REVIEW OF LITERATURE
Mulberry (genus *Morus*), a perennial tree or shrub, is an economically important plant used yielding foliage and is the sole food for the domesticated silkworm, *Bombyx mori*. Mulberry is widely distributed in Asia, Europe, North and South America and Africa, and it is cultivated extensively in East, Central, and South Asia for silk production. Because it adapts easily to different ecological conditions and is easily hybridized, both naturally and artificially, abundant mulberry germplasm resources are available, making its genetic background rather complicated and highly heterozygous (Dandin, 1998). China and India, being the top silk producing countries, have developed a number of mulberry varieties suitable for a wide range of agro climatic conditions (Datta, 2000; Pan, 2000 and Pan 2003). Most of these mulberry varieties were developed from a few species such as *Morus alba* L., *M. atropupurea* Roxb, *M. bombycis* Koidz, *M. indica* L., *M. latifolia* Poir and *M. multicaulis* Perr, through more than 150 species were cited in the Index Kewensis and nearly 68 species are recognized and received wide acceptance (Datta, 2000). The major reasons for this restricted utilization of species are reported to be the lower leaf yield and the poor acceptability by silkworms as feed material. The reasons may be coarseness of the leaf, lower moisture content, lower moisture retention capacity in the harvested leaves and poor quality (Das 1984). Thus, a good number of species are unutilized and remains in wild condition.

In the recent revelation, it is reported that the genetic pool of the domesticated species is shrinking (Tikader and Dandin, 2007) and the wild species such as *M. serrata*, *M. laevigata*, *Morus nigra* and *M. tartarica* hold genes for several important traits like abiotic and biotic response and may be suitable for exploitation. Some of the varieties and species are attaining threshold level in yield which needs to be broken by both conventional and unconventional breeding
methods. Keeping this in view, several countries including India have taken strong initiatives for acquisition and utilization of wild relatives of mulberry genetic resources. Conservation of mulberry genetic resources entails several activities such as acquisition of germplasm, characterization, conservation and evaluation for agronomic traits to utilize the genetic resources for breeding and other research activities.

The literature pertaining to quantitative and qualitative evaluation of mulberry germplasm have been reviewed and presented as follows.

2.1. EVALUATION OF MULBERRY GERMPLASM FOR DIFFERENT GROWTH AND YIELD PARAMETERS

2.1.1 Growth and yield parameters

Susheelamma et al. (1988) observed that genotypes associated with larger leaf size and higher leaf weight yielded better leaf yield than those having higher number of primary shoots, more number of leaves per meter of shoot length and higher plant height.

Sastry et al. (1982) selected plants from F1’s of desired parents which showed plant height of 146 cm (local x Kosen P18) to 224 cm (S30 x RFS175 P7), number of primary shoots from 4 (local x Kosen P18) to 16 (S30 x Kosen. P22) and internodal distance of 2.72 (local x Kosen) to 4.12cm (S30 x RFS175) and the sprouting percentage on 25th day after planting was from 13 (local x RFS135 P4) to 87 per cent (Local x Kosen P10).

Kasiviswanathan and Iyengar (1969) reported maximum leaf yield of mulberry from season to season in a particular year is due to the wide behavioral variation met with during its growth.
Bari et al. (1988a) studied 64 accessions of mulberry and reported significant differences between the genotypes for various quantitative traits. The branch height ranged from 65.04 to 110.36 cm, number of branches from 11.11 to 37.5, number of leaves per branch from 23.87 to 34.02, leaf area from 55.44 to 190.18 cm$^2$, single leaf weight from 70 to 275g, internodal distance from 2.61 to 3.70 cm and leaf yield per plant from 101.44 to 402.11g over four seasons.

Aliev (1961) reported that, mulberry variety “Adreuli” was a rapidly developing variety with respect to traits viz., annual growth of stem, number of branches, length of the internodes and leaf yield as compared to variety ‘Syhgez’, in Azerbaijan region. He opined that the selection of genotypes of mulberry over the local genotypes could be made by considering the leaf yield, annual growth of stem, number of branches and length of the internodes.

Europeev (1966) obtained high leaf yield from introduced mulberry varieties and their hybrids. While evaluating the nutritive quality of introduced mulberry strains, importance was also given to leaf yield by considering different yield attributing characters.

Craiciu (1968) observed higher weight of leaves in four Soviet mulberry varieties than in Local variety ‘comun’. Among 45 selections made from open pollinated seedlings, wide range of variability was noticed regarding height of the plant, number of nodes per shoot and internodal distance. In another group of plants obtained from open pollinated strains of Kanva-2, significant difference between the plants for leaf yield was noticed (Anon., 1968a). It was further reported that plant height, number of nodes, length of the internode and leaf size were desirable characters for improvement of mulberry through selection (Anon., 1968b).
Das and Krishnaswami (1969) reported the possibilities of estimating the leaf yield in mulberry by concentrating yield attributing traits like plant height, number of branches, leaf size and internodal distance. Paolieri and Frota, (1970) selected six mulberry varieties showing higher leaf yield and leaf size from a group of 25 varieties.

Penkov (1979) studied five hybrids obtained between crossing of Bulgarian and Foreign varieties and found vigorous growth, cold resistance nature of the hybrids with medium to large sized leaves of entire or palmate type and leaf yield of 8250 to 9173 kg/ha/yr.

Shikata et al. (1981) conducted an experiment on yield performance of two Taiwan and Shimaguwa species of mulberry indicated that Taiwan mulberries recorded higher leaf yields than the Shimaguwa mulberries.

Gatin and Ogrustov (1981) studied the growth pattern in seven mulberry varieties and concluded that highest leaf yield was given by the varieties possessing vigorous growth of branches, number of vigorous branches of first order and highest number of buds and leaves.

Das (1986) mentioned the criteria for selection in mulberry that included characters like plant height, internodal distance, number of primary and secondary shoots, leaf area and leaf yield per plant.

Dandin (1986) opined that selection of promising genotypes was essential for planning and devising breeding programmers. In addition to the leaf yield, due importance was given to the yield attributing traits that reduced ineffective selection of genotypes.

Bari et al. (1988b) compared the morphological characters of some open pollinated progenies of mulberry and their parents and suggested that clone No’s
17 and 58 were the best performers and produced significantly higher leaf yield per plant than best improved selection BSRB-19.

Bari et al. (1989) reported that leaf size, number of leaves per plant and weight of the stem to be considered during selection programme were strongly associated with leaf yield in mulberry.

Sarathchandra et al. (1992) recorded high leaf yield in six mulberry varieties viz., S-36, RFS-135, English Black, Sujanpur-5, C-776 and S-799 as compared to Kanva-2 and S-54, S-36 followed by RFS-135, C-776 and S-54.

Twelve promising mulberry genotypes were studied for their leaf yield characters in winter, summer and rainy seasons. Under coastal salinity area, BC-259, S-30 and S-36 performed better for all the seasons with respect to leaf yield. Among the seasons, winter was found to be best suited for mulberry (Agastian et al. 1999).

Balakrishna et al. (1999) selected five high yielding and promising mulberry genotypes along with Kanva-2 and Mysore local for tolerance to coconut shade. Significant differences between genotypes were observed for all the characters like leaf area, total shoot length, number of branches. The interaction between shade and variety was significant under coconut shade, Kanva-2 × Kosen, RFS-135 and MR-2 recorded significantly higher leaf yield over control. Based on the study the genotypes Kanva-2 × Kosen and MR-2 recorded maximum and significantly higher leaf yield under coconut shade than varieties tolerant to coconut shade.

Prakash et al. (1999) studied nine genotypes of mulberry for their suitability to tree types with drought tolerance characters with an intention to introduce promising mulberry genotypes in watershed areas of Bijapur district which indicated that S-1 and S-1635 genotypes were superior with respect to plant
height, no of branches, leaf yield, moisture per cent and moisture retention capacity as compared to M-5 variety.

Tikader and Ananda Rao (2002) in their studies on growth performance of the mulberry observed that internode distance, leaf size, shoot length, leaf number and weight had positive effects on the leaf yield and recommended them as suitable characters for selection of cultivars.

Gargi Kumar et al. (1997) reported on growth and yield parameters in fourteen mulberry varieties. The plant height ranged from 1.73 to 2.30 cm, total shoot length from 9.49 to 8.19 m, number of leaves per meter length of shoot from 18.20 to 27.00, weight of 100 fresh leaves from 170.50 to 511.75 g, moisture content from 69.30 to 79.90 per cent, leaf yield /ha/year from 16.03 to 27.19 MT and overall results indicated that S-1635 variety performed better for all parameters followed by Kanva-2 and Tr-4.

Vijayan et al. (1998) utilized 33 triploid mulberry genotypes for the study and observed range of values for different quantitative traits; number of branches per stump (29 to 119.33), length of the longest shoot (65.67 to 152.33 cm), internodal distance (2.65 to 3.96 cm), moisture content (59.78 to 79.58 %), moisture retention (56.91 to 73.23 %), leaf yield (3928.71 to 33008.37 kg/ha/yr).

Fourteen exotic mulberry genotypes were evaluated for their suitability and significant differences in yield and yield attributing characters were observed. Among the genotypes leaf yield was maximum during Jun-Aug and Sep–Nov harvests. Papua New Guinea, Taisong-2 and Morus lembang were found superior for most of the yield attributing parameters. Papua New Guinea recorded leaf yield of 4294.3 g/plant/crop as compared to only 2434.2 g/plant/crop in case of Kanva-2 (Ninge Gowda and Sudhakar, 2002).
Chikkaswamy et al. (1999) conducted analysis of leaf peroxidase isozyme in ten mulberry genotypes. During analysis the variation was noticed in plant height from 152.44 to 170.46 cm, number of primary branches from 4 to 6.

Patil et al. (1999) studied the 15 quantitative parameters in relation to leaf yield among six genotypes and exhibited range of values. The number of branches / plant ranged from 6.16 to 8.85, total shoots length / plant from 572.36 to 833.93 cm, number of leaves per plant from 171.17 to 324.42, fresh weight of 100 leaves from 166.49 to 374.98 g, leaf yield /plant from 314.54 to 465.96 g.

Anonymous, (1970a) observed quantitative traits of some F₁ hybrids at CSRTI, Mysore and revealed wide range of variability for average number of shoots per plant (2.82 to 6.5), plant height (94 to 178 cm), internodal distance (2.5 to 3.3 cm), number of leaves per meter length of shoot (26 to 39) and weight of 50 fresh leaves (89.7 to 122.6 g).

Raju and Suhasini, (1982) studied ten triploid strains and reported that plant height ranged from 105 (Tr-4) to 174 cm (Tr-10) internodal distance from 1.72 (Tr -7) to 3.31 cm (Tr-10), number of leaves per meter length of shoot from 31 (Tr-10) to 58 (Tr -7) and weight of 50 fresh leaves from 42.7 (Tr -4) to 90.7g (Tr -3).

Anonymous, (1983a) reported the significant difference between the genotypes for plant height (71 to 146.85 cm), number of branches per plant (2.3 to 6.3), internodal distance (1.72 to 4.89cm) and leaf yield per plant (182 to 524.5g) under rain fed conditions.

Anonymous, (1983b) studied ten F₁ progenies and found that height of the plant ranged from 184.2 (Sujanpur x Phillippine P₀) to 212.40 cm (Sujanpur x Philippine, P₃), internodal distance from 3 (AB x Kokuso 13.P₄) to 4.51 cm (AB x Kokuso 13.P₁), sprouting percentage from 81.77 (K2 x BC.P₃) to 93.44 per cent
(AB × Philippine.P9) and moisture content of leaves from 72.50 (Mizusawa × cattaneo.P7) to 89.60 per cent (K2 × BC.P5).

Dandin et al. (1983) studied certain yield contributing characters like nature of leaf, percentage of consumable portion of leaf, growth rate, internodal distance and fresh weight of 100 leaves in 161 germplasm accessions at CSRTI, Mysore. For all the characters studied frequency of maximum variables were noticed.

Jolly and Dandin (1986) studied 250 accessions of both wild and cultivated forms belonging to 13 Morus spp., from 11 different countries and developed a descriptor including nine major groups of characters covering 138 characters contributing directly or indirectly to the growth and yield. Among the characters studied, plant height ranged from 100.30 to 355.40 cm, internodal distance from 2.25 to 7.38 cm, weight of 100 leaves from 98 to 1400g, sprouting percentage from 1.36 to 99.2, leaf area per meter length of shoot from 1225.73 to 7093.75 cm² and rooting percentage from 2.44 to cent per cent were recorded.

Lakshminarasimhaiah (1995) studied eight mulberry varieties like Mysore local, Kanva-2, S-30, S-36, S-41, S-54, S-13 and S-34 for morphological characters. Wide range of variation observed for total shoot length, number of branches per plant, internodal distance, petiole length, fresh weight of single leaf.

Fotedar et al. (2003) studied yield attributes in two varieties; S-146 variety gave better results in respect of number of shoots/plant (20.98), total shoot length (896.3 cm), number of nodes / meter (24.45), over Chakmajra variety.

Chikkalingaiah et al. (2008) evaluated twenty four mulberry accessions for different growth parameters. Mean values varied for different traits viz., plant height (14.17 to 152.33 cm), number of branches per plant (2.00 to 9.33), leaf area (11.00 to 163.00 cm²) and moisture content at 3 h (51.70 to 93.36%), at 6 h (56.17 to 87.40%), 12 h (49.63 to 80.65%), at 24 h of leaf storage (33.78 to 87.99%) and
dry weight (1.24 to 11.20 g). Based on mean performance, MI-79 was better for most of the growth parameters \textit{viz.}, plant height, number of branches per plant, number of leaves per plant and leaf moisture content at different duration of leaf storage. High heritability was recorded for plant height (0.83), number of leaves per plant (0.83), petiole length (0.81), leaf area (0.88) and leaf dry weight (0.83).

Fotedar \textit{et al.} (1989) observed variation in leaf yield from 20.15 tons to 27.07 tons/hectare among the different cultivars. Kokuso-27 recorded the maximum leaf yield followed by Kairyoroso and the differences were significant over Goshoerami which is the widely cultivated variety in Kashmir.

Yokoyama (1962) reported that the leaf yield depends upon the number and length of shoots, internodal distance and number and weight of leaves per plant.

Sujay Kumar \textit{et al.} (2007) evaluated eight mulberry genotypes \textit{viz.}, Anantha, S-34, S-30, S-11, S-30, V-1, MR-2 and K-2 or M-5. Parameters pertaining to propagation, growth and yield were studied in different seasons and the average values were counted through selection index for bringing out the best performer \textit{i.e.}, a suitable variety. S-13 performed well for propagation parameters while for growth and yield parameters Anantha variety excelled.

Mir \textit{et al.} (2003) reported that Goshoerami, Togowase, Kaiyoroso, Ichinose and KNG were found superior in terms of leaf yield per plant, Rokokuyaso, Chinese White and Tr-10 in terms of number of branches per plant, whereas Ensatakasuke and Sanish-5 were superior in terms of number of nodes per meter length of shoot.

Santhosha Gowda Patil (2002) evaluated mulberry genotypes for irrigated condition which revealed that S-1635 genotype recorded higher total shoot length, fresh leaf weight, dry leaf weight, larger leaf area, leaf yield /plant (58% more) and better leaf quality as compared to M-5 genotype.
Naidu et al. (2008) conducted studies on mulberry accessions for leaf yield, shoot yield and yield attributing parameters and the results revealed that MI-0461 and MI-0463 were significantly superior over the other mulberry accessions.

Vijayashekara (2009) evaluated fifty mulberry accessions for morphological characters in rainy and winter season. It was reported that leaf yield per plant was maximum in C-763 (2888.68g), C-20 (2446.6g) in rainy season. Whereas, in winter season ME-27 (1658.0g) and S-13 (1399.7g) recorded maximum leaf yield per plant.

2.1.2 Trichome density

In mulberry (Morus spp.) genotypes, fully expanded leaves are usually devoid of epidermal hairs and have only idioblasts. But their tender growing shoot tips are covered with glandular and non-glandular trichomes in varying densities (Shah and Kachoo, 1975). In many crops plants, the trichomes are reported to play a major role through antixenosis, a mode of plant defense against insect damage (Levin, 1973) and adaptations to arid conditions (Fabn, 1986). In some mulberry genotypes, the trichome density was found to increase in response to water deficit treatment (Jalaja Kumar et al., 2003) and tukra infestation (Babu et al., 2004).

In mulberry, trichome density is very high in younger parts but decreases rapidly with leaf expansion. The indumentums of non-glandular trichomes and lipophilic substances secreted by glandular trichomes serve as a barrier against herbivores and pathogens (Allen, 1991), UV-B radiation (Karaboumiotis et al., 1993), extreme temperatures and excessive water loss (Ehleringer, 1982). Leaf pubescence as a genetically controlled character (Bernard and Singh, 1969; Muttuthamby et al., 1969; Leisle, 1974) was found to be important in breeding for pest resistance in cotton (Ramey, 1962), wheat (Leisle, 1974).
Chandrashekara and Basavaiah (2010) studied trichome density, the number per mm length of epidermis, in transverse sections of tender stem, petiole and leaf (adaxial and abaxial surfaces) of shoot tips in eight colchitetraploids of popular mulberry genotypes. Among the colchitetraploids studied, the trichome density was found high in Mysore local (4x) and RFS-175 (4x), medium in DD (4x) and Ber. S1(4x). So, Mysore local (4x) and RFS-175 (4x) are better parents in breeding pest resistance and drought tolerance in mulberry.

2.1.3 Moisture content

Anonymous (1970b) noticed wide range of variation for moisture content in tender (61.58 to 74.17 %), medium (58.48 to 70.35 %) and coarse mulberry leaves (53.36 to 69.00 %).

Ninge Gowda et al. (1988) studied fifteen exotic mulberry varieties for moisture content. Results revealed that Okinawa-2, Morus lambing, Thailand, Papuva, Morus nigra, Morus multicaulis varieties have higher moisture content compare to control K-2 variety.

The moisture content of the leaf fit for young age silkworm rearing ranged from 75 (Ber S1) to 78 per cent (S-41) whereas S-30 and S-36 showed 74 per cent leaf moisture. (Anon., 1983b). Maximum moisture content in Chawki leaf was recorded in Kosen (77.34 per cent) followed by Ber C-799 (77.30 %) out of 25 varieties except in S-1 where the moisture content was not above 70 per cent (Anon., 1983c).

Govindan et al. (1988) observed significant difference in moisture content at 8 and 24 h after harvest in leaves of six varieties of mulberry like Mysore local, Kanva-2, S-30, S-36, S-41 and S-54.
Sastry et al. (1980) observed the loss of moisture from 9.00 am to 4.00 pm in leaves of improved strains of mulberry like S-30, S-36, S-41, S-54, Kanva-2 and Mysore local in three traits. The loss of moisture content was found to be 17.61 per cent ± 0.94 in S-30 and 23.17 per cent ± 0.98 in S-36. There were considerable varietal differences with regard to the degree of moisture loss from the leaves.

Susheelamma et al., (1988) utilized twelve drought resistant mulberry varieties along with two cultivars for evaluation under natural stress (rain fed) condition. Moisture per cent and moisture retaining capability of leaves after 6, 12 and 24 h of excision were estimated. It was observed that the new mulberry varieties DTS-14, DRS-28, DRS-3, and DRS-34 retained more moisture in the leaves after 6, 12 and 24 hours of excision.

Mala et al., (1992) studied moisture per cent and moisture retention capacity in five mulberry varieties and concluded that S-36, S-30, K-2 varieties possessed maximum moisture per cent and moisture retention capacity as compared to other varieties.

Bongale and Chaluvachari (1995) reported that Mysore local variety possessed lower leaf moisture content and moisture retention, while English Black, KNG, Berhampore-5 variety had relatively higher moisture and moisture retention capacity out of eight mulberry varieties used for the study.

Vijayan et al. (1997) studied 152 mulberry varieties for leaf moisture and observed wide range of variation in different seasons. The leaf moisture varied from 54.93 to 82.43 per cent, 61.66 to 84.39 per cent and 56.73 to 80.39 per cent during summer, rainy and winter seasons respectively.

Mallikarjunappa et al. (2000) evaluated four improved mulberry genotypes namely S-30, S-36, Viswa and M-5 for moisture content and moisture retention
capacity. The leaf moisture content was significantly higher in Viswa (77.74%) and S36 (77.24%) genotypes. Leaf moisture loss at 6 h after harvest was significant less in S-36 and S-30 genotypes (13.46 and 13.92% respectively).

Sujathamma and Dandin (2000) studied 23 elite mulberry genotypes and observed wide range of variation in moisture content of fresh leaves which ranged from 64.4 to 76.94 per cent. The maximum value was found in Tr-10 followed by Tr-4 (75.99%) and minimum moisture percentage was recorded in Sujanpur-5. The moisture retention ranged from 57.39 to 71.41 per cent in 23 elite genotypes. Higher moisture retention was found in Tr-10 (71.41%) followed by Tr-4 (70.14%) and the minimum was noticed in Sujanpur-5 (57.39%).

Tikader and Roy (2003) conducted the experiment on 15 accessions for moisture per cent and recorded maximum values for Senmates (81.40%) and lower in Kajli (56.83%), moisture retention capacity was higher in Senmates (88.07%) and lower in M. indica (35.21%).

Susheelamma and Dandin (2006) studied five mulberry varieties for moisture per cent and moisture retention capacity which ranged from 74.15 to 79.00 per cent, 61.60 to 66.15 per cent respectively. The improved cultivars like S-13, S-34 and V-1 exhibited higher moisture content and moisture retention capacity of leaf compare to commercial cultivars like Kanva-2 and S-36.

Tikader and Thangavelu (2005) utilized wild species of M. laevigata and M. serrata for hybridization programme and F₁ progenies showed enhancement for growth traits over that of both parents. Single leaf weight, leaf area, moisture per cent, moisture retention per cent, and leaf yield showed increase from 8.44 to 45.50 per cent than female and 11.84 to 102.67 per cent than male parent.
Thangamani and Vivekanandan (1984) observed wide range of variation in eight varieties of mulberry for moisture content (63.67 to 70.60 %) and total sugars (8.64 to 15.58 %).

Ramachandra et al. (2008) evaluated the leaf quality of five selected varieties of mulberry viz., S-36, S-54, M-5, DD and V-1 and their study indicated that significant difference was observed for leaf moisture content, protein, sugar, total chlorophyll. Among all the varieties V-1 showed better values for all the parameters.

Jalaja Kumar and Ram Rao (2008) studied leaf quality parameters in seven mulberry genotypes viz., V-1, V-2, V-4, K-2, S-13, S-36 and S-54 and reported higher leaf moisture content (LMC) and moisture retention capacity (MRC) in V-1 (75.93% and 82.17%) followed by V-4 (75.67% and 81.64%) and S-36 (75.14% and 81.27%), while these two traits were found to be lowest in K-2 (69.50% and 76.25%). Leaves characterized by higher LMC and MRC were identified as superior quality leaves (Bongale and Chaluvachari, 1995). Also the above two traits are closely associated with the feeding efficiency and growth rate of silkworm larvae (Paul et al., 1992 and Chaluvachari and Bongale, 1995).

Mamrutha et al. (2010) studied variability for moisture retention capacity (MRC, measured as leaf relative water content after one to five hours of air-drying) by screening 250 diverse mulberry accessions and the relationship between MRC and leaf surface (cuticular) wax was determined. Leaf MRC was significantly different among accessions and was found to correlate strongly with leaf surface wax.

2.1.4 Pests and diseases

Leaf spot and leaf rust intensity varied considerably among the genotypes studied. Ten genotypes were resistance to leaf spot and the PDI varied from
1.21 (Miz x S-41) to 4.80 (S30 x Ber. C-776), the PDI for leaf rust ranged from 9.58 (Acc 155 x Ber. S-799) to 17.50 (Miz x RFS-135) (Philip et al., 1996).

The spread of tukra in V-1 variety is less compared to other varieties like local, K2, S13, S34, S36 suggesting V-1 variety to be relatively tolerant to tukra (Anon., 1998).

Manjunatha et al. (2001) observed maximum (1.87%) incidence of thrips during March and the same was minimum (0.31 %) during August. The maximum temperature had a significant positive correlation with the thrips population (r=0.6115), whereas relative humidity (r= -0.6730) and rainfall (r=0.3256) had a significantly negative correlation with the thrips population.

Rajagopal Reddy et al. (2004) reported that infestation of mealy bug caused 30-40 per cent of mulberry leaf yield loss, due to which affected the rearing capacity.

Reddy et al. (2008) evaluated the leaf yield and reported that MV-5 (Anantha) was significantly superior over other mulberry varieties including S-1635, S-36 and Kanva-2. Anantha exhibited tolerance to pest and diseases as compared to other mulberry varieties.

Chattopadhyay et al. (2010) screened about 147 germplasm sources, representing 18 countries of origin, for resistance to Phyllactinia guttata (syn. P. corylea) in six seasonal field and greenhouse trials after exposure to natural and artificial inoculum, respectively. In the field, the level of plant responsiveness to disease was assessed from 30 to 62 days after pruning in each season as there was variation in the disease severity index (DSI), disease incidence (DI%) and area under the disease progress curve (AUDPC). These measures differed significantly among the germplasm. Of 147 germplasm sources, 6.8 per cent had useful resistance (two high and nine moderately resistant) to the powdery mildew
pathogen on the basis of DSI. The AUDPC values were 13.5 fold higher in the most susceptible accession (Philippines) than the least responsive.

Vasudha Prabhakar (2011) evaluated 100 mulberry genotypes for their reaction to sucking and defoliating pests. Variability in pest incidence among individual genotypes was observed but maximum infestation of sucking pests (Pink mealy bug and thrips) was recorded in pre-monsoon season whereas maximum infestation of defoliators (Bihar hairy caterpillar and wingless grass hopper) was registered in post monsoon season.

Vasudha Prabhakar and Neelu Nangia (2012) reported that the level of infestation of Pink mealy bug in pre-monsoon season was highest (26.18%) compared to other two seasons viz., monsoon (6.02%) and post monsoon (7.17%). Mulberry genotypes namely ME-84 and ME-18 were found susceptible to sucking pests and defoliators during pre-monsoon, monsoon and post monsoon seasons. Whereas, ME-86 was resistant to sucking pests and defoliators.

**2.1.5 Types of leaf venation**

Penkov (1979) studied five hybrids obtained between crossing of Bulgarian and Foreign varieties and found vigorous growth, cold resistance nature of the hybrids with medium to large sized leaves of entire or palmate type and leaf yield of 8250 to 9173 kg/ha/yr.

**2.1.6 Evaluation of mulberry germplasm for fruit traits**


Machii et al. (1999) used 260 mulberry genotypes to study traits such as inflorescence, fruit quantities and sizes, fruit sugar content and seeds per fruit. The
Ahizensei-roso, Tenmokuyotsume and Itouwase genotypes bore large quantities of fruit. The okaragawa genotype had the largest fruit.

Chikkalingaiah *et al.* (2009) evaluated 35 mulberry accessions for their fruit characteristics. It is observed that fruits are formed in two seasons in a year during October-November and March-May. Maximum length of the fruit was recorded by accession ME-18 (3.20 cm) followed by Karanahalli (3.0 cm) and S-46 (2.8 cm) as against average of 2.58 cm. However Minimum fruit length of 0.90 cm was recorded by Surat local.

Iqbal *et al.* (2010) reported that four mulberry cultivars Black Mulberry (*Morus nigra*), White Mulberry (*Morus alba*), Red Mulbery (*Morus rubra*) and Kabli Mulberry differed significantly in average fruit weight and length that ranged from 2.54 to 3.02 g and 1.61 to 2.23 cm, respectively. The fruit of Red Mulberry was more heavier and longer followed by Kabli Mulberry which were statistically similar. Kabli Mulberry was superior in sensory assessment in terms of taste, colour and flavour followed by Black Mulberry, which was comparable to Kabli Mulberry.

### 2.1.7 Genetic variability

For effective selection and utilization of genotypes for breeding programme, a thorough study of genetic variability present in the plant material is needed and helps to compare the genetic variability present in different traits.

Kasiviswanathan and Iyengar, (1969) documented wide range of variability for most of the quantitative traits like number of shoots per plant, plant height, number of leaves per meter length of shoot and fresh weight of 100 leaves in some indigenous mulberry varieties.
Rangaswami *et al.* (1978) noted wide range of variability in different strains of mulberry for various yield dependent characters like leaf shape and size, plant height, internodal distance, number of primary shoots and secondary shoots and mentioned the importance of concentrating on these characters before aiming at selecting the genotypes for higher leaf yield.

Out of 23 selections made from open pollinated seedlings, the quantitative traits like plant height (117 to 235 cm), number of shoots per plant (2 to 10), internodal distance (1.62 to 2.89 cm) and number of leaves per meter length of shoot (12 to 32) showed considered amount of variation (Sastry *et al.*, 1980).

Jolly *et al.* (1982) recorded wide range of variation regarding plant height (117 to 300 cm), number of shoots per plant (3 to 8), internodal distance (1.62 to 5.0 cm), weight of 100 leaves (182.8 to 450.2 g) and leaf yield of two harvests (232 to 562 g) in 28 open pollinated hybrids at CSR and TI, Mysore.

Bhat (1989) reported that high degree of variability for shoot to root ratio by length, shoot to root ratio by dry weight, number of secondary shoots, number of primary shoots, weight of 100 fresh leaves and number of leaves per plant showed moderate amount of variation.

Among 11 mulberry accessions, wide range of variability was noticed for leaf yield (1.12 to 2.07 kg), 100 leaf weight (306.17 to 786.33 g), leaf area (248.67 to 561.00 cm$^2$) and moisture content (66.22 to 72.33 %) (Sekhar *et al.*, 1997).

Tikader and Roy (1999) studied the genetic variability and character association in 15 mulberry germplasm accessions and the studies revealed that all the traits exhibited significant differences indicating the presence of sufficient genetic variability in the germplasm accessions. Among the accessions Kosen and Mandalaya gave significantly higher values for number of shoots, length of longest shoot, leaf area and leaf yield per plant.
An experiment was conducted with 18 mulberry genotypes revealed lot of variation for quantitative traits viz., plant height (120 to 258 cm), number of branches (4.3 to 38), total length of branches (214 to 2900 cm), number of leaves /length of branch (12.3 to 24.5), weight of 100 leaves (189 to 464 g), leaf area (74.5 to 201 cm²), leaf yield /plant (144 to 1054 g), weight of shoot /plant (97 to 1044 g) moisture content of leaf (66.4 to 83 %), moisture retention capacity of leaf (20.6 to 59 %) (Masilamani et al., 2000)

Tikader and Roy (2001) reported variation in growth traits in 15 mulberry germplasm accessions which ranged from 14.33 to 100 for shoot number, 31.67 to 153.67 cm for length of the longest shoot, 779.33 to 10153.33 cm for total shoot length, 2.12 to 4.03 cm for internodal distance, 106.85 to 311.28 cm² for leaf area, 56.83 to 81.40 per cent for moisture content, 35.21 to 78.07 per cent for moisture retention, 95.77 to 157.70 g for single leaf weight and 0.85 to 5.00 kg for leaf yield per plant.

A wide range of variability in 328 mulberry germplasm lines for growth attributes in different characters was noticed. Maximum variability was observed for number of branches per plant, total shoot length, 100 leaves weight, leaf area, petiole length, leaf yield per plant. Minimum variation was observed in moisture content, moisture per cent after 6 h, internodal distance (Tikader and Ananda Rao, 2002).

Tikader et al. (2003) studied one hundred and sixteen genotypes of exotic mulberry accessions (Morus spp.) under tropical dry climate of Hosur. Variability was observed in different growth attributes such as number of shoots (2 to 66), length of longest shoot (23.67 to 235 cm), internodal distance (2.5 to 7.01 cm), total shoot length (42.33 to 6586.33 cm), 100 leaf weight (78.48 to 1241.85 g), leaf yield per plant (0.07 to 2.38 kg), moisture content (61.19 to 86.63 %),
moisture retention capacity (26.80 to 82.56 %) and total biomass weight (0.113 to 4.70 kg).

Variability in respect of growth and anatomical parameters were studied in 15 mulberry germplasm accessions. A wide range of variation was observed among different accessions for different growth parameters. Number of branches ranged from 100 in Mandalaya to 14.3 in Kanva-2, longest shoot length was higher in Mandalaya (153.67 cm) and lower in Tushimakowa (31.67 cm), total shoot length varied from 779.33 cm in Tushimakowa to 10153.33 cm in Mandalaya, internodal distance was higher in Kosen (4.03 cm) and lower in Tushimakowa (2.12 cm). Variation in leaf area was observed among accessions; maximum in Tushimakowa (311.28 cm²) and minimum in Kajli (106.85 cm²) (Tikader and Roy, 2003).

Eswar Rao et al. (2004) studied seven genotypes of mulberry with wide range of variation for average number of branches/plant (5.45 to 8.31), total shoot length/plant (524.07 to 1394.09 cm), internodal length (4.15 to 5.66 cm), fresh weight of 100 leaves (320.44 to 706.87 g), leaf area (168.196 to 255.296 cm²) and leaf yield/plant (0.479 to 0.880 kg). The genotypes of different ploidy levels exhibited variation with respect to growth and yield parameters, wherein triploids performed better compare to other ploidy levels.

An estimation of genetic variability was made by Rahman et al. (2004) for 45 mulberry varieties maintained in the germplasm bank of Bangladesh Sericulture Research and Training Institute, Rajshahi for ten quantitative characters with observation of wide scale of variation for all the characters and sufficient variability existed within the characters and among the genotypes.

Tikader et al. (2004) characterized 300 mulberry germplasm accessions. High co-efficient of variations were observed in exotic and indigenous accessions
for number of shoots, total shoot length per plant, lamina weight, petiole weight, 100 leaf weight, and leaf yield per plant indicating ample scope for improvement in these traits through selection. Moderate variability was observed for longest shoot and internodal distance. The low variability was recorded for leaf moisture percentage and leaf moisture retention at 6 h. A low variability for these characters emphasized the need for generating more variability.

Tikader and Dandin (2005) utilized 15 accessions of M. *serrata* in CSGRC, Hosur. The variation in different growth attributes ranged from 5.1 to 21.33 for shoot number, 57.50 to 175.00 cm for length of the longest shoot, 3.97 to 7.63 cm for internodal distance, 298.97 to 829.58 g for 100 leaf weight, 68.10 to 80.22 per cent for moisture content, 55.13 to 75 per cent for moisture retention capacity and 0.33 to 2.22 kg for leaf yield /plant.

Variation was observed in fifteen mulberry germplasm accessions for different growth attributes with branch number ranged from (25 to 97), biomass weight (2.25 to 45.0 kg), internodal distance (2.54 to 5.29 cm), leaf area (64.03 to 242.00 cm$^2$) and leaf yield per plant (1.25 to 23.00 kg) (Tikader and Roy, 2006).

Jyoti Biradar (2010) utilized 90 mulberry accessions for genetic variability studies. The range of variability was maximum for plant height, total shoot length, number of leaves per plant and leaf yield per plant. All parameters studied were least affected by environment showing a close correspondence between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) in both seasons. High heritability estimates were for all the parameters except leaf moisture content, leaf moisture retention capacity at different hours and fruit traits.
2.1.8 Correlation studies

Yield being a complex character, entails information regarding its correlation with other yield attributing characters. An understanding of correlation that exists among important characters provides useful information for planning future breeding programmes.

Wright (1921) elaborated the correlation technique and developed path co-efficient analysis which was later demonstrated by Dewey and Lu (1957) for use in plant selection. This measures the direct influence of one variable upon other and permits the separation of correlation co-efficient into components of direct and indirect effects.

Susheelamma and Jolly (1986) reported while evaluating 61 germplasm accessions of mulberry for various morpho-physiological parameters associated with drought resistance, a negative correlation between stomatal size and moisture retention capacity of leaf.

Susheelamma et al. (1988) worked out correlation and path analysis in 64 genotypes of mulberry and their study revealed that average number of primary branches per plant showed high significant correlation and positive direct effect on leaf yield in stress and non-stress conditions. But number of secondary shoots per plants showed significant positive correlation and positive direct effect on leaf yield in stress condition only, weight of 100 leaves showed positive correlation and negative direct effect and negative correlation and negative direct effect on leaf yield under non stress and stress conditions respectively. The number of leaves per meter length of shoots and leaf moisture percentage showed negative correlation with leaf yield. Average length of the shoot showed negative and positive association with leaf yield under stress and non-stress conditions respectively.
Bari et al., (1988a) used open pollinated four parental lines of mulberry for phenotypic, genotypic and environmental variability of nine quantitative characteristics over four seasons and the results revealed that there was less environmental co-efficient of variation and high genetic advance was observed for all characters studied, except branch height and internodal distance, indicating that the variations in most of the traits were genetically controlled. Significant interaction between genotype and season was also noticed.

Bari et al. (1988b) observed significant positive correlation between branch height, leaf yield, leaf number per branch and internodal distance but branch height showed negative and significant association with leaf yield. Number of branches per plant had positive and significant association with leaf yield and number of leaves per branch. Weight of single leaf increased with increased internodal distance but decreased with increased in number of branches and number of leaves per branch.

Bari et al. (1989) concluded that leaf size, leaf number per plant and stem weight per plant were strongly associated with leaf yield per plant in mulberry. Four varieties and sixty open pollinated selections of mulberry were used to study correlation co-efficient and the estimation of simple correlation co-efficient indicated a highly variable spectrum of relationship. Highly significant and positive association was observed between leaf yield and branch height, leaf number per plant, leaf size and stem weight per plant. Both negative and positive associations were observed among component characters.

Rahman et al. (1994) also found the significant and positive association of total branch number and total branch height with total leaf yield, however, nodes/meter showed negative correlation with other characters including leaf yield at both phenotypic and genotypic levels.
Correlation between leaf yield and various morpho-anatomical characters revealed a wide spectrum of variation in 33 tropical mulberry varieties. Positive significant correlations were found between leaf yield and number of primary branches per plant, leaf thickness, spongy layer thickness and weight of 100 leaves (Vijayan et al., 1998).

Maslamani and Kamble, (1998) indicated genotypic correlations of leaf yield per plant and were highly significant and positive with plant height, number of primary branches, total number of leaves per plant, weight of 100 leaves and leaf area. Maximum direct contribution of leaf yield per plant was made by number of nodes per meter length of a branch and weight of 100 leaves.

Tikader and Roy (2001) studied the correlation co-efficient among 14 characters for 15 accessions. Number of shoots showed positive significant correlation with the length of the longest shoot, total shoot length, and leaf yield per plant. Nodal distance recorded significant negative correlation with leaf area and single leaf weight but, moisture percentage was positively related with single leaf weight.

Correlation matrix between leaf yield and various morpho-anatomical parameters were analyzed for 15 accessions. Positive significant correlations were observed between leaf yield with number of shoots, longest shoot length and total shoot length per plant and single leaf weight. However, leaf yield showed negative correlation with longest shoot length, internodal distance and survival per cent. Further, positive significant correlation was obtained with leaf area and moisture per cent (Tikader and Roy, 2003).

Rahman et al. (2004) studied the phenotypic and genotypic correlation co-efficient between pairs of characters for 45 mulberry varieties at phenotypic level with total branch number showing significant positive correlation with total branch
height, total stem weight, total leaf yield and non significant but positive correlation with height of the longest shoot, stem girth and moisture percentage.

Chaturvedi and Pandey, (2005) studied the genotypic and phenotypic correlation of plant biomass, plant height, stem diameter and other biomass component traits were analyzed in thirty provenances of *Bombyx ceiba*. In general, the magnitude of genotypic correlations was higher than phenotypic correlations. Stem diameter and plant biomass showed highly significant genotypic correlations with all the traits except the number of secondary branches and plant biomass with leaf biomass. Plant height had the highest positive direct effect on plant biomass followed by the number of primary branches/plant and the number of leaves/plant. On the basis of this study, a higher plant biomass would be achieved through direct selection based on plant height, the number of primary branches and the number of leaves/plant. Therefore, the study is important in selection of traits of economic importance based on other characters, whose direct effect is not visible.

Tikader and Dandin (2005) studied correlation co-efficient matrix which was recorded among eight parameters. The number of shoots showed positive significant correlation with internodal distance, total shoot length, and leaf yield. The correlation matrix showed that leaf yield is highly associated with shoot number, length of the longest shoot, internodal distance, that shoot length and moisture retention capacity.

Ram Rao *et al.* (2006) studied the correlation for ten quantitative characters of thirty mulberry genotypes. The number of leaves / plant number of primary branches / plant and leaf area showed high GCV and PCV, for number of leaves/plant, number of primary branches/plant, weight of 100 leaves and biological yield/plant with high heritability and high GA exhibited strong positive correlation and high direct effect on leaf yield. Over all study revealed that number of primary branches/plant, number of leaves/plant, leaf area, weight of 100 leaves,
biological yield/plant and harvest index are the major yield determining characters.

Eswar Rao et al. (2004) studied seven genotypes of mulberry with wide range of variation observed for average number of branches/plant (5.45 to 8.31), total shoot length/plant (524.07 to 1394.09 cm), internodal length (4.15 to 5.66 cm), fresh weight of 100 leaves (320.44 to 706.87 g), leaf area (168.196 to 255.296 cm²), leaf yield/plant (0.479 to 0.880 kg) the genotypes of different ploidy levels with respect to growth and yield parameters triploids performed better compare to other ploidy levels.

Banerjee et al. (2007) studied the correlation which suggested that the direct selection of lamina length, fresh leaf weight, leaf area, and single leaf weight will be rewarding for mulberry leaf yield improvement.

2.2 BIOCHEMICAL COMPOSITION

The nutritional status of mulberry leaves influences the silkworm nutrition as the growth of the worm entirely depends upon the quality of leaf (Anonymous, 1975). The nutritive value of mulberry leaves depends on various factors and one of them is the varietal component of leaf. The leaf contains different level of carbohydrates, proteins and minerals (Agastain and Vivekanandan, 1977).

Leaf quality of five selected varieties of mulberry viz., S-36, S-54, M-5, DD and V-1 were evaluated for leaf moisture content, protein, sugar, total chlorophyll. Significant differences were recorded among the varieties. Among all the varieties V-1 showed better values for all the parameters (Ramachandra et al., 2008).

Jalaja Kumar and Ram Rao (2008) studied the leaf quality characters in seven mulberry genotypes viz., V-1, V-2, V-4, K-2, S-13, S-30 and S-54, under field conditions of CSR&TI, Mysore. The quality traits viz., leaf moisture,
moisture retention (at 6 h of harvest), protein, nitrogen, carbohydrate and amino acid contents were found to be high in V-1 followed by V-4 and S-36.

Bongale et al. (1991); Chaluvachari and Bongale (1995) and Bose and Bindroo (2001) reported that different quality traits such as leaf moisture content, protein content, carbohydrate content, nitrogen content, amino acid content and chlorophyll content are responsible for leaf quality.

Doss et al. (2007) evaluated twenty five improved mulberry varieties for physio-biochemical parameters, growth and leaf yield etc., under irrigated conditions of West Bengal. Photosynthetic rate, stomatal conductance, transpiration rate and photosynthetic water use efficiency were found varying significantly among the varieties tested. Leaf protein, sugar, phenol, moisture contents were found higher in different varieties. Among them, the variety, C-2017, having higher leaf yield (39,845 kg/ha/yr), higher chlorophyll content (2.453 mg/g/fw), moderately higher sugar (43.87 mg/g/fw), soluble protein (34.78 mg/g/fw) and phenol content (9.97 µg/g/fw) and a higher leaf moisture content (76.76%) and moisture retention capacity (80.11%) may be utilized for commercial exploitation.

Varieties possessing high nitrogen and amino acids contents in leaves are nutritively superior and promote growth and development of silkworm (Machii and Katagiri, 1991; Suryanarayanan and Shivashankar Murthy, 2002)

Jalaja Kumar and Ram Rao (2008) analyzed leaf quality of seven mulberry genotypes and reported that total chlorophyll content was the highest in S-13 (3.35 mg/g fresh wt.), V-1 (3.24 mg/g fresh wt.) and V-4 (3.12 mg/g fresh wt.), while it was the lowest in S-36 2.55 mg/g fresh wt.). Higher chlorophyll content in leaves indicates the photosynthetic efficiency; therefore it can be used as one of the
criteria for quantifying photosynthetic rate in mulberry (Sujathamma and Dandin, 2000).

Jalaja Kumar and Ram Rao (2008) reported that among seven genotypes evaluated, total protein content was the highest in V-1 (24.56%) followed by S-36 (23.89%) and V-4 (22.67%). High leaf protein content is closely associated with higher moisture and moisture retention capacity in leaves and favours the larval weight and moulting ratio in second moult (Chaluvachari and Bongale, 1996). Also it was reported that low LMC and protein content in leaves affect the larval growth and cocoon weight (Li and Sonu, 1984). On the other hand, Machii and Katagiri (1991) opined that increased protein content beyond the optimal level in mulberry leaves leads to a marginal improvement in cocoon productivity.

Protein and amino acids are of particular importance for the silkworm larvae because of their active utilization for the synthesis of silk proteins. Horie (1978) who studied the utilization of food stuff by silkworm reported that the optimum dietary protein level of 20-21 per cent is required for better growth of silkworm larvae.

In mulberry leaves carbohydrates are available in plenty (Hiratsuka, 1917) and it was reported to be chief source of energy for silkworm (Horie, 1978). Carbohydrates are estimated based on the amount of sugar and starch content available in leaves (Bose and Bindroo, 2001). If the leaves have high carbohydrate content, silkworms gain more energy and in turn may enhance the synthesis of silk protein.
2.3 SILKWORM REARING PARAMETERS AND CONSUMPTION INDICES

2.3.1 Economic Parameters

Jalaja Kumar and Ram Rao (2008) studied the leaf quality characters in seven mulberry genotypes viz., V-1, V-2, V-4, K-2, S-13, S-30 and S-54, under field conditions of CSR&TI, Mysore. The bioassay study with silkworm race PM×NB4D2 also revealed that the silkworm growth and cocoon characters were optimum when the leaves of V-1, V-4 and S-36 were fed to the larvae. Overall study revealed that the genotypes V-1, V-4 and S-36 were superior to other genotypes in terms of leaf quality and leaf quantity.

Fotedar and Dandin (1997) observed wide range of variation in mulberry genotypes and discussed the importance of quality of mulberry leaves used as feed for silkworm. Pillai and Jolly (1985) recorded some distinct varietal superiority on the cocoon characters. Growth and development of *B. mori* and inturn economic traits viz., cocoon yield, cocoon weight, shell weight and shell ratio were greatly influenced by the nutritional level of mulberry leaf (Krishnaswami *et al.*, 1971).

Krishnaswami *et al.* (1970) observed that Berhampore variety was better than Kosen and Mandalaya with regard to effective rate of rearing and mean cocoon weight. According to Saratchandra *et al.* (1992) the varieties S-36, RFS-135 and C-776 are equally good in their leaf yield and cocoon yield.

The effect of nine mulberry varieties viz., Kanva-2, Kosen, LM-1, LM-2, Mysore local, S-30, S-36, S-41 and S-54 on the growth and development of silkworm, *Bombyx mori* L., was assessed. Significant differences were observed in larval duration, weight of larvae, single cocoon weight, shell percentage, fecundity and yield of cocoons when the silkworm larvae were fed on these mulberry varieties. However, S-54 showed higher values in all the characters. In general, S-
54 variety of mulberry was observed superior followed closely by S-41 and Kanva-2 for feeding the silkworm larvae for yield and yield contributing traits (Tayade et al., 1988).

Ninge Gowda and Sudhakar (2002) utilized fourteen exotic mulberry genotypes maintained in the germplasm bank at Bangalore University, Bangalore for the study. After the initial establishment for three years, the genotypes were evaluated for growth, leaf yield parameters and rearing traits for one year and compared with local variety Kanva-2 grown under similar conditions. Papua New Guinea recorded leaf yield of 4294.3 g/plant/crop as compared to only 2434.2 g/plant/crop. With respect to growth, leaf yield, quality and rearing traits, Papua New Guinea could be considered a potential genotype for breeding high yielding varieties for tropical regions in India.

Tikader and Thangavelu (2002) reported that more than 20 kg cocoon / 100dfls were harvested after feeding the *M. serrata* leaves at late age with bivoltine hybrids.

The rearing performance of *M. laevigata* was assessed throughout rearing and observed larval period (26 days); weight of ten mature larvae (32.02g); yield/10000 larvae (5077 no.); 6400g by weight; single cocoon weight (1.28g); shell weight (0.223g) and silk ratio (17.33%) (Tikader, 1993).

Effect of feeding leaves of *M. alba* and *M. laevigata* were assessed on larval growth and silk yield of *B. mori* L. by Mahmood et al., 1987 and the result indicated that *M. laevigata* leaf was better in rearing performance than *M. alba*.

Dar et al. (1988) evaluated three improved Japanese cultivars of mulberry, namely Ichinose, Gosherami and Kokusu-27, those introduced in Kashmir valley and reported that feeding of Ichinose leaves resulted in higher weight of mature
larvae and improvement of economic traits of cocoon such as, cocoon and shell weights and silk percentage as compared to other two varieties.

Khan *et al.* (2007) evaluated seven mulberry genotypes *viz.*, SKM-20, SKM-27, SKM-33, SKM-36, SKM-48, Goshoerami and Ichinose through chemo and bio-assays. The study revealed that Ichinose was the most outstanding genotype for twelve evaluated parameters *viz.*, Nitrogen, Phosphorous, Calcium, Sulphur, Manganese, moisture per cent, moisture retention percentage, yield/10,000 larvae by weight, cocoon weight, cocoon shell weight, cocoon shell percentage and filament length followed by Goshoerami which ranked first in eleven parameters *viz.*, Phosphorous, Potassium, Calcium, Manganese, moisture per cent, moisture retention percentage, yield/10,000 larvae by weight, cocoon weight, cocoon shell weight, cocoon shell percentage and filament length. SKM-27 and SKM-48 occupied 3rd and 4th rank as their performance was outstanding in 10 and 7 parameters, respectively.

Sujathamma *et al.* (2001) evaluated the feed quality of 25 mulberry varieties utilizing two popular silkworm races *viz.*, the crossbreed PM×CSR2 and PM×NB4D2. Significant differences were observed for all the characters *viz.*, larval weight, survival rate, cocoon weight, shell weight, shell ratio, average filament length and filament denier, when the larvae were fed on different mulberry varieties. The nutritive quality of leaves Tr-10 and MR-2 varieties were found superior than that of the other varieties, as larvae fed on these two varieties have shown higher values for all the characters studied.

Rajkhowa *et al.* (2005) studied seven mulberry genotypes for quantitative and qualitative performance through evaluation of leaf yield potential and bioassay. Leaf productivity was recorded significantly highest in JRH variety. This was followed by S-1635, V-1 and RFS-175 which were statistically at par. Bioassay studies revealed less variation among genotypes. However, genotype
JRH and V-1 were found to be superior followed by S-1635, RFS-175 with regard to yield and rearing parameters.

Talebi Esfandarani et al. (2002) conducted the rearing of fourth and fifth instars larvae of silkworm (B. mori L.) on leaves with 66.77 per cent and 68.13 per cent (low), 69.87 per cent moisture (control), 72.48 per cent and 73.87 per cent moisture (high) and effect of moisture content of leaf on some parameters was determined. The male cocoon, cocoon shell and pupal weights were significantly increased in 72.48 per cent but male cocoon shell ratio was significantly decreased in this treatment. The female cocoon, cocoon shell and pupal weights were significantly increased in high moisture group but female cocoon shell ratio was significantly decreased. The egg productivity was significantly increased in 72.48 per cent.

Friend (1958) and Waldbauer (1968) highlighted the importance of dietary moisture content and reported that phytophagous insects require high water intake for normal development and feeding of larvae with wilted foliage produced adverse effects.

Chakraborti et al. (2004) conducted bioassays on silkworm hybrid N×YB and reported maximum cocoon yield/10,000 larvae by weight in CCB9 (19.93Kg) followed by CCB5 (19.91Kg). While maximum shell ratio was found in CCB3 (17.49%) followed by CCB4 (16.90%) and maximum non-breakable filament length in CCB8 (857m) followed by CCB3 (843m).

Jalaja Kumar and Ram Rao (2008) reported that the quality traits viz., leaf moisture, moisture retention (after 6 hours of harvest), protein, nitrogen, carbohydrates, amino acid contents were found to be high in V-1 followed by V-4 and S-36. The silkworm growth and cocoon characters were optimum when the leaves of V-1, V-4 and S-36 were fed to the larvae.
Parpiev (1968) reported that the higher moisture content of leaves favoured the palatability of the food as also the assimilability of the nutrients in the food. He also concluded that the water content in the leaves may serve as one of the criteria in estimating their quality.

Khan et al. (2007) evaluated seven mulberry genotypes through chemo and bio-assays. Maximum moisture content was recorded in Ichinose (74.46 %), whereas, maximum moisture retention capacity was observed in Goshoerami (77.98%). SKM-27 recorded the highest larval weight (52.59 g) and ERR (91.53 %). However, in the case of yield by weight, there was no significant difference among SKM-48, Goshoerami, Ichinose, SKM-27 and SKM-20. The highest cocoon weight and shell weight were recorded in Goshoerami (2.20 g and 41.00 cg, respectively). The highest filament length was recorded in Ichinose (1206 m).

Growth and development of silkworm (B. mori L.) and the cocoon crop yield are influenced largely by the varietal difference and nutritional quality of mulberry (Morus sps.) leaf used as food (Parpiev, 1968, Krishnaswami et al., 1970). Leaf moisture content and water retention positively influenced the silkworm larval growth and development (Chaluvachari and Bongale, 1995).

Higher levels of leaf water content, total soluble sugars, soluble proteins, total chlorophyll and leaf water retention resulted in decreased larval duration and increased larval weight, effective rate of rearing (ERR) by weight, cocoon weight, shell weight and shell ratio (Patil et al., 2001).

Higher amino acids and protein content are of particular importance to the silkworm larvae because of their active utilization for the synthesis of silk protein (Sujathamma and Dandin, 2000).

Patil et al. (2001) reported that higher levels of leaf water content, total soluble sugars soluble proteins, total chlorophyll and leaf water retention resulted
in decreased larval duration and increased larval weight, effective rate of rearing (ERR) by weight, shell weight and shell ratio.

Bohidar *et al.* (2007) studied the efficiency of six varieties of mulberry leaves namely V-1, DD, S-36, S-41, Mysore Local and Khurda Local under laboratory condition. It was found that, maximum shell weight was in V1 and S36 and V-1 varieties of mulberry leaves are recommended for feeding in order to achieve better silk yield.

Bose *et al.* (1995) reported that succulent mulberry leaves with less fibre and high mineral content stimulate the metabolic activities in silkworm resulting in quantitative improvement of cocoon and silk.

Vasudha Prabhakar and Neelu Nangia (2012) studied three mulberry genotypes namely ME-18, ME-84 and MR-86 for rearing of fifth instar silkworm PMXCSR2 larvae. Economic parameters namely cocoon weight, shell weight, shell ratio and silk productivity were recorded. Among the genotypes used, the maximum cocoon weight (1.38g and 1.48g), shell weight (0.31g and 0.32g), shell ratio (21.35% and 21.55%) and silk productivity (2.98cg/g) on ME-18 and ME-84 genotypes which has registered maximum value of biochemical constituents and minimum phenol content and surface leaf wax.

### 2.3.2 Consumption indices:

Narayanaprakash *et al.* (1985) reported that assimilated food converted into body tissue and conversion efficiency decreased with decreasing dietary moisture content in mulberry leaves and also shell weight and fibroin content of the cocoons increased with increasing dietary moisture.

Paul *et al.* (1992) reported that absolute consumption and growth rate per day per larvae, the quality of dry matter consumed and digested, the values of
efficiency of conversion of ingested and digested food and final larval weight increased with increasing percentage of leaf water and approximate digestibility increased progressively up to 70 per cent leaf moisture but was reduced at the control dietary water level (76.6% leaf moisture).

Kanika Trivedy et al. (2006) tested the new productive genotypes viz., K-519, K-1138, V-1, K-2, K-63 and K-1133, to make a comparative evaluation of these genotypes for feed conversion efficiency using the popular bivoltine hybrid, CSR₂ × CSR₄. The existing popular mulberry variety, S-36 served as the control. Among the genotypes K-1133, ranked first with regard to the major nutritional index efficiency of conversion of ingesta to cocoon shell (ECI shell %). The ECI shell of K-1133 was 16.01 per cent more than that of S-36. The larvae fed with the leaves of K-1133 variety consumed significantly less amount of leaf and could convert it more efficiently to the end product, the cocoon shell.

Dar et al. (1988) evaluated three improved Japanese cultivars of mulberry, namely Ichinose, Gosherami and Kokusu-27, those were introduced in Kashmir valley for nutritional potential by feeding experiments. It was observed that ingestion and faeces voided were significantly low in larvae fed with Ichinose leaves, thus decreasing the consumption index and increasing the efficiency of conversion of ingested and digested food into body matter.

2.3.3 Correlation between biochemical constituents and cocoon weight and shell weight

Total chlorophyll and total soluble sugar parameters in mulberry leaves showed increase in larval weight. Higher content of these parameters may have an indirect effect to accelerate the growth and development of the late age silkworm and also the cocoon production. Total chlorophyll content, total soluble sugars, the soluble proteins and the total nitrogen content in mulberry leaves showed positive
association with ERR by weight, single cocoon weight, shell weight (in protein) and shell ratio (in nitrogen) (Patil et al., 2001).

The positive correlation coefficients of the cocoon shell weight and cocoon yield with the protein content in mulberry leaves is reported by Sarkar et al. (1997). The mulberry varieties with higher content of nitrogen in leaf show higher production efficiency of cocoon shell weight (Machii and Katagir, 1991). Sudo et al. (1981) found a significant correlation between the nitrogen content in the leaf, silkworm body weight and cocoon shell weight.