealy pulp. (Plate – 55A)

Table 66 - collected species of genus *Rivea*

Sr. No.	Scientific Name
1	*Rivea hypocrateriformis* (Desr.) Choisy

1. ***Rivea hypocrateriformis*** (Desr.) Choisy, Mém. Soc. Phys. Genève 6: 408

Analysis:

Examination of R. hypocrateriformis leaves resulted in nine effective PCs depicting 96.18 % cumulative variance. (Table 67). PC1 was the highest contributor towards the shape variation. Effects of PC1 was mainly on the development of leaf apex and petiole. It also effected length to width ratio developing broader leaves. Effects of PC2 and PC3 were mainly on leaf base development contributing to a cordate leaf base. PC4 and PC5 depicted the variation in right proximal part of leaf and development of right lobe of the leaf. Effects of PC6 and PC7 were almost similar depicting variation in leaf tip development. PC8 and PC9 showed minor variation towards the leaf base and leaf margin. (Plate – 56A)

Table 67 - Eigen values and PC analysis of *R. hypocrateriformis*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.01391	42.80	42.80
PC2	0.00626	19.27	62.07
PC3	0.00460	14.15	76.22
PC4	0.00254	7.81	84.03
PC5	0.00148	4.55	88.58
PC6	0.00075	2.30	90.88
PC7	0.00071	2.17	93.05
PC8	0.00058	1.79	94.84
PC9	0.00044	1.34	96.18

4.11. Genus: *Stictocardia* Hallier

Stictocardia Hallier, f. Bot. Jahrb. Syst. 18: 159 (1893)

Type: *Stictocardia tiliifolia* (Desr.) Hallier f.

4.11.1. General Description of genus Stictocardia:

Annual to woody perennial with trailing and twining stems. Cotyledons bilobed, with the lobes ovate oblong, diverging and greatly exceeding the base. (Table 68). Leaves ovate or orbicular, mainly cordate at the base, the lower surface with many minute glands. Inflorescence axillary, cymose, 1-many flowered; bracts deciduous. Sepals 5, subequal, elliptic or orbicular, obtuse to emarginate, sub-coriaceous, often with thinner margin, much accrescent in fruit. Corolla red or purple, large, funnel-shaped, the mid-petaline bands often somewhat pilose outside or at the distal end and with minute glands like the leaves. Stamens and style included. Filaments inserted near the corolla base; pollen grains spheroidal and polypantoporate with a spinulose surface. Ovary glabrous, 4-celled, each cell with 1 ovule; style 1, stigma bi-globular. Fruit much enclosed by the much-enlarged calyx, globular, dissepiments with 2 transverse wings at the surface of the fruit, dehiscing irregularly between the wings exposing 4 pubescent seeds. (Plate – 55B)

Table 68 - Collected species of genus *Stictocardia*

Sr. No.	Scientific Name
1	*Stictocardia tiliifolia* (Desr.) Hallier f.

1. ***Stictocardia tiliifolia*** (Desr.) Hallier f.

Analysis:

Examination of *S. tiliifolia* leaves resulted in 10 effective PCs showing 96.52 % cumulative variance. PC1 depicted the highest amount of variation leading cordate leaf shape. It effected the development of leaf base and posterior lobes. PC2 contributed towards the variation of the right proximal part of leaf blade effecting overall leaf shape. Effects of PC3 and PC4 were mainly seen on leaf base development when positive or negative it contributed to the development of posterior lobes and giving leaf a cordate base. PC5 and PC6 mainly affected the development of distal part of the leaf and leaf apex. Effects depicted by PC7, PC8, PC9 and PC10 have similar values and showed variation on leaf base and along the margin (Plate – 56B).

Table 69 - Eigen values and PC analysis of *S. tilifolia*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00943	44.32	44.32
PC2	0.00427	20.06	64.38
PC3	0.00290	13.62	78.01
PC4	0.00169	7.94	85.95
PC5	0.00065	3.07	89.02
PC6	0.00053	2.47	91.49
PC7	0.00036	1.68	93.17
PC8	0.00030	1.39	94.57
PC9	0.00022	1.04	95.61
PC10	0.00019	0.90	96.52

4.12. Genus: *Turbina* Raf.

Turbina Rafinesque, F1. Tellur. 4: 81. 1838.

= ***Legendrea*** Webb and Berthelot, Hist. Nat. Iles Canar. 3(2): 26. 1844.

Type: *Turbina corymbosa* (L.) Raf.

4.12.1. General description of genus *Turbina*:

Lianas or erect shrubs; roots enlarged and fusiform in some species; sap milky in some species; older stems woody, twining, scrambling or prostrate, rarely erect, the tips herbaceous and usually twining, silvery pubescent or glabrous. (Table 70). Leaves petiolate or subsessile, the blade simple, cordiform or ovate [or narrowly oblong or linear], with 4-8 pairs of secondary veins, the veins often prominent on the under surface of the blade. Inflorescence cymose or thyrsiform or flowers solitary, axillary or terminal on lateral branches, the bracts 2, scale-like or foliaceous or subulate or linear, often reddish colored and sometimes persistent in fruit. Flowers showy, sometimes fragrant; sepals 5, quincuncial, equal or unequal, appressed to the corolla at anthesis, accrescent, scarious and + spreading in fruit; corolla campanulate, funnelform or salverform, greenish-white, pink, lavender or red, sericeous on the interplicae or with only a minute tuft of trichomes at the tip of each petal and otherwise glabrous; stamens 5, the filaments dilated basally and adnate to the corolla tube, free and filamentous above, with a tangle of glandular hairs around the point where each filament departs from the corolla, glabrous above and below that area; pollen spheroidal, spinulose, pantoporate; disc annular, ovary conical to ovoid, glabrous or silvery sericeous, bilocular, ovules 4, the style terminal, simple, glabrous [or silvery sericeous], the base often indurated and persistent in fruit, stigmas 2, globose. Fruit indehiscent, with a coriaceous or subligneous pericarp, usually 1-seeded, cap- ped by the style base, subtended by the scarious, accrescent calyx. Seed ovoid or ellipsoid, puberulent with erect trichomes, rarely glabrous. (Plate – 55C)

Table 70 - Collected species of Genus *Turbina*

Sr. No.	Scientific name
1	*Turbina corymbosa* (L.) Raf.

1. *Turbina corymbosa* (L.) Raf.

Analysis:

Examination of *T. corymbosa* leaves resulted in nine effective PCs depicting 97.29 % cumulative variance. (Table 71). Most of the variation in leaf shape was depicted by PC1. Effects of PC1 was seen in development of leaf base and length to width ratio. PC2 contributed towards the leaf width variation developing broad leaf base. Effects of PC3 were mainly on leaf apex and leaf base development contributing towards the ovoid leaf shape. PC4 depicted variation towards the right part of leaf lamina. PC5 and PC6 showed variation along the leaf apex and base. The rest of PCs (PC7, 8 and 9) showed minor variations along the margin and petiole development. (Plate – 20B)

Table 71 - Eigen values and PC analysis of *T. corymbosa*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00619	42.35	42.35
PC2	0.00448	30.69	73.04
PC3	0.00136	9.29	82.34
PC4	0.00071	4.86	87.20
PC5	0.00045	3.09	90.29
PC6	0.00035	2.40	92.69
PC7	0.00028	1.91	94.60
PC8	0.00023	1.55	96.15
PC9	0.00017	1.14	97.29

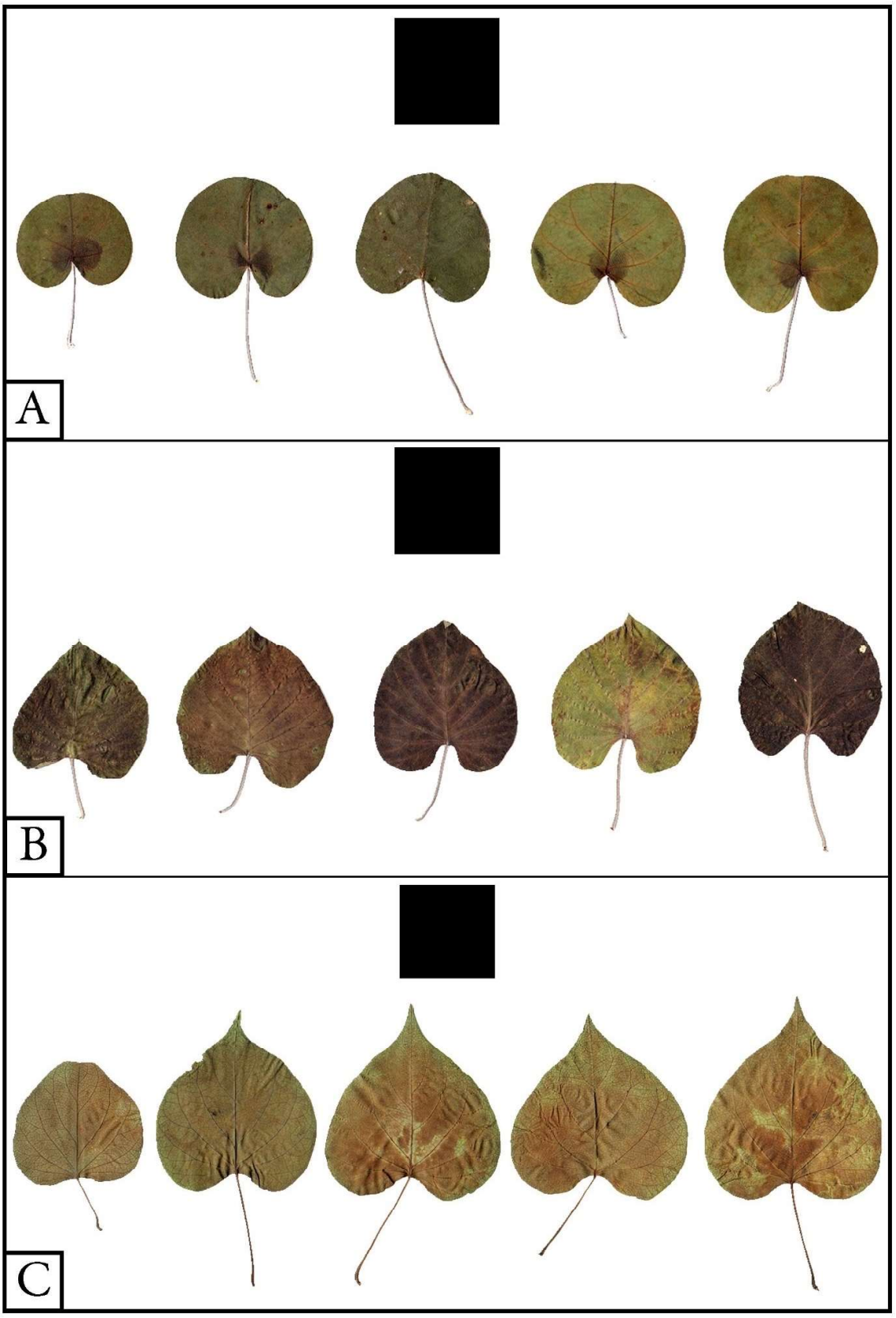

Plate 55 - Leaf sample of Rivea, Stictocardia and Turbina (**A**- *R. hypocrateriformis*; **B**- *S. tilifolia*; **C**- *T. corymbosa*) (Scale - 3 X 3 cm)

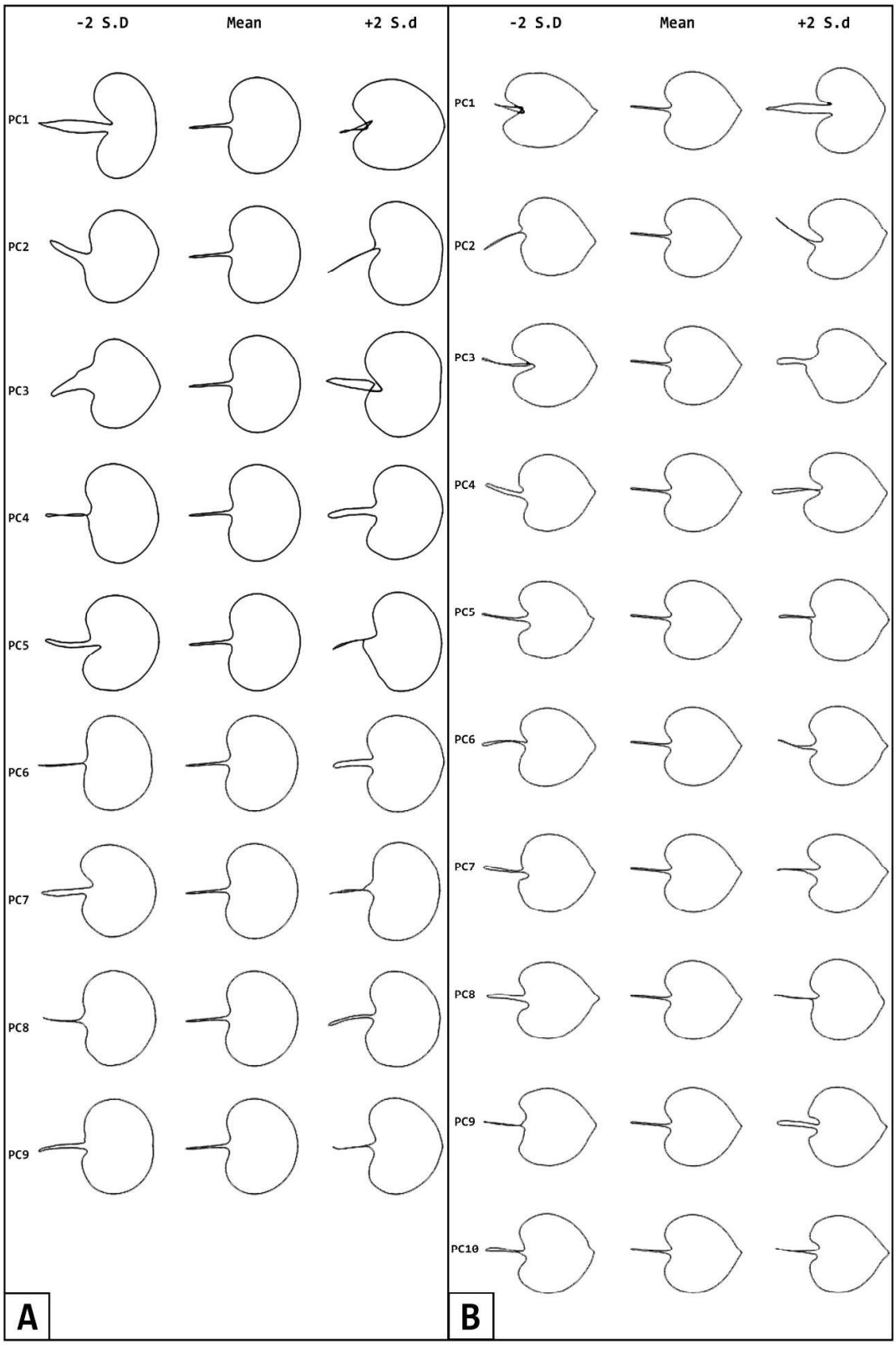

Plate 56 - Processed image showing leaf shape variation (**A**- *R. hypocrateriformis*; **B**- *S. tilifolia*)

4.13. Genus: *Xenostegia* D. F. Austin & Staples

Xenostegia D. F. Austin & Staples, Brittonia 32: 533 (1980 publ. 1981)

Type: ***Xenostegia tridentata*** (L.) D. F. Austin & Staples, Brittonia 32: 533 (1980 publ. 1981)

4.13.1. General Description of genus *Xenostegia*:

Slender twiners or prostrate herbs; stems angulate to narrowly winged; leaves simple, basally dentate or hastate to pinnately lobed; sepals long acuminate or emarginate and mucronate, entire, undulate or pinnately incised; corolla yellow to white, glabrous; anthers longitudinally dehiscing; pollen pantoporate; ovary densely pubescent (less often glabrous); fruit a four-valved chartaceous capsule; seeds completely glabrous. (Plate – 51C)

Table 72 - List of collected species of genus *Xenostegia*

Sr. No.	Scientific name
1	*Xenostagea tridentata* (L.) D.F. Austin & Staples

1. ***Xenostegia tridentata*** (L.) D. F. Austin & Staples, Brittonia 32: 533 (1980 publ. 1981)

   = *Merremia tridentata* (L.) Hallier f. in Bot. Jahrb. Syst. 16: 552 (1893)

Analysis:

Examination of *X. tridentata* leaves resulted in 10 effective PCs covering 82.06% cumulative variance. (Table 73). PC1 was the highest contributing component among all the analysed PCs. Effects of PC1 was seen on overall leaf shape, development of leaf base and leaf apex. PC2 was depicted by development variation at the leaf base. PC3 showed variation along the margin and PC4 was depicted by development variation at the leaf apex. PC5 and PC6 were depicted by the development of a dentate shape at leaf base. Variation depicted by PC7 and PC8 was seen mainly on leaf apex and overall leaf width changing the length-to-width ratio. Last 2 PCs (PC9 and PC10) represented minor variation at the leaf apex and around the margin of leaf blade. (Plate – 17A)

Table 73 - Eigen values and PC analysis of *X. tridentata*

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	0.00298	27.69	27.69
PC2	0.00140	13.03	40.72
PC3	0.00102	9.48	50.20
PC4	0.00087	8.08	58.28
PC5	0.00064	5.98	64.25
PC6	0.00057	5.31	69.56
PC7	0.00042	3.90	73.46
PC8	0.00038	3.53	76.99
PC9	0.00029	2.67	79.66
PC10	0.00026	2.40	82.06