# 4. MORPHOLOGICAL VARIATIONS OF *S. obtusifolia* PROVENANCES

*S. obtusifolia* (L.) Irwin and Barneby, a wild weed of Fabaceae, is an annual shrubs or sub-shrubs prevalent in the Indian subcontinent. The plant is substantially rich having a wide galore of medicinal properties as well as nutraceuticals (Mao et al., 2017). Variations between the natural populations of a species growing in a varied ecogeographical regions generally exhibit intraspecific diversity with respect to a number of traits, expressing phenotypic plasticity for subtle genetic variation and represent diversity among provenances. Variations in different morphometric characters may be due to the adaptations resulting from the genetic differences caused by diverse environmental conditions the provenances are exposed to (Ginwal et al., 2005; Ghosh and Singh, 2011). Different soil types, provenances are growing on, might also be a cause of it (Elmagboul et al., 2014). Takuathung et al., (2012) advocated for selecting the top provenance based on the productivity of the species. Recently, Mao et al., (2018) reported morphometric analysis of several species of this genus. Several other authors also have their views regarding the morphological aspects of different species (Holman and Playford, 2000; Soladoye et al., 2010b; Takuathung et al., 2012; Rahman et al., 2013).

This study analyses several morphometric traits for identifying intraspecific variations among twenty different provenances of the species. Provenances were grown together in a field under with a provision of uniform environmental conditions to eliminate the chances of variation due to environmental factors. Twenty-two quantitative characters of the stem, root, leaf, flower, pod and seed were dealt with for interpreting intraspecific variations in the species. Since, either or both of the ecological variations and genetic differences may affect the productivity of active biomolecules of a species, any

variation in morphometric traits may also serve as a good index or marker for tracing the right provenance with maximum yield.

## 4.1 MATERIALS AND METHODS

The plant materials used for studying morphological variations are same as that taken for studying phenological variations. The collection of germplasm, seed germination, raising of plants, scarification and sowing of seeds, study location, experimental design and layout, are described in Chapter 3. The Accession numbers of the germplasms of *S. obtusifolia* from different provenances are given in Table 3.1 of Chapter 3. All the morphometric data were recorded when the plants attained maturity and used for analysis.

### 4.1.1 Morphometric Analysis

The plant species from all the provenances are almost erect, bushy with solid, obtuse angled to cylindrical stem, mostly glabrous, sometimes fine hairs are present in the upper tender portions, woody basal part (Figure 4.1). Root system is deep seated tap root with secondary and tertiary branches (Figure 4.2). Leaves alternate and paripinnately compound with 3 pairs of obovate and somewhat oblong leaflets. Leaf bears 2 stipules at the base of each petiole. Trichomes present on adaxial surface of the leaflets, rachis, petiole, and the abaxial surface of leaflets are glabrous (Figure 4.3). The upper part of petiole is grooved and extended till the tip of rachis. Base of the leaflets is asymmetrical, wedgy, rounded, oval or obovate at the top, with a notch at tip of the mid vein, margin ciliated. A minute spine like stipel is present at the juncture point of the first two leaflets from the base.

Flowers are in pairs or solitary at the axils of leaf with bracts. Flower borne on pedicels consists of 5 free, keel shaped sepals, light green colour at maturity, 5 petals, free, whitish yellow while in bud, turn bright yellow on maturity with trichomes on both petals and sepals (Figure 4.4). Petals are asymmetrical, papilionaceous, uppermost largest petal is vexillum, two lateral petals winglike alae and the anterior pair of united petals are keel. Both the petals and sepals showed quincuncial aestivation.

**Figure 4.1** Matured *S. obtusifolia*


**Figure 4.2** Root of *S. obtusifolia*


**Figure 4.3** Leaf of *S. obtusifolia*


**Figure 4.4** Flower of *S. obtusifolia*


**Figure 4.5** Pods of *S. obtusifolia*

The flowers of *S. obtusifolia* are asymmetrical and slightly rotated on the axis. Hairs are observed both in stamens and carpel. The heterantherous flowers of *S. obtusifolia* have 10 basifixed stamens of which 3 are staminodes and the rest 7 are fertile. Among the 7 fertile stamens the larger 3 are abaxial stamens and there are a 4 set of stamen of medium height, all of them are beaked with poricidal anthers.

The gynoecium is somewhat curved with numerous ovules. The tip of the stigma is oblique. The pod is long sickle shaped, deep green when young while become deep brown when ripe ending in a tapering beak more or less cylindrical bearing rhombohedral seeds kept one in each groove in a series framed inside the pod (Figure 4.5). The seeds are shiny brown with a very hard seed coat with narrow areoles.

There exists several characteristics for studying the morphological variations (Holman and Playford, 2000; Jeruto et al., 2017). The quantitative characteristics related to leaf, flower, pod and seed that are readily observable were considered for the morphometric study. Characters that were less important and unsuitable for rapid and accurate scoring were discarded. In this study, twenty-two major morphological characteristics were identified to study the morphological variations among the *S. obtusifolia* samples collected from twenty provenances. The list of morphological characteristics, their units and abbreviations are presented in Table 4.1. These abbreviations are used only for this chapter.

**Table 4.1** Abbreviation used in the analysis of morphological characteristics of S. *obtusifolia*

| Characteristics | Unit | Abbreviation |
|---|---|---|
| Plant Height | cm | PLH |
| Root Length | cm | RTL |
| Number of Branches | --- | NBR |
| Inter-node Length | mm | INL |
| Girth | mm | GRT |
| Leaf Length | mm | LFL |
| Leaf Width | mm | LFW |
| Rachis Length | mm | RCL |
| Stipule Length | mm | STL |
| Stipel Length | mm | SPL |
| Bract Length | mm | BRL |
| Pedicel Length | mm | PCL |
| Sepal Length | mm | SLL |
| Petal Length | mm | PTL |
| Anther Length | mm | ANL |
| Filament Length | mm | FML |
| Pistil Length | mm | PSL |
| Number of Flowers | --- | NFL |
| Number of Pods | --- | NPD |
| Pod Length | mm | PDL |
| Number of Seeds per Pod | --- | NSP |
| Seed Weight | gm/20 seeds | SDW |

All readings were recorded after the plants attained maturity for all the accessions. The collected data were keyed into a Microsoft excel spreadsheet. The calculation of mean

values and standard deviations of the recorded measurements were derived from the excel spreadsheet. The correlation matrix was also derived accordingly. Characteristics that contribute majorly to the delimitation of the taxa are identified through Principal component analysis (PCA). Finally, the cluster analysis (CA) was performed to determine how closely the *S. obtusifolia* samples from different provenances are related. Results related to both the PCA and CA were obtained using R (R Core Team 2012).

## 4.2 RESULTS AND DISCUSSIONS

Based on the recorded data, variations in the considered quantitative morphological characteristics of *S. obtusifolia* samples collected from twenty provenances are presented in Figure (4.6 - 4.27).

The mean and SD of morphological characteristics of *S. obtusifolia* species of 20 provenances are presented in Table (4.2 - 4.3). These values are obtained based on 10 observations for each characteristic corresponding to independent provenances. Major variations were observed for pod length (PDL), number of pods (NPD), plant height (PLH), and number of flowers (NFL). Root length (RTL), inter-node length (INL), and rachis length (RCL) have shown moderate variability. The rest of the morphological characteristics do not vary much among all the considered samples collected from different provenances.

The composite mean, maximum, minimum, and SD of the morphological characteristics of *S. obtusifolia* samples from twenty provenances are summarized in Table 4.4. The pattern of variations is similar to that of individual provenances. This has been evidenced greatly during the field work and data collection.

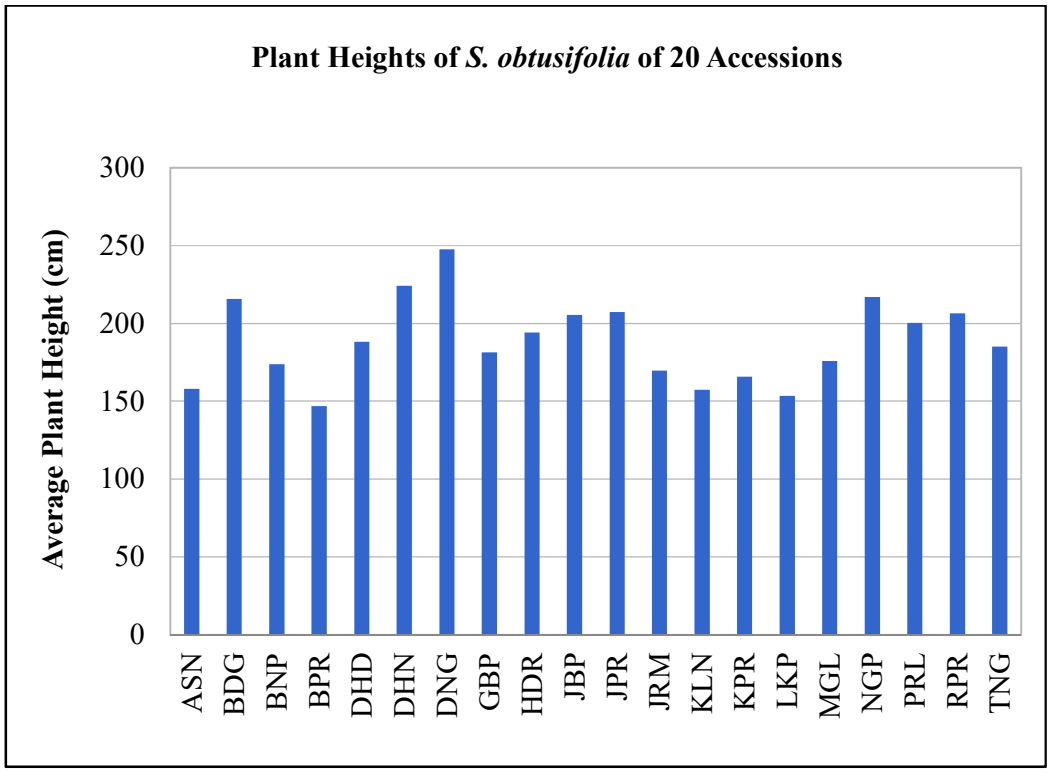


**Figure 4.6** Plant heights of *S. obtusifolia* of 20 accessions

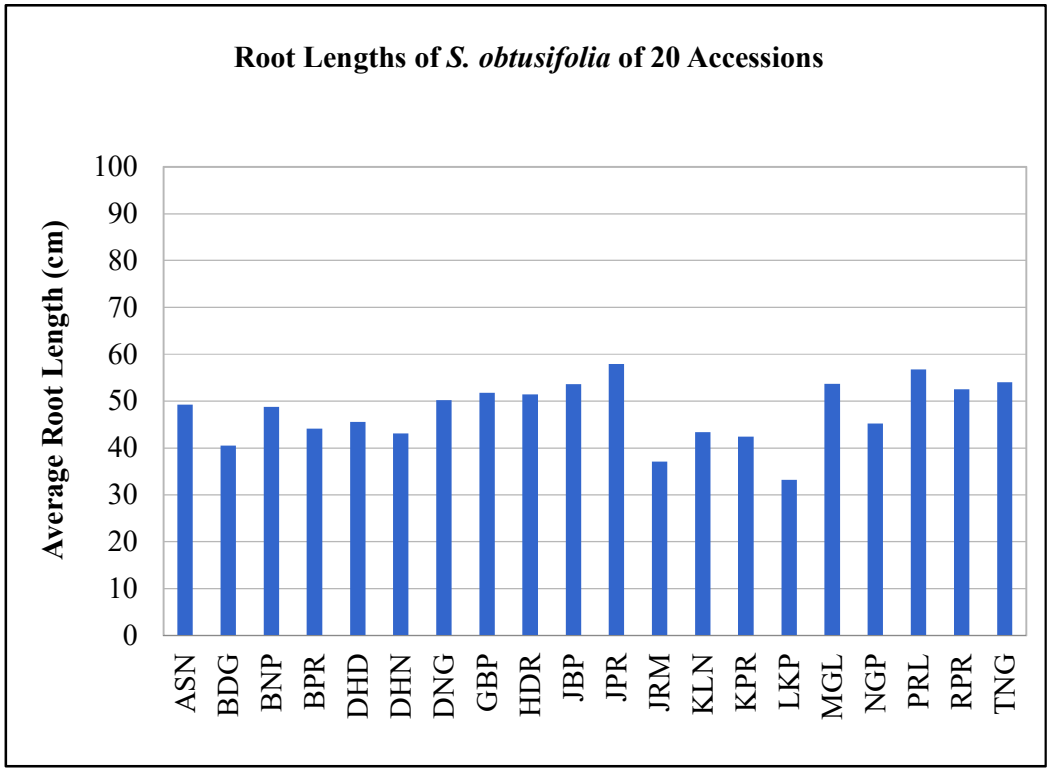


**Figure 4.7** Root lengths of *S. obtusifolia* of 20 accessions

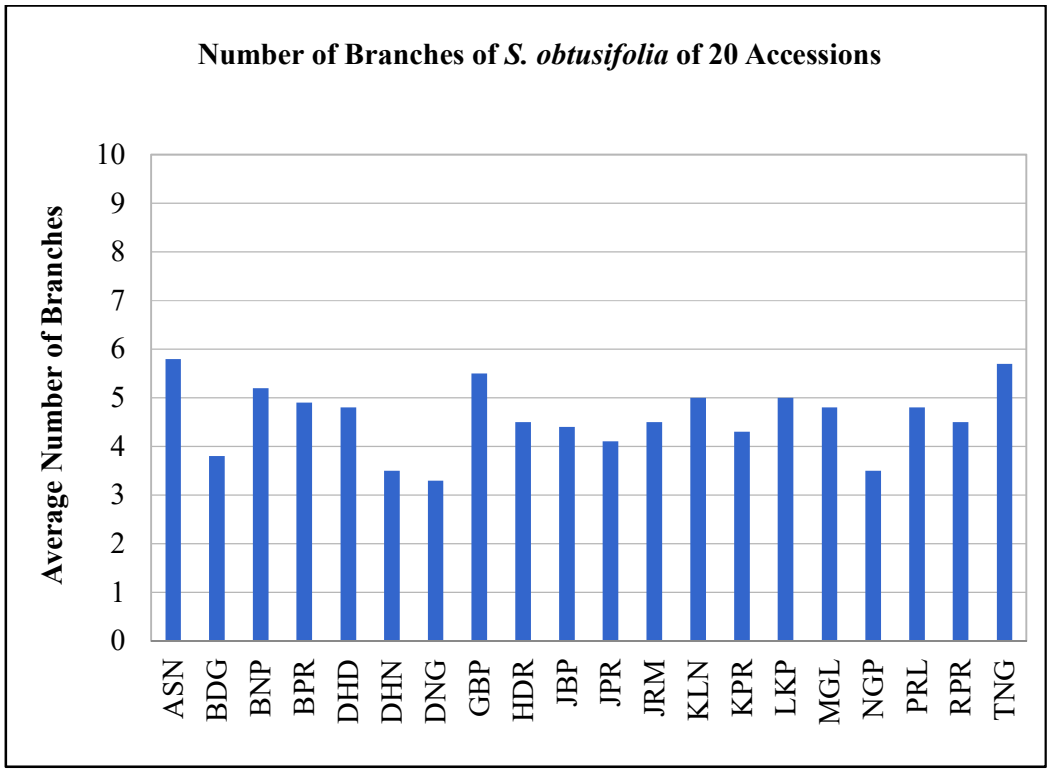


**Figure 4.8** Number of branches of *S. obtusifolia* of 20 accessions

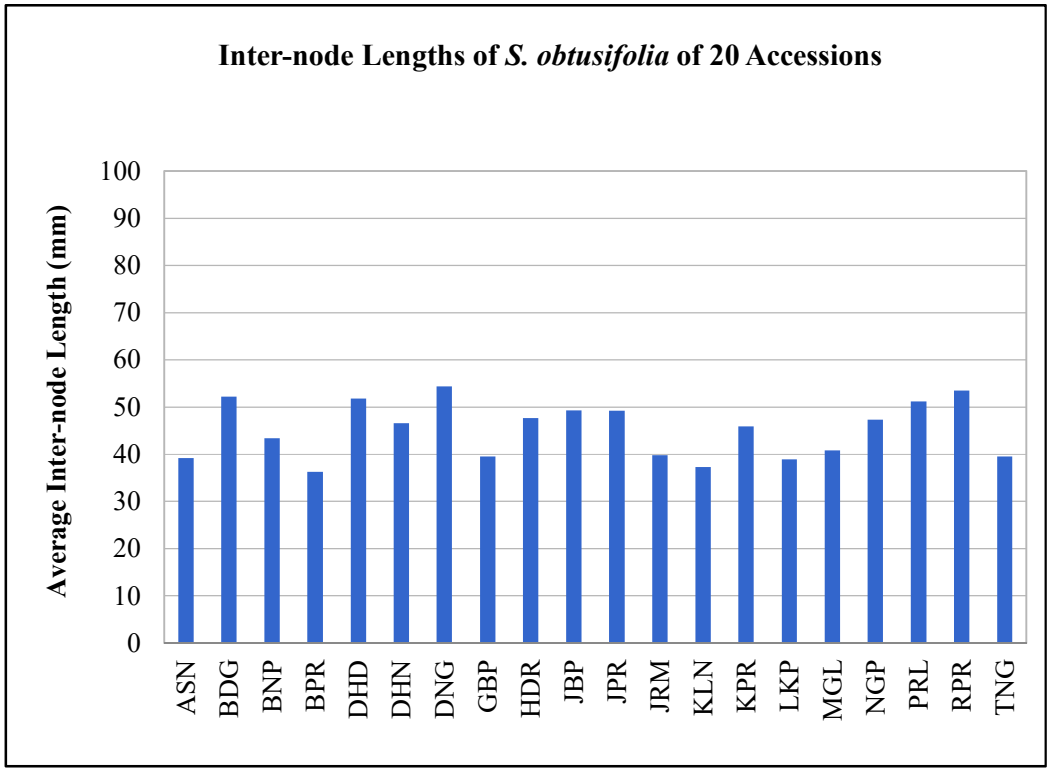


**Figure 4.9** Internode lengths of *S. obtusifolia* of 20 accessions

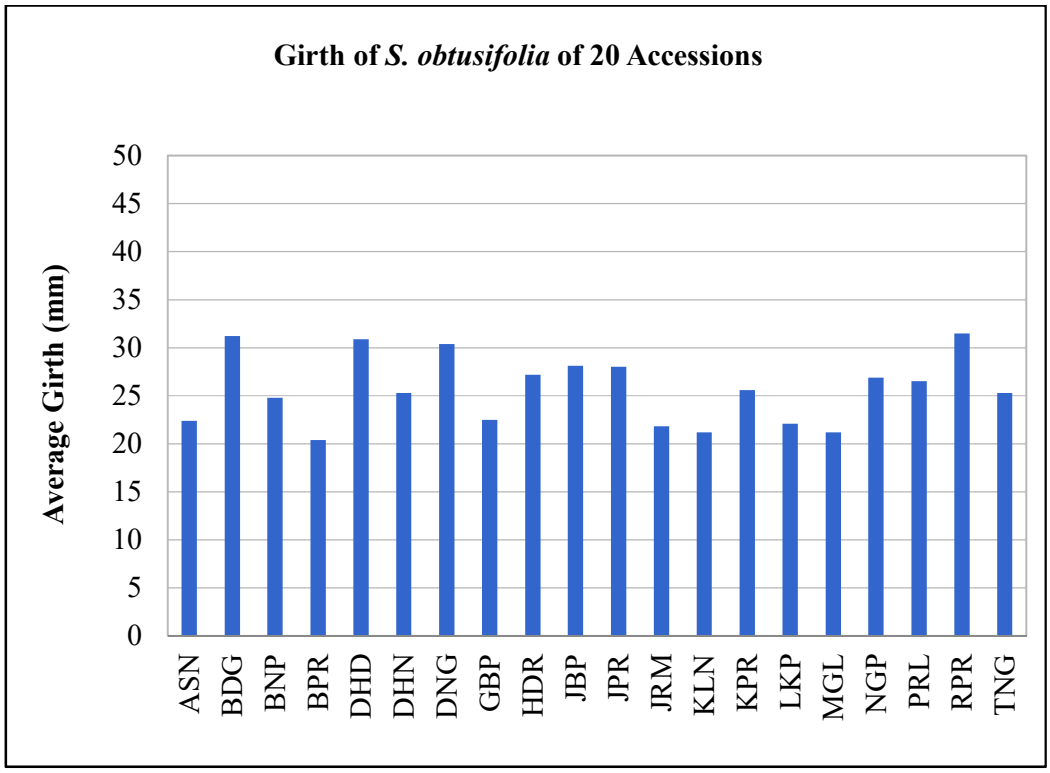


**Figure 4.10** Girth of *S. obtusifolia* of 20 accessions

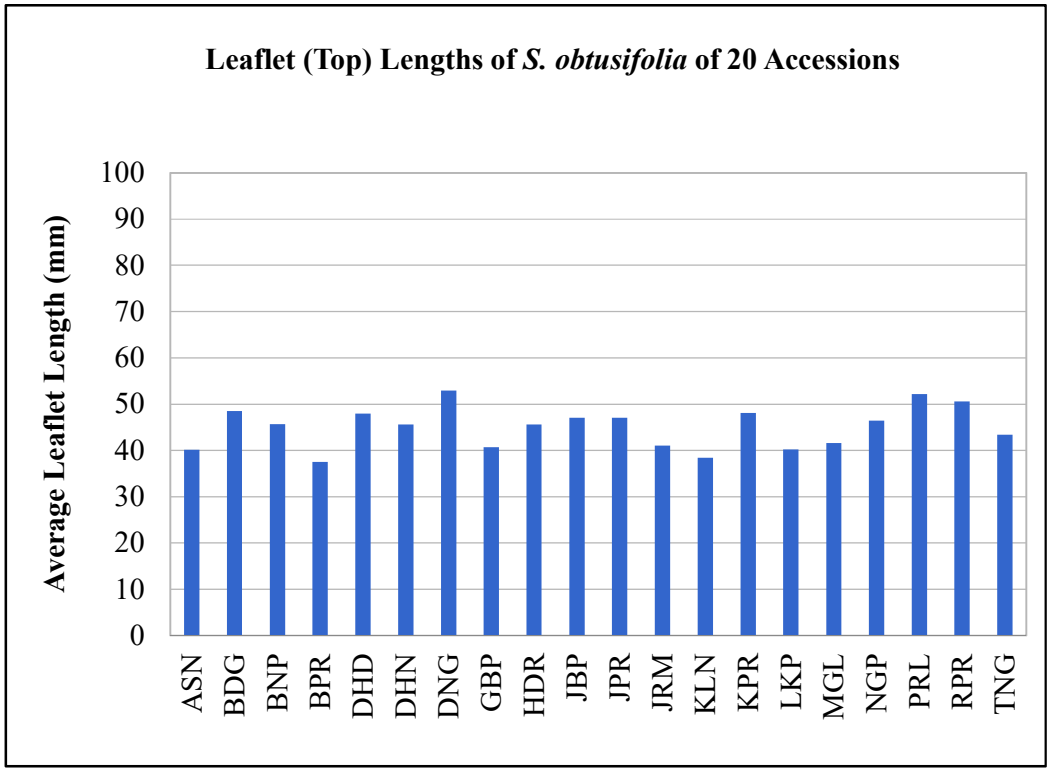


**Figure 4.11** Leaflet (top) lengths of *S. obtusifolia* of 20 accessions

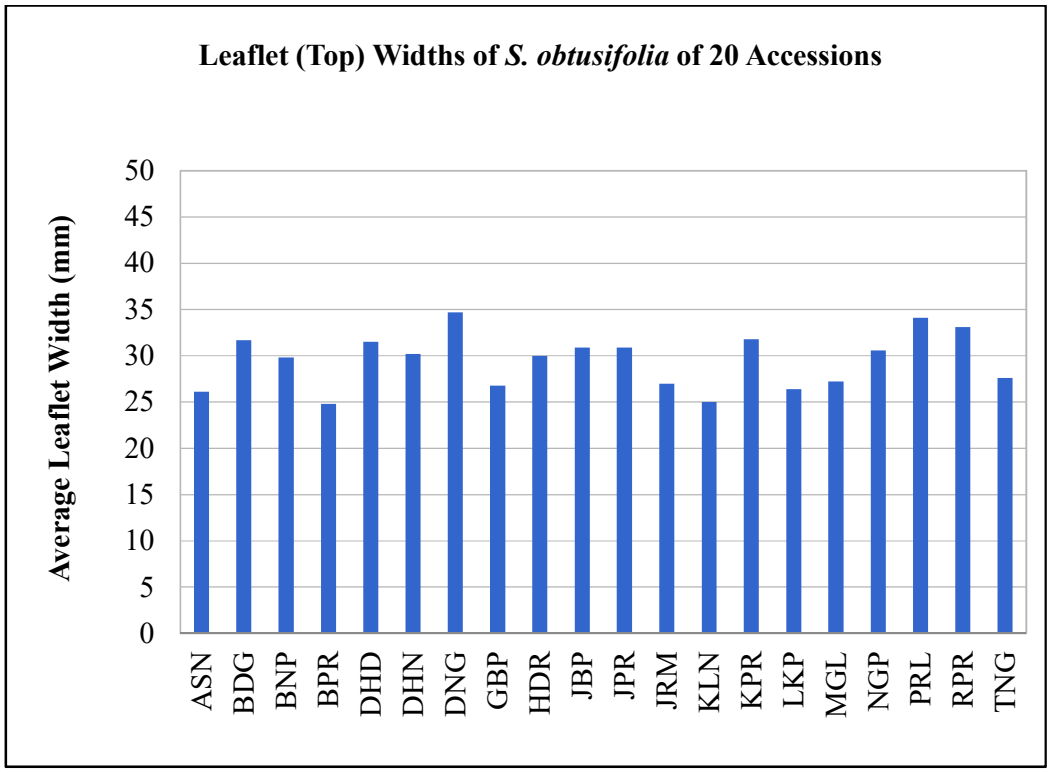


**Figure 4.12** Leaflet (top) widths of *S. obtusifolia* of 20 accessions

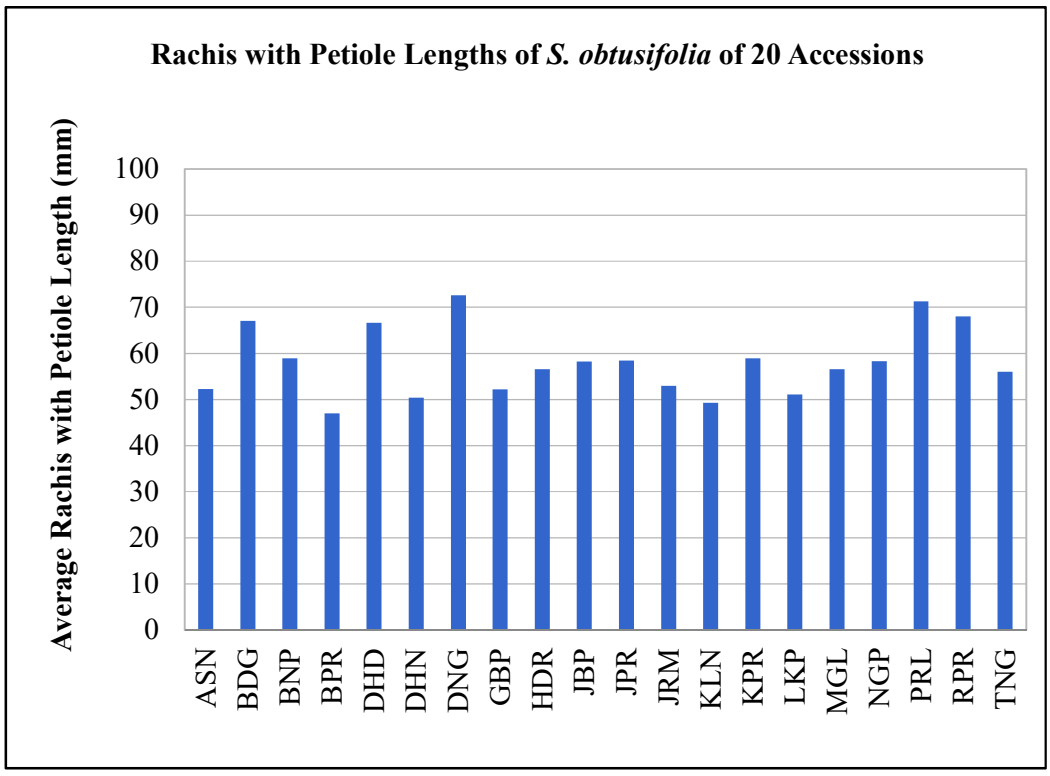


**Figure 4.13** Rachis with petiole lengths of *S. obtusifolia* of 20 accessions

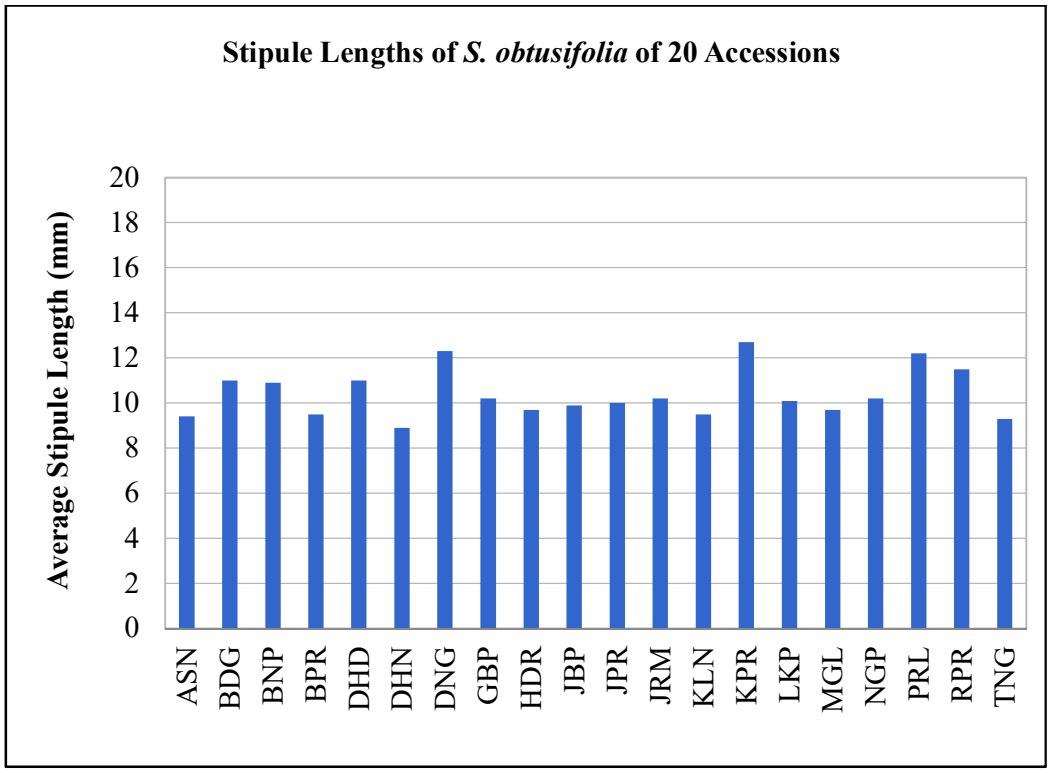


**Figure 4.14** Stipule lengths of *S. obtusifolia* of 20 accessions

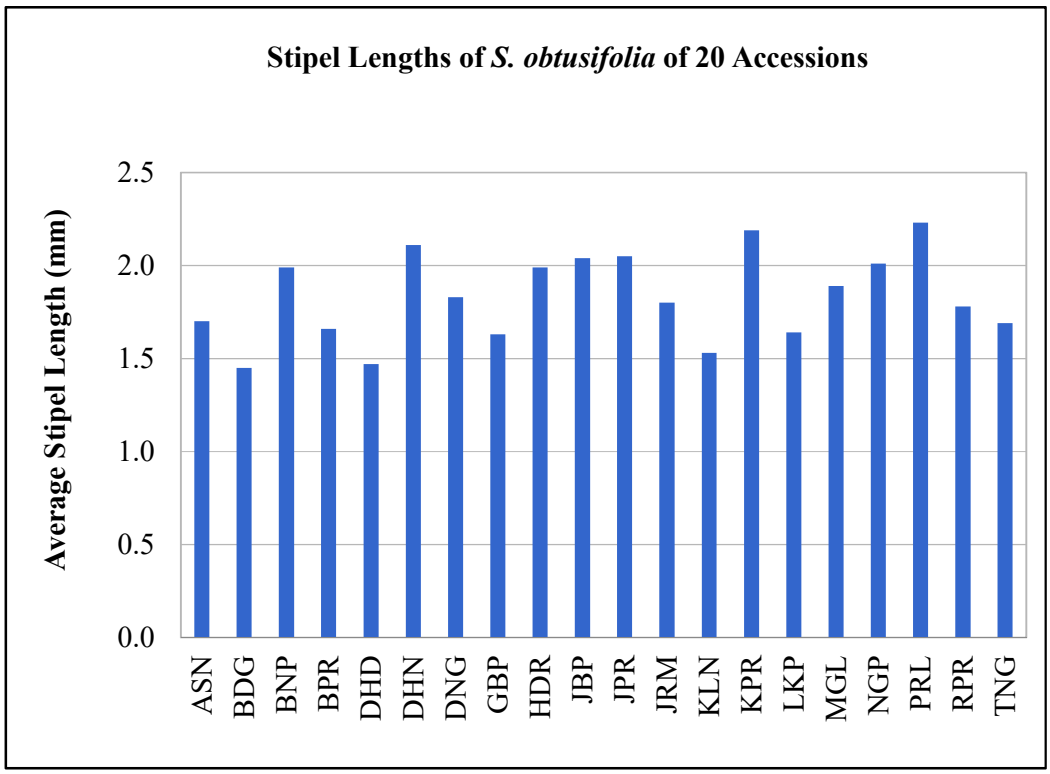


**Figure 4.15** Stipel lengths of *S. obtusifolia* of 20 accessions

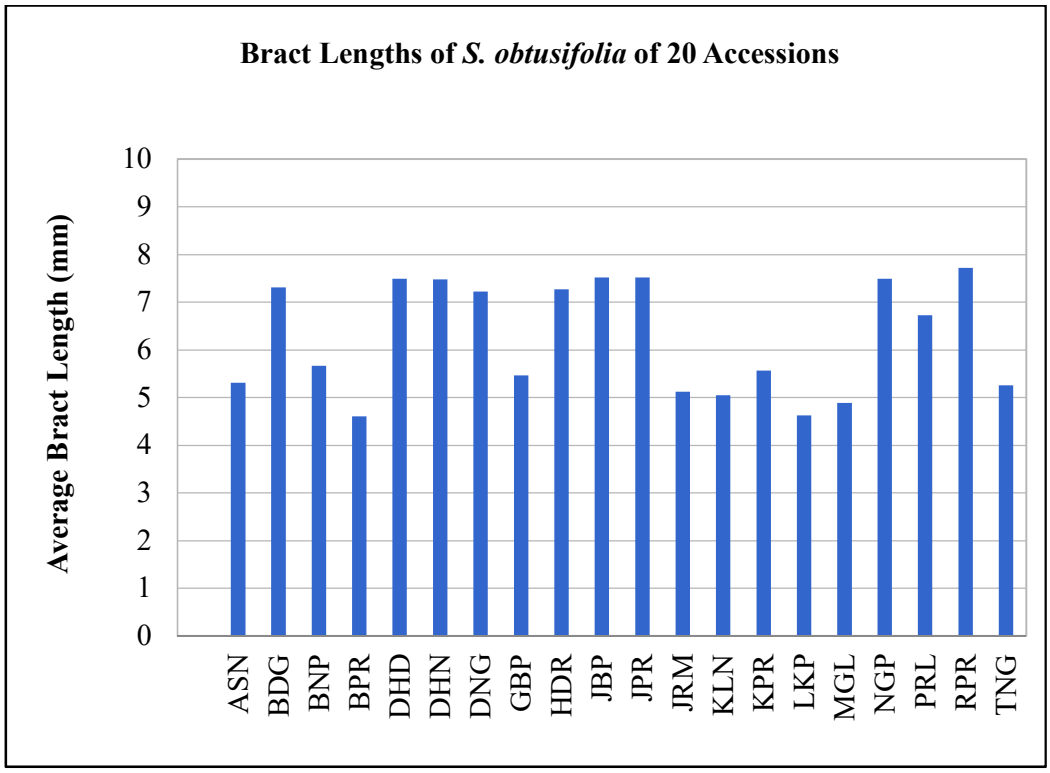


**Figure 4.16** Bract lengths of *S. obtusifolia* of 20 accessions

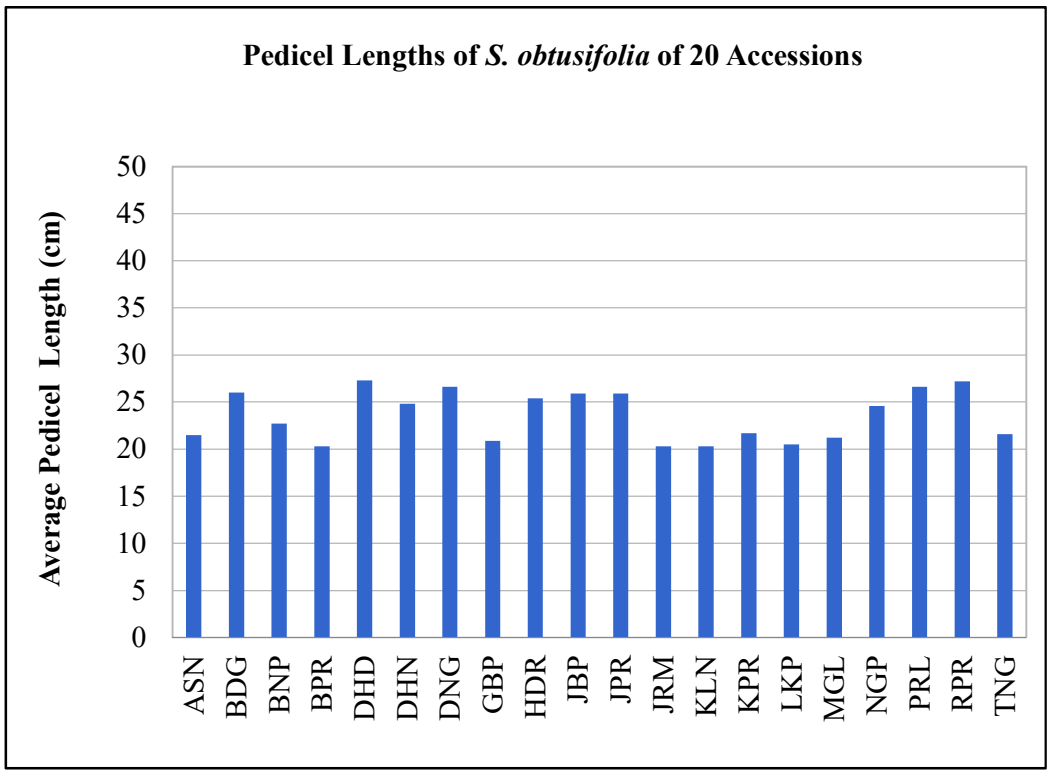


**Figure 4.17** Pedicel lengths of *S. obtusifolia* of 20 accessions

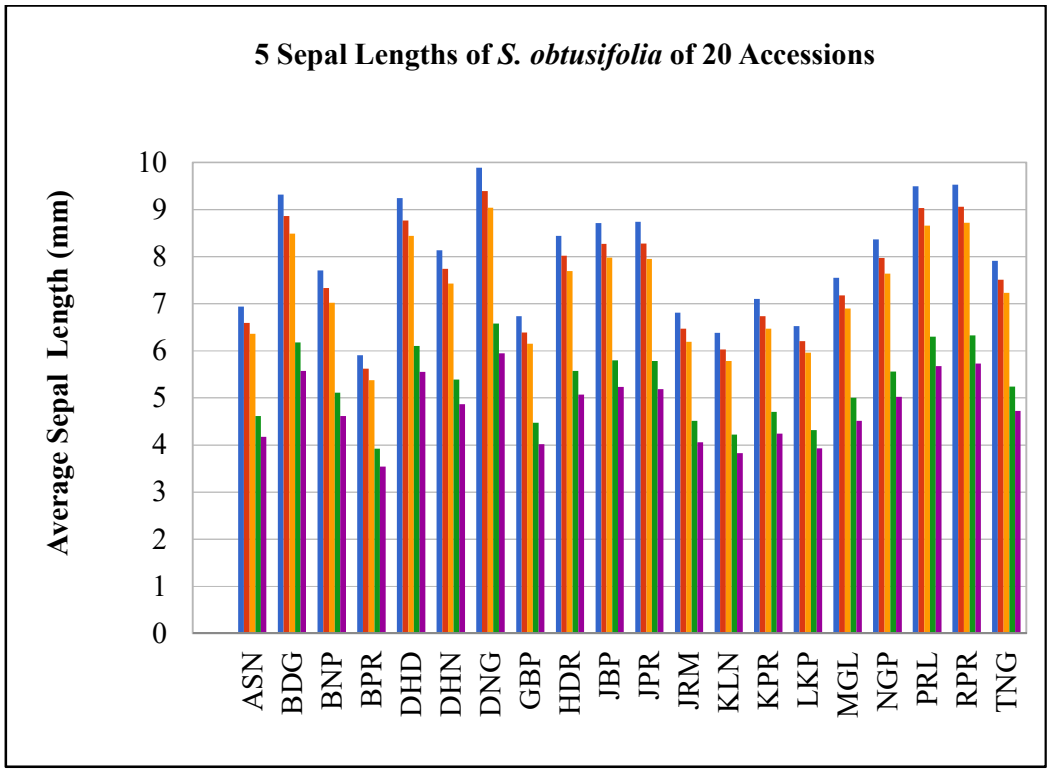


**Figure 4.18** Sepal lengths of *S. obtusifolia* of 20 accessions

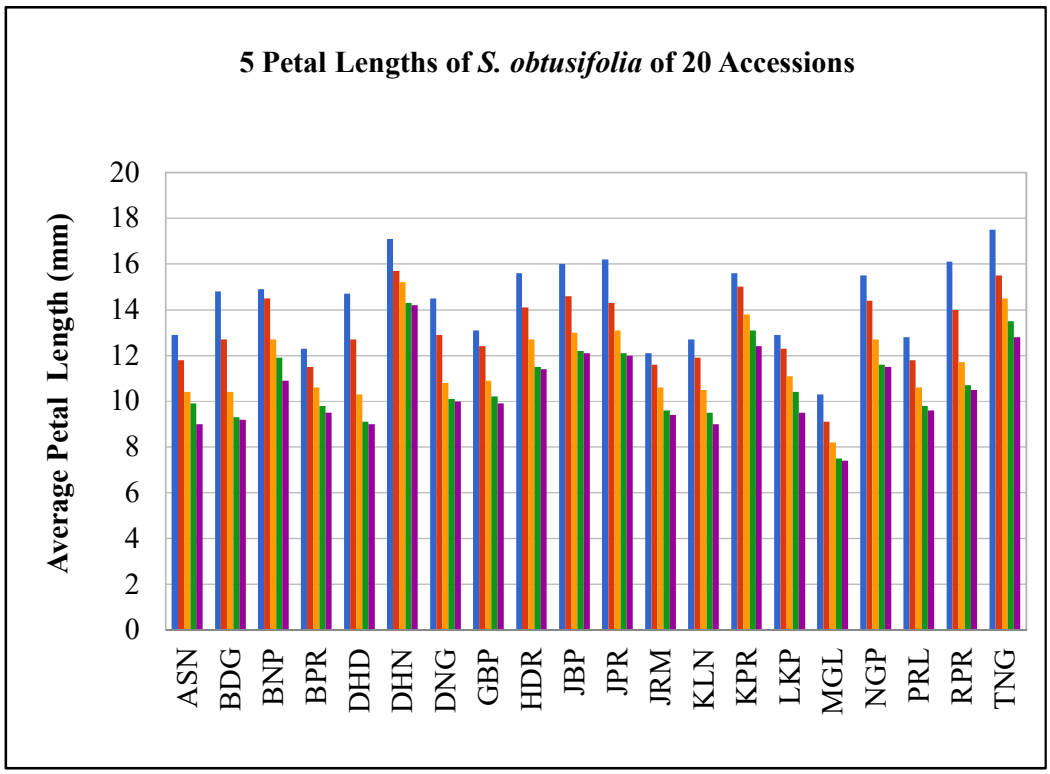


**Figure 4.19** Petal lengths of *S. obtusifolia* of 20 accessions

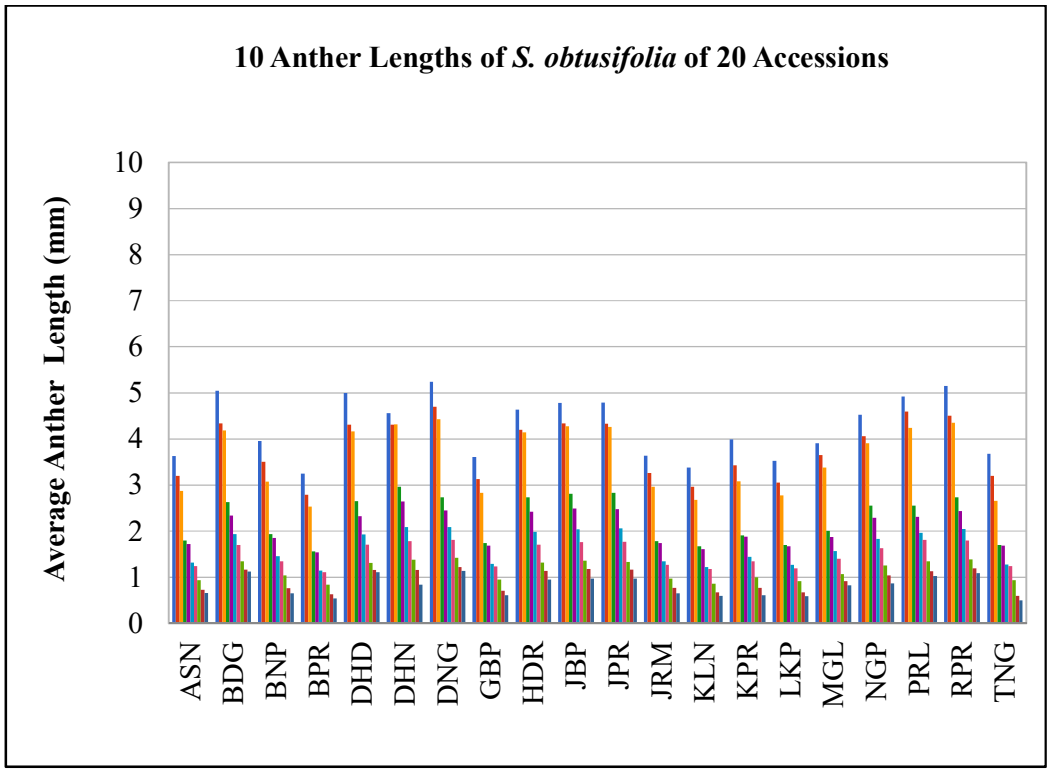


**Figure 4.20** Anther lengths of *S. obtusifolia* of 20 accessions

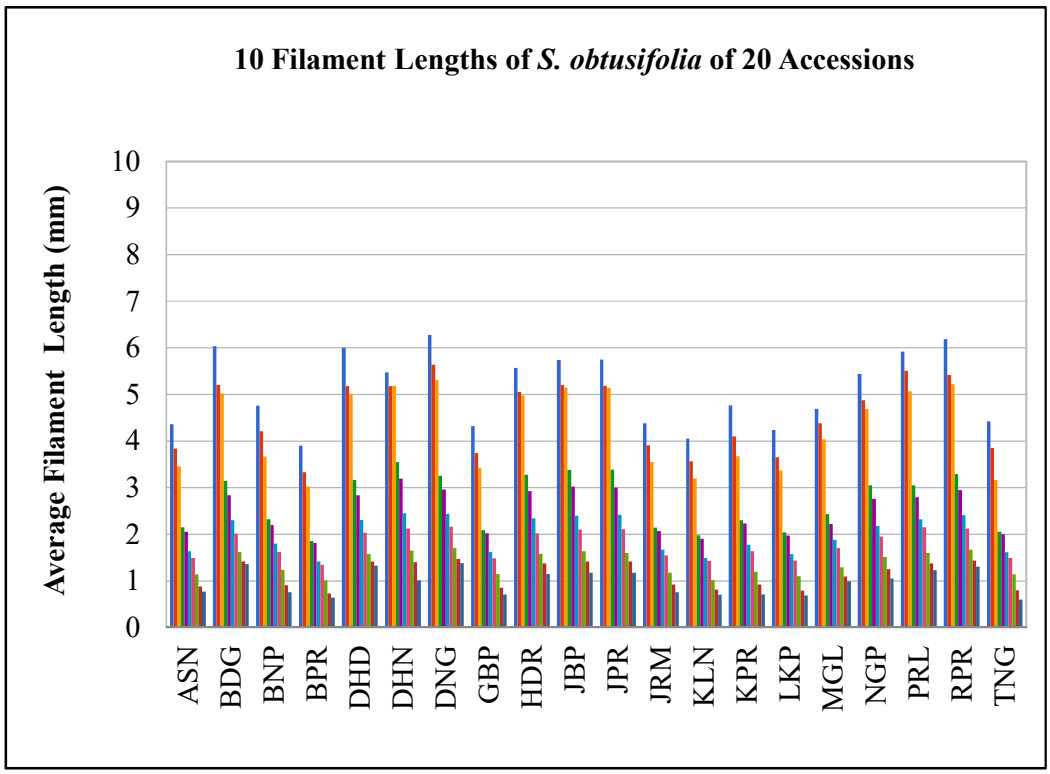


**Figure 4.21** Filament lengths of *S. obtusifolia* of 20 accessions

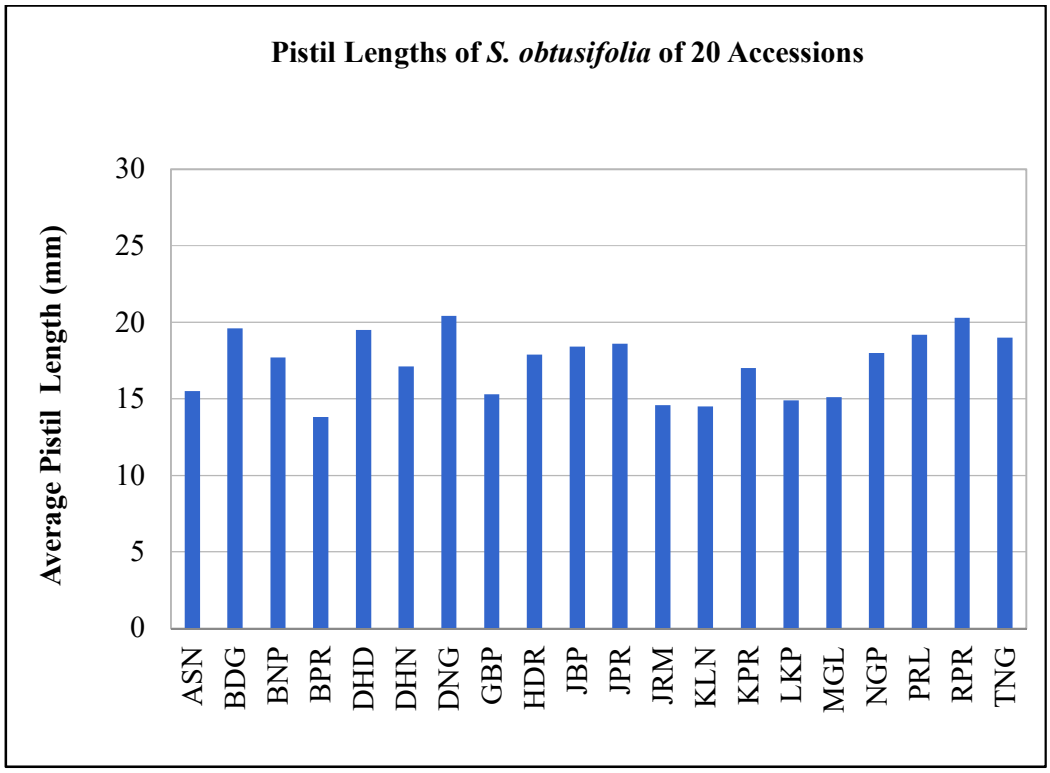


**Figure 4.22** Pistil lengths of *S. obtusifolia* of 20 accessions

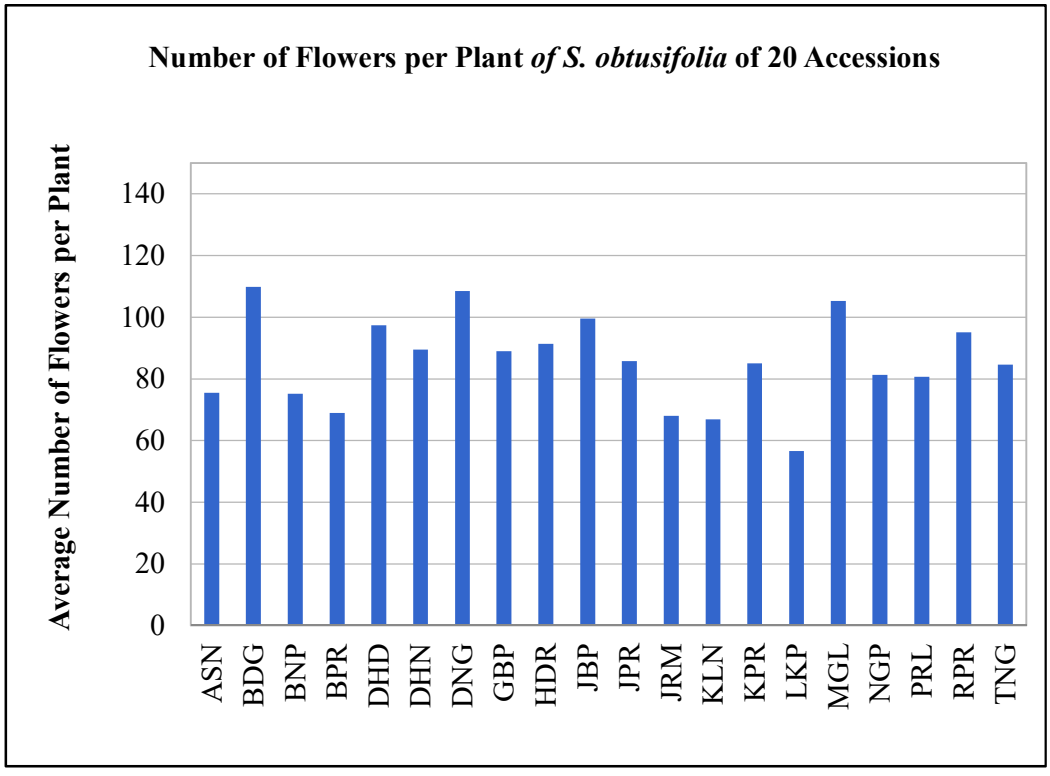


**Figure 4.23** Number of Flowers per Plant of *S. obtusifolia* of 20 accessions

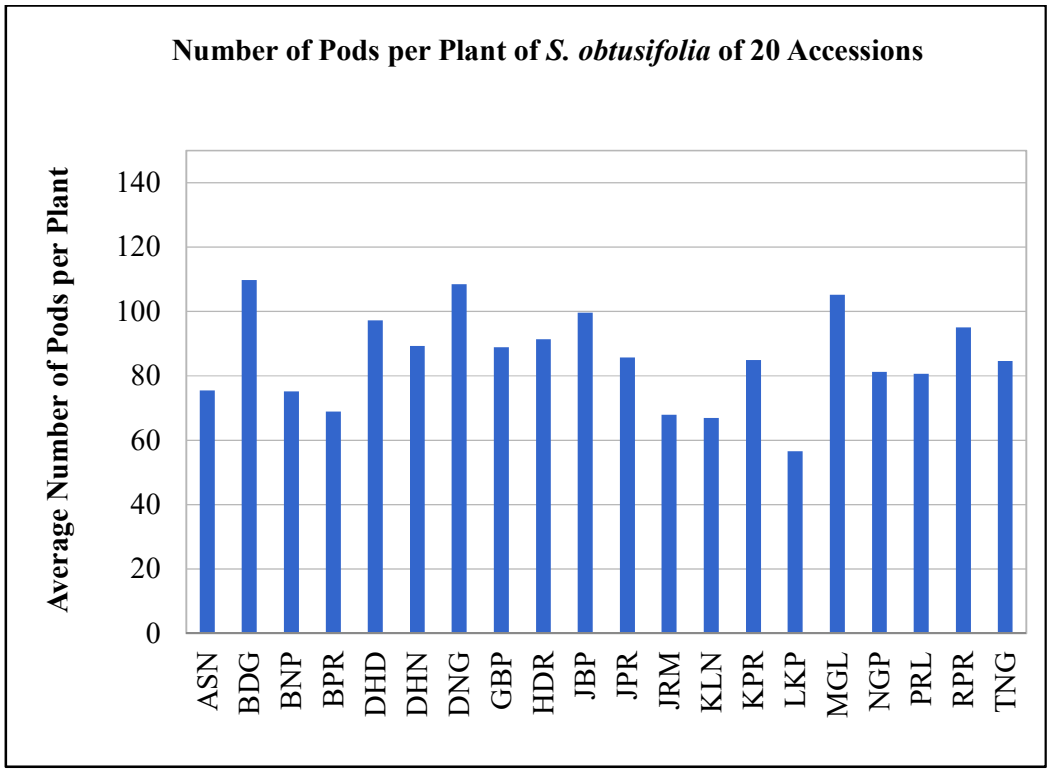


**Figure 4.24** Number of Pods per Plant of *S. obtusifolia* of 20 accessions

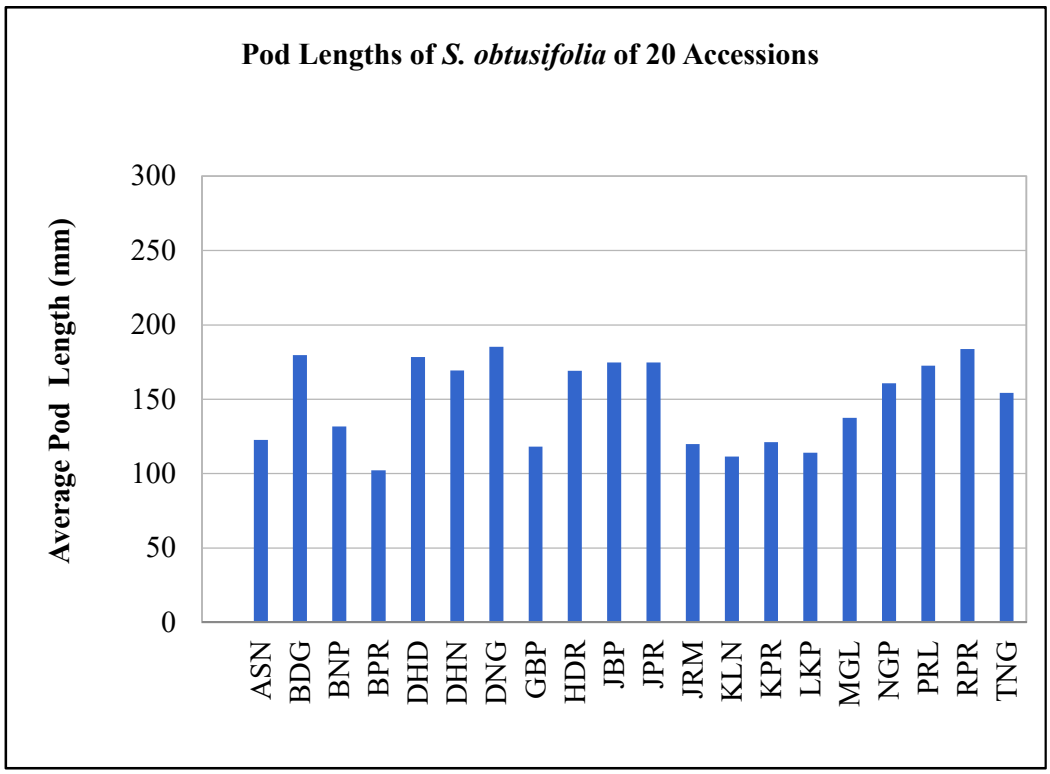


**Figure 4.25** Pod lengths of *S. obtusifolia* of 20 accessions

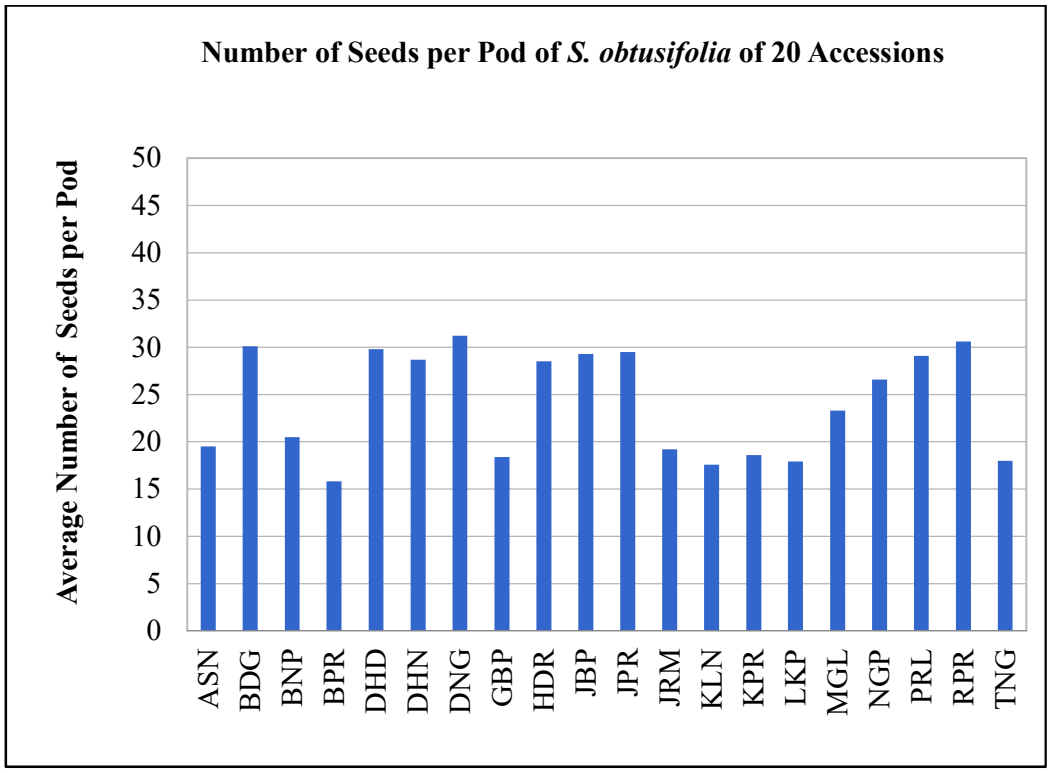


**Figure 4.26** Number of seeds per pod of *S. obtusifolia* of 20 accessions

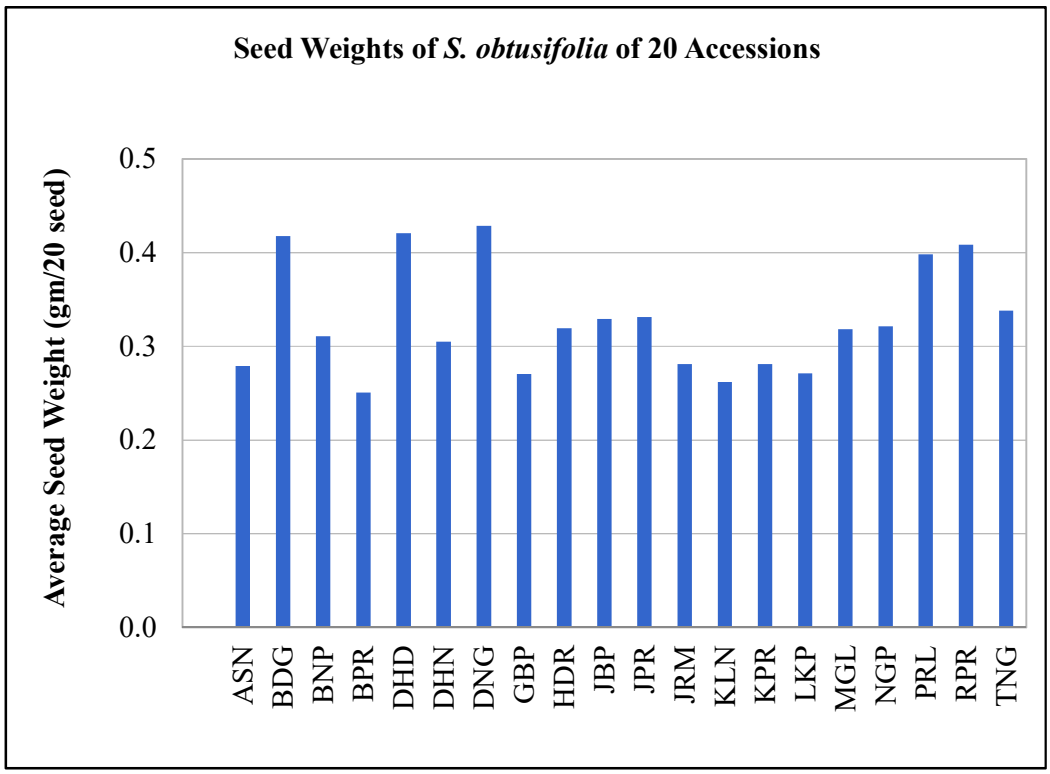


**Figure 4.27** Seed weights of *S. obtusifolia* of 20 accessions

**Table 4.2** Mean and SD of morphological characteristics of *S. obtusifolia* species of 20 accessions

| Charac-teristics | ASN | BDG | BNP | BPR | DHD | DHN | DNG | GBP | HDR | JBP | JPR | JRM | KLN | KPR | LKP | MGL | NGP | PRL | RPR | TNG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLH | 157.99 ±25.05 | 215.72 ±27.46 | 173.91 ±21.03 | 146.71 ±17.39 | 188.21 ±25.82 | 224.10 ±30.06 | 247.60 ±34.67 | 181.40 ±23.24 | 194.10 ±20.65 | 205.51 ±26.34 | 207.31 ±26.23 | 169.69 ±19.33 | 157.39 ±26.03 | 165.81 ±21.70 | 153.39 ±20.14 | 176.01 ±24.49 | 216.89 ±30.37 | 200.32 ±28.41 | 206.50 ±23.32 | 184.98 ±29.22 |
| RTL | 49.24 ±7.80 | 40.48 ±5.17 | 48.77 ±5.89 | 44.15 ±5.24 | 45.54 ±6.24 | 43.13 ±5.80 | 50.19 ±7.04 | 51.82 ±6.65 | 51.46 ±5.47 | 53.63 ±6.87 | 57.98 ±7.34 | 37.12 ±4.24 | 43.36 ±7.19 | 42.45 ±5.55 | 33.21 ±4.36 | 53.71 ±7.49 | 45.28 ±6.33 | 56.80 ±8.05 | 52.55 ±5.93 | 54.05 ±8.53 |
| NBR | 5.8 ±0.9 | 3.8 ±0.6 | 5.2 ±0.8 | 4.9 ±0.7 | 4.8 ±0.8 | 3.5 ±0.5 | 3.3 ±0.5 | 5.5 ±0.5 | 4.5 ±0.5 | 4.4 ±0.5 | 4.1 ±0.9 | 4.5 ±0.5 | 5.0 ±0.9 | 4.3 ±0.7 | 5.0 ±0.7 | 4.8 ±0.8 | 3.5 ±0.5 | 4.8 ±0.9 | 4.5 ±0.5 | 5.7 ±0.8 |
| INL | 39.2 ±6.2 | 52.2 ±6.8 | 43.4 ±5.3 | 36.3 ±4.2 | 51.8 ±6.9 | 46.6 ±6.3 | 54.4 ±7.4 | 39.5 ±4.9 | 47.7 ±5.0 | 49.3 ±6.2 | 49.2 ±6.1 | 39.8 ±4.6 | 37.3 ±6.1 | 45.9 ±6.2 | 38.9 ±5.1 | 40.8 ±5.7 | 47.3 ±6.7 | 51.2 ±7.4 | 53.5 ±5.9 | 39.5 ±6.1 |
| GRT | 22.4 ±3.6 | 31.2 ±4.0 | 24.8 ±3.0 | 20.4 ±2.5 | 30.9 ±4.2 | 25.3 ±3.4 | 30.4 ±4.3 | 22.5 ±3.1 | 27.2 ±2.9 | 28.1 ±3.5 | 28.0 ±3.4 | 21.8 ±2.5 | 21.2 ±3.5 | 25.6 ±3.3 | 22.1 ±3.0 | 21.2 ±3.0 | 26.9 ±3.6 | 26.5 ±3.7 | 31.5 ±3.5 | 25.3 ±3.9 |
| LFL | 40.1 ±6.3 | 48.5 ±6.2 | 45.7 ±5.5 | 37.5 ±4.4 | 48.0 ±6.5 | 45.6 ±6.3 | 52.9 ±7.5 | 40.7 ±5.2 | 45.6 ±4.9 | 47.1 ±6.0 | 47.1 ±6.0 | 41.0 ±4.8 | 38.4 ±6.3 | 48.1 ±6.4 | 40.2 ±5.4 | 41.6 ±5.9 | 46.4 ±6.5 | 52.2 ±7.4 | 50.6 ±5.9 | 43.4 ±6.7 |
| LFW | 26.1 ±4.3 | 31.7 ±4.1 | 29.8 ±3.5 | 24.8 ±2.9 | 31.5 ±4.4 | 30.2 ±4.0 | 34.7 ±5.0 | 26.8 ±3.5 | 30.0 ±3.4 | 30.9 ±3.9 | 30.9 ±4.1 | 27.0 ±3.0 | 25.0 ±4.2 | 31.8 ±4.2 | 26.4 ±3.3 | 27.2 ±3.9 | 30.6 ±4.2 | 34.1 ±4.9 | 33.1 ±3.7 | 27.6 ±4.3 |
| RCL | 52.3 ±8.1 | 67.1 ±8.7 | 58.9 ±7.1 | 47.0 ±5.4 | 66.6 ±9.0 | 50.4 ±6.8 | 72.6 ±10.1 | 52.2 ±6.6 | 56.6 ±6.0 | 58.2 ±7.5 | 58.5 ±7.3 | 53.0 ±6.3 | 49.3 ±8.1 | 58.9 ±7.6 | 51.1 ±6.8 | 56.6 ±7.7 | 58.3 ±8.2 | 71.3 ±10.2 | 68.0 ±7.7 | 56.0 ±8.7 |
| STL | 9.4 ±1.6 | 11.0 ±1.4 | 10.9 ±1.4 | 9.5 ±1.1 | 11.0 ±1.6 | 8.9 ±1.3 | 12.3 ±1.8 | 10.2 ±1.4 | 9.7 ±1.1 | 9.9 ±1.3 | 10.0 ±1.2 | 10.2 ±1.3 | 9.5 ±1.4 | 12.7 ±1.8 | 10.1 ±1.5 | 9.7 ±1.5 | 10.2 ±1.4 | 12.2 ±1.5 | 11.5 ±1.4 | 9.3 ±1.4 |
| SPL | 1.70 ±0.27 | 1.45 ±0.18 | 1.99 ±0.24 | 1.66 ±0.20 | 1.47 ±0.20 | 2.11 ±0.29 | 1.83 ±0.27 | 1.63 ±0.22 | 1.99 ±0.21 | 2.04 ±0.25 | 2.05 ±0.27 | 1.80 ±0.21 | 1.53 ±0.26 | 2.19 ±0.29 | 1.64 ±0.19 | 1.89 ±0.26 | 2.01 ±0.29 | 2.23 ±0.30 | 1.78 ±0.21 | 1.69 ±0.26 |
| BRL | 5.31 ±0.83 | 7.31 ±0.94 | 5.66 ±0.67 | 4.60 ±0.54 | 7.49 ±1.02 | 7.48 ±1.00 | 7.22 ±1.02 | 5.47 ±0.70 | 7.27 ±0.77 | 7.52 ±0.97 | 7.52 ±0.95 | 5.12 ±0.59 | 5.05 ±0.83 | 5.57 ±0.73 | 4.63 ±0.63 | 4.89 ±0.69 | 7.49 ±1.03 | 6.73 ±0.96 | 7.72 ±0.87 | 5.26 ±0.82 |

**Table 4.3** Mean and SD of morphological characteristics of *S. obtusifolia* species of 20 accessions

| Charac-teristics | ASN | BDG | BNP | BPR | DHD | DHN | DNG | GBP | HDR | JBP | JPR | JRM | KLN | KPR | LKP | MGL | NGP | PRL | RPR | TNG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PCL** | 21.5 ±1.8 | 26.0 ±2.4 | 22.7 ±2.0 | 20.3 ±2.8 | 27.3 ±3.5 | 24.8 ±3.4 | 26.6 ±2.7 | 20.9 ±1.7 | 25.4 ±2.7 | 25.9 ±3.3 | 25.9 ±3.3 | 20.3 ±1.8 | 20.3 ±1.3 | 21.7 ±2.5 | 20.5 ±1.6 | 21.2 ±2.5 | 24.6 ±3.3 | 26.6 ±3.6 | 27.2 ±2.5 | 21.6 ±2.1 |
| **SLL** | 6.94 ±1.12 | 9.32 ±1.16 | 7.71 ±0.92 | 5.91 ±0.68 | 9.24 ±1.27 | 8.14 ±1.07 | 9.89 ±1.39 | 6.73 ±0.86 | 8.44 ±0.90 | 8.71 ±1.11 | 8.74 ±1.10 | 6.81 ±0.77 | 6.38 ±1.07 | 7.10 ±0.93 | 6.52 ±0.85 | 7.55 ±1.04 | 8.37 ±1.17 | 9.49 ±1.34 | 9.53 ±1.07 | 7.91 ±1.26 |
| **PTL** | 12.9 ±2.1 | 14.8 ±1.8 | 14.9 ±1.9 | 12.3 ±1.6 | 14.7 ±2.1 | 17.1 ±2.3 | 14.5 ±2.3 | 13.1 ±1.9 | 15.6 ±1.4 | 16.0 ±1.6 | 16.2 ±1.7 | 12.1 ±1.7 | 12.7 ±2.3 | 15.6 ±2.0 | 12.9 ±1.7 | 10.3 ±1.3 | 15.5 ±2.0 | 12.8 ±1.9 | 16.1 ±1.5 | 17.5 ±2.7 |
| **ANL** | 3.63 ±0.58 | 5.05 ±0.64 | 3.96 ±0.47 | 3.25 ±0.39 | 5.00 ±0.68 | 4.56 ±0.63 | 5.24 ±0.73 | 3.61 ±0.46 | 4.64 ±0.50 | 4.78 ±0.63 | 4.79 ±0.64 | 3.64 ±0.42 | 3.38 ±0.56 | 3.99 ±0.52 | 3.53 ±0.49 | 3.91 ±0.54 | 4.53 ±0.67 | 4.92 ±0.74 | 5.15 ±0.57 | 3.68 ±0.58 |
| **FML** | 4.36 ±0.72 | 6.04 ±0.77 | 4.76 ±0.56 | 3.90 ±0.47 | 6.00 ±0.82 | 5.47 ±0.74 | 6.28 ±0.86 | 4.32 ±0.54 | 5.57 ±0.60 | 5.74 ±0.74 | 5.75 ±0.77 | 4.38 ±0.48 | 4.05 ±0.68 | 4.77 ±0.63 | 4.24 ±0.57 | 4.69 ±0.62 | 5.44 ±0.80 | 5.92 ±0.90 | 6.19 ±0.69 | 4.42 ±0.71 |
| **PSL** | 15.5 ±2.8 | 19.6 ±2.8 | 17.7 ±2.1 | 13.8 ±1.8 | 19.5 ±2.8 | 17.1 ±2.5 | 20.4 ±3.2 | 15.3 ±1.8 | 17.9 ±2.1 | 18.4 ±2.3 | 18.6 ±2.4 | 14.6 ±2.0 | 14.5 ±2.5 | 17.0 ±2.4 | 14.9 ±1.9 | 15.1 ±2.1 | 18.0 ±2.4 | 19.2 ±3.0 | 20.3 ±2.3 | 19.0 ±3.2 |
| **NFL** | 79.5 ±12.4 | 115.7 ±14.7 | 78.8 ±9.5 | 72.4 ±8.6 | 102.3 ±14.1 | 94.1 ±12.6 | 114.4 ±16.0 | 93.6 ±12.1 | 96.2 ±10.3 | 104.7 ±13.5 | 89.7 ±11.5 | 71.5 ±8.1 | 70.3 ±11.7 | 89.3 ±11.7 | 59.7 ±7.9 | 110.3 ±15.3 | 85.4 ±12.1 | 85.0 ±12.1 | 99.8 ±11.4 | 89.1 ±14.0 |
| **NPD** | 75.5 ±12.1 | 109.8 ±13.7 | 75.2 ±9.1 | 68.9 ±8.1 | 97.3 ±13.2 | 89.4 ±11.9 | 108.5 ±15.2 | 88.9 ±11.3 | 91.4 ±9.5 | 99.6 ±12.9 | 85.7 ±10.8 | 68.0 ±7.8 | 66.9 ±11.0 | 85.0 ±11.3 | 56.6 ±7.5 | 105.2 ±14.7 | 81.2 ±11.5 | 80.7 ±11.5 | 95.1 ±10.8 | 84.6 ±13.4 |
| **PDL** | 122.7 ±19.3 | 179.8 ±22.9 | 131.7 ±15.9 | 102.2 ±11.9 | 178.3 ±24.4 | 169.5 ±22.6 | 185.1 ±25.8 | 118.1 ±15.1 | 169.3 ±17.8 | 174.6 ±22.2 | 174.7 ±22.2 | 119.9 ±13.7 | 111.3 ±18.4 | 121.0 ±15.8 | 114.0 ±14.8 | 137.5 ±19.2 | 160.8 ±22.6 | 172.7 ±24.6 | 183.7 ±20.8 | 154.2 ±24.4 |
| **NSP** | 19.5 ±3.2 | 30.1 ±3.9 | 20.5 ±2.5 | 15.8 ±1.8 | 29.8 ±4.1 | 28.7 ±3.9 | 31.2 ±4.5 | 18.4 ±2.2 | 28.5 ±3.1 | 29.3 ±3.8 | 29.5 ±3.8 | 19.2 ±2.1 | 17.6 ±2.9 | 18.6 ±2.4 | 17.9 ±2.2 | 23.3 ±3.1 | 26.6 ±3.7 | 29.1 ±4.1 | 30.6 ±3.4 | 18.0 ±2.9 |
| **SDW** | 0.2793 ±0.0432 | 0.4177 ±0.0418 | 0.3110 ±0.0341 | 0.2507 ±0.0439 | 0.4207 ±0.0709 | 0.3048 ±0.1845 | 0.4288 ±0.0433 | 0.2706 ±0.0567 | 0.3194 ±0.0663 | 0.3294 ±0.0528 | 0.3313 ±0.0681 | 0.2811 ±0.0197 | 0.2619 ±0.0439 | 0.2810 ±0.0303 | 0.2713 ±0.0461 | 0.3184 ±0.0431 | 0.3215 ±0.0408 | 0.3982 ±0.0569 | 0.4085 ±0.0417 | 0.3382 ±0.0461 |

**Table 4.4** Descriptive statistics and LSD of morphological characteristics of *S. obtusifolia*

| Characteristics | Mean | Minimum | Maximum | SD | LSD (0.05 level) |
|---|---|---|---|---|---|
| PLH | 188.68 | 146.71 | 247.60 | 26.10 | 22.49 |
| RTL | 47.75 | 33.21 | 57.98 | 6.44 | 5.70 |
| NBR | 4.6 | 3.3 | 5.8 | 0.7 | 0.5 |
| INL | 45.2 | 36.3 | 54.4 | 5.8 | 5.3 |
| GRT | 25.7 | 20.4 | 31.5 | 3.5 | 3.0 |
| LFL | 45.0 | 37.5 | 52.9 | 4.4 | 5.3 |
| LFW | 29.5 | 24.8 | 34.7 | 2.9 | 3.5 |
| RCL | 58.1 | 47.0 | 72.6 | 7.2 | 6.9 |
| STL | 10.4 | 8.9 | 12.7 | 1.0 | 1.3 |
| SPL | 1.83 | 1.45 | 2.23 | 0.23 | 0.22 |
| BRL | 6.27 | 4.60 | 7.72 | 1.15 | 0.74 |
| PCL | 23.6 | 20.3 | 27.3 | 2.6 | 2.3 |
| SLL | 7.97 | 5.91 | 9.89 | 1.17 | 0.95 |
| PTL | 14.4 | 10.3 | 17.5 | 1.8 | 1.7 |
| ANL | 4.26 | 3.25 | 5.24 | 0.65 | 0.51 |
| FML | 5.11 | 3.90 | 6.28 | 0.78 | 0.62 |
| PSL | 17.3 | 13.8 | 20.4 | 2.1 | 2.2 |
| NFL | 90.1 | 59.7 | 115.7 | 14.9 | 10.7 |
| NPD | 85.7 | 56.6 | 109.8 | 14.2 | 10.2 |
| PDL | 149.1 | 102.2 | 185.1 | 28.0 | 17.8 |
| NSP | 24.1 | 15.8 | 31.2 | 5.5 | 2.9 |
| SDW | 0.3272 | 0.2507 | 0.4288 | 0.0561 | 0.0569 |

LSD values were also calculated at 5% significant level. As the sample size 10 is consistent for all the morphological characteristics and all provenances, only one LSD value was obtained for each characteristic. Any morphological characteristic corresponding to two different provenances can be compared using the LSD values. It is also easy to verify the significant difference, if exists, between the mean values of *S. obtusifolia* samples from two different provenances in terms of the considered characteristic. For example, the LSD value for the morphological characteristic plant height (PHL) at 5% significant level is 22.49. The mean plant height of the *S. obtusifolia* samples from Asansol (ASN) and Bandhavgarh (BDG) are, respectively, 157.99cm and 215.72cm (see, Table 4.2). The difference between these two mean values is 57.73cm (215.72 – 157.99). This difference is greater than the LSD value of 22.49. This implies that the *S. obtusifolia* samples from Asansol (ASN) and Bandhavgarh (BDG) are significantly different in terms of plant height. Following in a similar manner, the LSD values corresponding to other morphological characteristics can be used to find the difference between the mean values of any two *S. obtusifolia* samples from two different provenances are significant or not.

Next, the strength of relationship among the considered morphological characteristics is studied with the help of the correlation matrix. The resultant matrix and the correlation plot are presented in Table 4.5 and Figure 2.28, respectively.

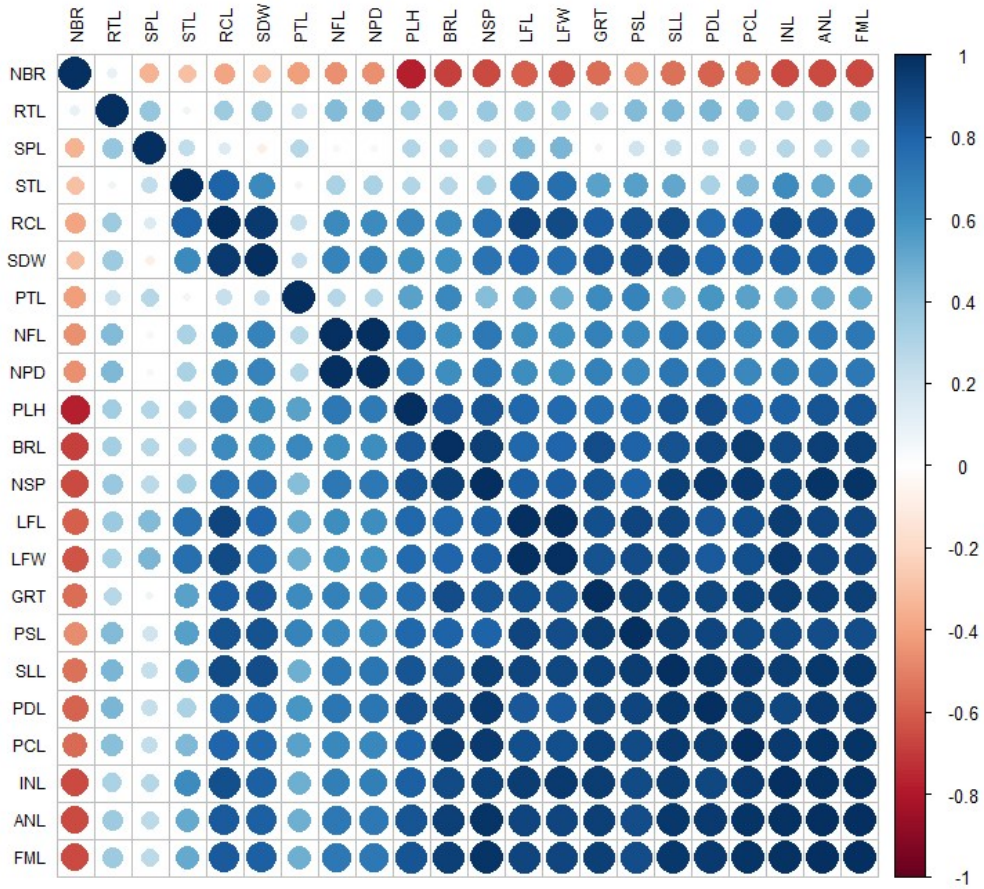


**Figure 4.28** Correlation plot of morphological characteristics of *S. obtusifolia*

**Table 4.5** Correlation matrix of 22 morphological characteristics of *S. obtusifolia* (abbreviations of the characteristics are described in Table 4.1)

| Charac-teristic | PLH | RTL | NBR | INL | GRT | LFL | LFW | RCL | STL | SPL | BRL | PCL | SLL | PTL | ANL | FML | PSL | NFL | NPD | PDL | NSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RTL | 0.343 | | | | | | | | | | | | | | | | | | | | |
| NBR | -0.773 | 0.100 | | | | | | | | | | | | | | | | | | | |
| INL | 0.819 | 0.310 | -0.657 | | | | | | | | | | | | | | | | | | |
| GRT | 0.767 | 0.274 | -0.558 | 0.943 | | | | | | | | | | | | | | | | | |
| LFL | 0.783 | 0.361 | -0.594 | 0.950 | 0.872 | | | | | | | | | | | | | | | | |
| LFW | 0.780 | 0.337 | -0.623 | 0.956 | 0.863 | 0.997 | | | | | | | | | | | | | | | |
| RCL | 0.653 | 0.353 | -0.393 | 0.877 | 0.826 | 0.911 | 0.895 | | | | | | | | | | | | | | |
| STL | 0.298 | 0.064 | -0.300 | 0.629 | 0.533 | 0.750 | 0.754 | 0.802 | | | | | | | | | | | | | |
| SPL | 0.290 | 0.383 | -0.348 | 0.288 | 0.070 | 0.435 | 0.458 | 0.145 | 0.245 | | | | | | | | | | | | |
| BRL | 0.850 | 0.335 | -0.682 | 0.898 | 0.882 | 0.784 | 0.793 | 0.621 | 0.274 | 0.286 | | | | | | | | | | | |
| PCL | 0.802 | 0.418 | -0.561 | 0.957 | 0.929 | 0.875 | 0.875 | 0.800 | 0.446 | 0.246 | 0.941 | | | | | | | | | | |
| SLL | 0.854 | 0.454 | -0.544 | 0.949 | 0.920 | 0.918 | 0.904 | 0.894 | 0.511 | 0.232 | 0.865 | 0.951 | | | | | | | | | |
| PTL | 0.540 | 0.212 | -0.410 | 0.486 | 0.625 | 0.504 | 0.489 | 0.224 | 0.058 | 0.281 | 0.641 | 0.532 | 0.481 | | | | | | | | |
| ANL | 0.859 | 0.356 | -0.656 | 0.987 | 0.932 | 0.911 | 0.915 | 0.840 | 0.508 | 0.267 | 0.930 | 0.976 | 0.968 | 0.482 | | | | | | | |
| FML | 0.859 | 0.356 | -0.656 | 0.987 | 0.932 | 0.911 | 0.915 | 0.840 | 0.508 | 0.267 | 0.930 | 0.976 | 0.968 | 0.482 | 1.000 | | | | | | |
| PSL | 0.784 | 0.439 | -0.462 | 0.897 | 0.944 | 0.912 | 0.887 | 0.863 | 0.548 | 0.197 | 0.809 | 0.896 | 0.945 | 0.663 | 0.888 | 0.888 | | | | | |
| NFL | 0.711 | 0.438 | -0.454 | 0.690 | 0.679 | 0.614 | 0.608 | 0.631 | 0.311 | 0.040 | 0.618 | 0.645 | 0.724 | 0.281 | 0.718 | 0.718 | 0.649 | | | | |
| NPD | 0.709 | 0.442 | -0.453 | 0.689 | 0.678 | 0.613 | 0.607 | 0.630 | 0.310 | 0.044 | 0.618 | 0.645 | 0.723 | 0.280 | 0.718 | 0.718 | 0.648 | 1.000 | | | |
| PDL | 0.881 | 0.450 | -0.584 | 0.910 | 0.905 | 0.842 | 0.830 | 0.762 | 0.319 | 0.233 | 0.917 | 0.949 | 0.969 | 0.586 | 0.955 | 0.955 | 0.912 | 0.727 | 0.726 | | |
| NSP | 0.860 | 0.376 | -0.655 | 0.930 | 0.859 | 0.815 | 0.823 | 0.735 | 0.334 | 0.265 | 0.938 | 0.955 | 0.931 | 0.426 | 0.975 | 0.975 | 0.802 | 0.712 | 0.712 | 0.953 | |
| SDW | 0.618 | 0.356 | -0.301 | 0.818 | 0.843 | 0.797 | 0.770 | 0.950 | 0.630 | -0.087 | 0.609 | 0.789 | 0.889 | 0.222 | 0.811 | 0.811 | 0.861 | 0.664 | 0.663 | 0.790 | 0.730 |

From Table 4.5, we find that the value of the correlation coefficient for the following pairs of morphological characteristics are greater than 0.9:

GRT-INL, LFL-INL, LFW-INL, LFW-LFL, PCL-INL, PCL-BRL, SLL-INL, SLL-GRT, SLL-LFL, SLL-LFW, SSL-PCL, ANL-INL, ANL-GRT, ANL-LFL, ANL-LFW, ANL-BRL, ANL-PCL, ANL-SLL, FML-INL, FML-GRT, FML-LFL, FML-LFW, FML-BRL, FML-PCL, FML-SLL, FML-ANL, PSL-GRT, PSL-LFL, PSL-SLL, NPD-NFL, PDL-INL, PDL-GRT, PDL-BRL, PDL-PCL, PDL-SLL, PDL-ANL, PDL-FML, PDL-PSL, NSP-INL, NSP-BRL, NSP-PCL, NSP-SLL, NSP-ANL, NSP-FML, NSP-PDL.

The above pairs of morphological characteristics of *S. obtusifolia* were highly positively correlated. Internode length (INL) was found to have higly positive correlation with a maximum of nine characteristics – girth (GRT), leaf length (LFL), sepal length (SLL), pedicel length (PCL), leaf width (LFW), anther length (ANL), filament length (FML), number of seeds per pod (NSP) and pod length (PDL). Therefore, inter-node length influenced the maximum number of morphological characteristics of *S. obtusifolia* in a highly positive manner. Both pod length (PDL) and filament length (FML) were found to be highly positively correlated with eight morphological characteristics, followed by anther length (ANL) with seven and girth (GRT) with six characteristics. It was interesting to note that root length (RTL) and number of branches (NBR) were not found to be associated highy positivly or negatively with any characteristic. In particular, number of branches (NBR) was found to be negatively correlated (mostly weakly and in few cases moderately) with all other morphological characteristics of *S. obtusifolia*.

**Principal Component Analysis (PCA)**

PCA was utilized for finding the influencing factors among the considered morphological characteristics. Table 4.6 showed the results of the PCA analysis.

**Table 4.6** Eigen values and variance of the observed characters under PCA

| Component | Eigenvalue* | % of Variance* | Cumulative % of Variance** |
|---|---|---|---|
| 1 | 15.5595 | 70.8886 | 70.88863 |
| 2 | 1.6706 | 7.5937 | 78.48232 |
| 3 | 1.4715 | 6.6885 | 85.17086 |
| 4 | 1.2445 | 5.6568 | 90.82767 |
| 5 | 0.9330 | 4.2409 | 95.06855 |
| 6 | 0.5902 | 2.6829 | 97.75140 |
| 7 | 0.2511 | 1.1413 | 98.89274 |
| 8 | 0.1350 | 0.6136 | 99.50634 |
| 9 | 0.0695 | 0.3160 | 99.82233 |
| 10 | 0.0179 | 0.0814 | 99.90375 |
| 11 | 0.0122 | 0.0556 | 99.95933 |
| 12 | 0.0054 | 0.0245 | 99.98384 |
| 13 | 0.0027 | 0.0124 | 99.99629 |
| 14 | 0.0004 | 0.0018 | 99.99804 |
| 15 | 0.0003 | 0.0015 | 99.99959 |
| 16 | 0.0000 | 0.0002 | 99.99978 |
| 17 | 0.0000 | 0.0001 | 99.99989 |
| 18 | 0.0000 | 0.0001 | 99.99996 |
| 19 | 0.0000 | 0.0000 | 100.00000 |

* Correct upto 4 decimal places, ** Correct upto five decimal places

From the results of Table 4.6, it wass observed that there are four eigen values whose values are more than one. The values are 15.5595, 1.6706, 1.4715 and 1.2445, respectively. All other eigen values are less than one. Therefore, there are four major components for the morphological characteristics for the twenty *S. Obtusifolia* samples from twenty provenances. The principal components and their cumulative proportion of variance are shown in Figure 4.29.

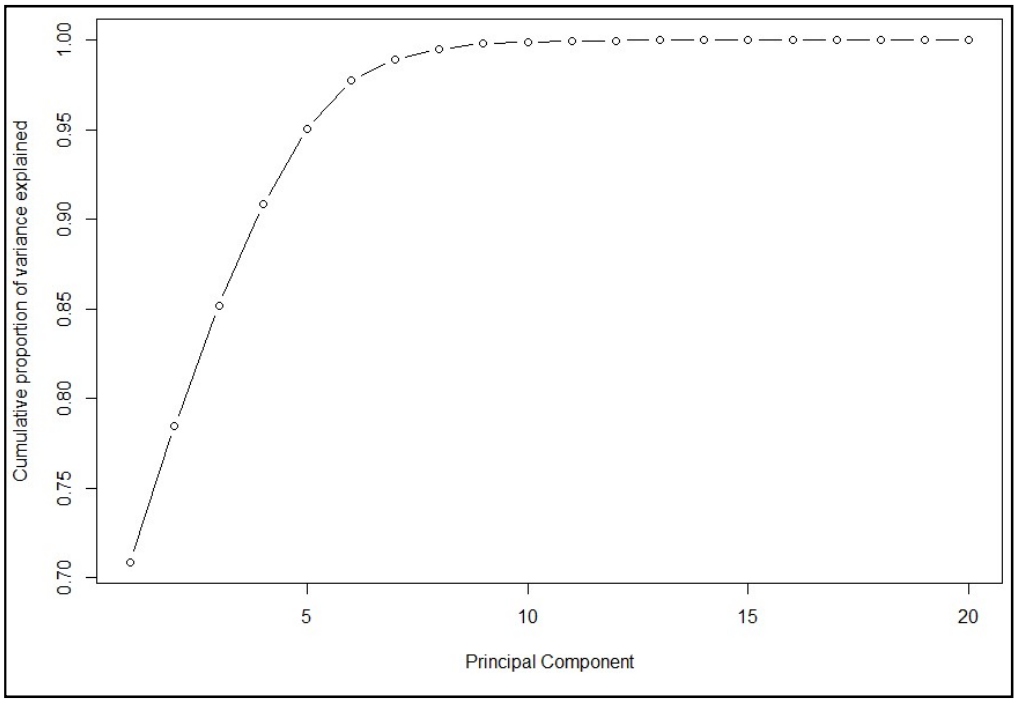


**Figure 4.29** Principal components and their cumulative proportion of variance

The largest eigen value captures 70.8886% of total variability. Four major components captured nearly 91% of total variability. As a result, twenty two morphological characteristics of *S. obtusifolia* samples can be grouped into four principal components.

The loading of the characteristis on four components are presented as the component matrix in Table 4.7

**Table 4.7** Component matrix

| Characteristic | Component 1 | Component 2 | Component 3 | Component 4 |
|---|---|---|---|---|
| PLH | 0.8767 | -0.270 | 0.092099915 | -0.07668170 |
| RTL | 0.4136 | -0.040 | 0.255122209 | 0.84209811 |
| NBR | -0.6381 | 0.399 | 0.208314528 | 0.40659176 |
| INL | 0.9821 | 0.038 | -0.107568055 | -0.08034420 |
| GRT | 0.9455 | 0.049 | 0.048105547 | -0.16926390 |
| LFL | 0.9447 | 0.092 | -0.291317876 | 0.06942168 |
| LFW | 0.9404 | 0.071 | -0.316747690 | 0.05043082 |
| RCL | 0.8746 | 0.453 | -0.133242721 | 0.04502003 |
| STL | 0.5570 | 0.562 | -0.555225421 | -0.00342010 |
| SPL | 0.2834 | -0.440 | -0.592740570 | 0.52889745 |
| BRL | 0.9038 | -0.330 | 0.062033172 | -0.10172210 |
| PCL | 0.9591 | -0.060 | 0.029041074 | -0.00742110 |
| SLL | 0.9814 | 0.061 | 0.054825773 | 0.04382548 |
| PTL | 0.5372 | -0.540 | -0.048450460 | -0.02582280 |
| ANL | 0.9855 | -0.030 | 0.005594703 | -0.06435840 |
| FML | 0.9855 | -0.030 | 0.005594703 | -0.06435840 |
| PSL | 0.9389 | 0.061 | -0.005705123 | 0.05312796 |
| NFL | 0.7566 | 0.096 | 0.454130587 | 0.07609814 |
| NPD | 0.7561 | 0.095 | 0.454062937 | 0.08102749 |
| PDL | 0.9569 | -0.140 | 0.164211352 | 0.01401140 |
| NSP | 0.9376 | -0.140 | 0.117311675 | -0.05261490 |
| SDW | 0.8404 | 0.478 | 0.121609606 | -0.02270990 |

“Component” denotes “Principal Component”

In the component matrix, the morphological characteristics having component loading close to 1 load heavily to that principal component. Therefore, it is evidenced from Table 4.6 that the morphological characteristics internode length (INL), girth (GRT), leaf length (LFL), leaf width (LFW), bract length (BRL), pedicel length (PCL), sepal length (SLL), anther length (ANL), filament length (FML), pistil length (PSL), pod length (PDL) and number of seeds per pod (NSP) load heavily to the principal Component 1. Some other characteristics like plant height (PLH), rachis length (RCL), number of flowers (NFL), number of pods (NDP) and seed weight (SDW) are also loading more towards Component 1. Only number of branches (NBR) loads negatively to Component 1.

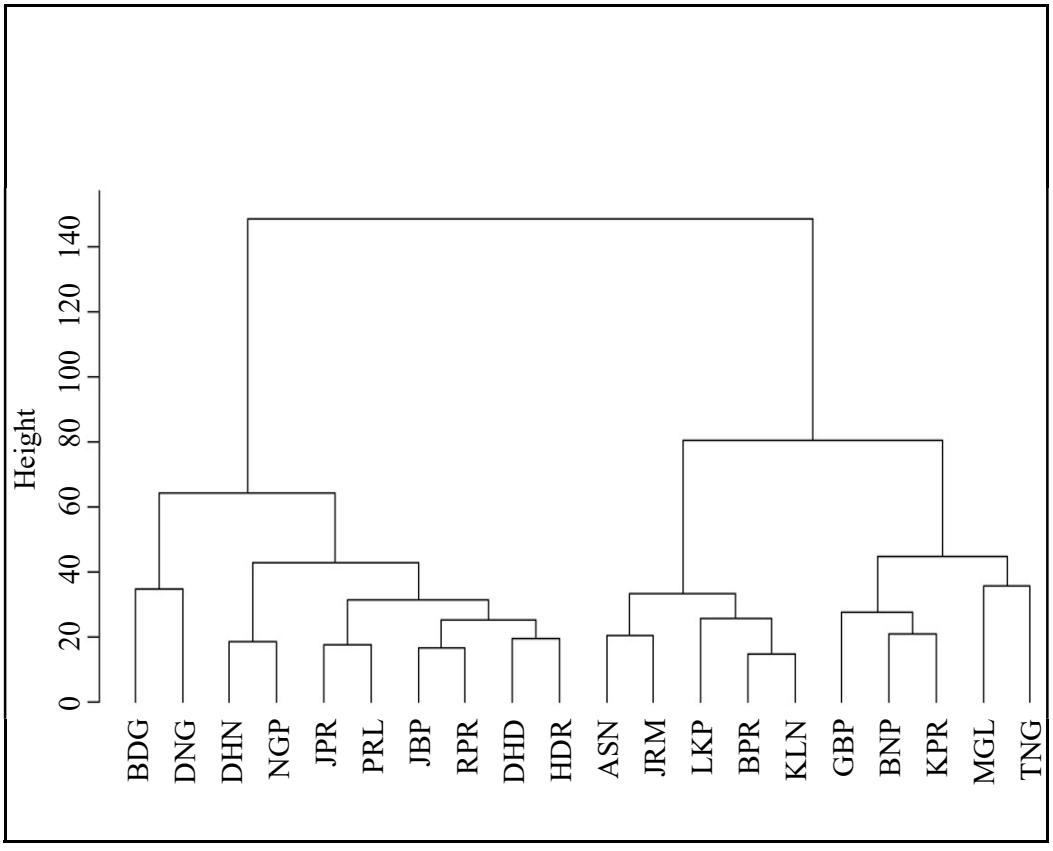


**Figure 4.30** Classification of *S. obtusifolia* based on morphological characteristics

Finally, the cluster analysis (CA) was performed to cluster the *S. obtusifolia* samples from different provenances based on morphological characteristics. It represents how closely the *S. obtusifolia* samples from twenty different provenances are related. The result of the cluster analysis is presented in Figure 4.30.

The results suggested that *the S. obtusifolia* samples from twenty provenances can be grouped into four clusters. The samples from Bandhavgarh (BDG) and Devendranagar (DNG) belong to the first cluster. These two samples have similar morphological characteristics. The samples from Dehradun (DHN), Nagpur (NGP), Jaipur (JPR), Purulia (PRL), Jabalpur (JBP), Raipur (RPR), Dahod (DHD) and Haridwar (HDR) belong to the second cluster. Within this cluster, *S. obtusifolia* samples from Jaipur (JPR) and Purulia (PRL) have no morphological variations. Similarly, there are no morphological variations between the samples from Jabalpur (JBP) and Raipur (RPR), and Dahod (DHD) and Haridwar (HDR). The samples from Asansol (ASN), Jhargram (JRM), Lakshmikantapur (LKP), Bolpur (BPR) and Kalyani (KLN) belong to the third cluster. In this cluster, samples from Asansol (ASN), Jhargram (JRM), and Bolpur (BPR), Kalyani (KLN) have similar morphological characteristics. The sample from Lakshmikantapur (LKP) has a minor morphological variation compared to the rest. The samples from Gobindapur (GBP), Bishnupur (BNP), Kharagpur (KPR), Mangalore (MGL) and Tatanagar (TNG) belong to the fourth cluster. Out of these, the samples from Bishnupur (BNP) and Kharagpur (KPR) have not much variation in terms of morphological characteristics. Similarly, the samples from Mangalore (MGL) and Tatanagar (TNG) have similar morphological characteristics.

### 4.2.1 Discussions

This chapter presents the study on morphological variations of twenty accessions of *S. obtusifolia* collected from different provenances from diverse geographical locations of various parts of West Bengal and also from some other states of India grown under similar edaphic conditions for two consecutive years. Investigating intraspecific diversity among populations was the objective of this study.

To accomplish the mentioned objective, 22 morphometric characteristics of the *S. obtusifolia* were selected. Selected characteristics are representatives of different plant parts like stem, root, leaves, flowers and pods. Out of all these, pod length had shown the maximum variability, followed by plant height, number of pods and flowers per plant. Both SD and LSD were used to measure the variability. For the pod length, the SD value is 28 and the LSD value is 17.80. Similarly, for the plant height the SD value is 26.10, and the LSD value is 22.49. For the flowers per plant, the SD value is 14.90, and the LSD value is 10.70. For number of pods per plant, the SD value is 14.20, and the LSD value is 10.20. The literature shows that the findings of Jeruto et al., (2017) was similar for *S. didymobotrya* considering 17 quantitative characteristics. Similar studies considering 9 provenances in Thailand of *Senna siamea* by Takuathung et al., (2012) regarding the variations related to growth and seed characters were recorded. Morphological variations in different genera of various species were studied by Gomez-Campo et al., (2001); Henderson and Ferreira, (2002); Sonibare, (2004); Bolourian and Pakravan, (2011).

Correlation analysis was performed to study the inter-relationships among the considered twenty two morphometric characteristics of *S. obtusifolia.* The study confirmed that internode length appeared to be the most influential characteristics

having highly positive correlation with a maximum of nine other characteristics - girth, number of seeds per pod, leaf width, filament, sepal, pedicel, anther, pod, and leaf lengths. The values of correlation coefficients vary from 0.910 to 0.987. In a similar way, the other influential characteristics are identified. The filament length and pod length were highly positively correlated with eight other characteristics. Number of branches is the only characteristic that was weakly negatively correlated with all other characteristics.

The literature revealed similar correlation studies on species like *Ficus sp* (Sonibare et al., 2004), and *S. didymobotrya* (Jeruto et al., 2017). For genus *Ficus sp,* correlation stufy revealed that the pairs leaf length, leaf width, leaf and lamina lengths, leaf and petiole lengths, lamina width and lamina length were highly positively correlated, while leaf length/leaf width ratio and leaf width, fruit length/ fruit petiole length ratio and petiole length were negatively correlated (Sonibare et al., 2004). Similarly, the correlation analysis for genus *S. didymobotrya* revealed that the pairs leaflet width and leaflet length, pod width and pod length, stem height and plant height were highly positively correlated (Jeruto et al., 2017).

The PCA on twenty two morphometric characteristics of *S. obtusifolia* samples collected from twenty provenances identified four major components corresponding to eigenvalues more than one. The largest eigenvalue is 15.5595 that accounts for more than 70% of the total variance. As a result, twelve out of twenty-two characteristics such as inter-node length, girth, leaf length, leaf width, pistil, sepal, pedicel, bract, anther, filament, pod lengths and number of seeds per pod load heavily to component 1. It was observed that the majority of the characteristics of flowers are loading heavily to Component 1. They are six in numbers out of eight. Therefore, the characteristics of

flowers are playing dominant role in the PCA of *S. obtusifolia* for constructing principle components. Root length is loading heavily to Component 4. On the other hand, no morphometric characteristic is loading heavily to either Component 2 or Component 3. For Component 2, stipel length is loading with a moderate value. For Component 3, number of flowers and number of pods are loading with maximum values compared to the other characteristics.

The PCA analysis of Mulumba and Kakudidi (2011) on *Acacia senegal*, revealed petiole length, leaflet length and leaflet number as the morphometric characteristics having highest loadings. Jeruto et al., (2017) in *S. didymobotrya* identified 6 components for contributing to the variation in the species. They observed that the characteristics of flowers loaded heavily, and hence played the dominating role in the PCA. Therefore, this finding is aligned with our study.

The cluster analysis on *S. obtusifolia* samples from twenty provenances suggested to group them into four clusters based on the values of the morphological characteristics. Bandhavgarh (BDG) and Devendranagar (DNG) belonged to the Cluster 1. Dehradun (DHN), Nagpur (NGP), Jaipur (JPR), Purulia (PRL), Jabalpur (JBP), Raipur (RPR), Dahod (DHD) and Haridwar (HDR) belonged to the Cluster 2. Asansol (ASN), Jhargram (JRM), Lakshmikantapur (LKP), Bolpur (BPR) and Kalyani (KLN) belonged to the Cluster 3. The rest of the others, Gobindapur (GBP), Bishnupur (BNP), Kharagpur (KPR), Mangalore (MGL) and Tatanagar (TNG) belonged to the Cluster 4. The members belonging to each cluster have similar morphometric characteristics. It was observed from the classification that the samples collected from the warmer provenances like Bandhavgarh (BDG), Devendranagar (DNG), Jabalpur (JBP), Purulia

(PRL), Raipur (RPR) showed larger values of almost all the morphometric characteristics. Also, they showed lowest morphometric variations among themselves.