DISCUSSION
V. DISCUSSION

Evaluation of any crop is a continuous process to evolve new varieties suitable for specific zones for commercial utilization. The present scenario of sericulture industry demands new varieties suitable for various agro-climatic conditions. Suitable parent material needs to be identified from large number of germplasm accessions for the purpose of breeding. For any genetic improvement programme in crop plants, the availability of large genetic stocks representing diverse genotypes is a pre requisite. The conservation of mulberry genetic material for possible future use and its subsequent utilization in plant breeding are two highly important spheres of activity in any genetic resources management. Germplasm enhancement or pre-breeding activates are required to be addressed to utilize the wild mulberry species collected from different agro-climatic conditions. Hence, evaluation of mulberry germplasm for both quantitative and qualitative traits is essential to identify suitable parent material for breeding programme.

Considering these points, the present study was carried out by evaluating eighty mulberry accessions which are maintained in the department of Sericulture, UAS, GKV, Bangalore. The mulberry germplasm is established during 2006. These germplasm were evaluated during rainy, winter and summer season of 2010-2012.

The results of the investigation on “Evaluation of mulberry germplasm for morphological characters and silkworm (Bombyx mori L.) rearing parameters” are discussed in this chapter in the light of available literature with the following subheadings.
5.1 EVALUATION OF MULBERRY GERMPLASM FOR DIFFERENT GROWTH AND YIELD PARAMETERS

5.1.1 Performance of 80 different mulberry accessions for different growth and yield parameters

The mean performance of eighty mulberry accessions used in the present study in rainy season indicated that no single accession was superior in respect of all the traits studied. However, the accession SB-21 was superior for two (number of leaves per plant and leaf yield per plant) out of ten characters. In contrast to this, V-1 recorded maximum plant height, MI-47 recorded shorter internodal distance and MI-79 recorded maximum number of branches per plant and confirms the earlier findings of Saratchandra et al. (1992) and Masilamani et al. (2000). ME-03 accession was superior in respect single leaf area. While Surat local accession was best for total shoot length in rainy season (Appendix 1).

In winter season also no single accession was superior in respect of all the traits studied. However, SB-21 was superior for leaf yield per plant and number of leaves per plant. The accession ME-03 was superior for two characters viz., 100 fresh leaf weight and single leaf area out of ten characters. Whereas, V-1 was superior for plant height, MI-79 and SB-21 were superior for number of branches per plant. S-34 recorded shorter internodal distance and Surat local exhibited higher values for total shoot length. Srinagar local recorded maximum stem girth (Appendix 4).

In summer season also no single accession was superior in respect of all the traits studied. However, the accession SB-21 was superior for three (leaf yield, plant height and number of leaves per plant) out of ten characters. In contrast to this, MI-79 recorded maximum number of branches. MI-014 had shorter internodal distance and Surat local accession exhibited maximum total shoot length. Srinagar local recorded maximum stem girth (Appendix 7).
Maximum number of trichomes per mm were observed in accession MI-240 during rainy and summer season whereas, it was maximum in ME-67 during summer season (Appendix 1, 4&7). These results are in line with the findings of Chandrashekara and Basavaiah (2010).

The mean performance of eighty mulberry accessions for moisture studies showed that accessions TB-21, V1, S-30 and MI-79 recorded highest moisture content and moisture retention capacity at 3, 6, 9, 12 and 24 h (Appendix 2, 5&8). These results are in agreement with the findings of Sastry et al. (1988), Mala et al. (1992), Balakrishna et al. (1999), Mallikarjunappa et al. (2000), Susheelamma and Dandin (2006), Jalaja Kumar and Ram Rao (2008).

5.1.2 Season wise comparison of leaf yield per plant

Leaf yield per plant of the accession SB-21 was 3452.44, 3148.07 and 2915.72 g / plant during rainy, winter and summer season, respectively. ME-144 recorded leaf yield of 3418.01, 3014.37 and 2646.45 g / plant during rainy, winter and summer season, respectively. C-776 recorded leaf yield of 3066.56, 2728.80 and 2350.3645 g / plant during rainy, winter and summer season, respectively. Hence, leaf yield per plant was maximum during rainy season followed by winter and summer season (Appendix 10). These results are in conformity with the findings of Vijayashekara (2009) who also reported maximum leaf yield per plant during rainy season followed by winter season.

5.1.3 Analysis of variance for different growth and yield performance of 80 mulberry accessions

The analysis of variance among for eighty accessions of mulberry indicated highly significant differences among them for sixteen characters indicating presence of sufficient amount of variability with respect of all the characters studied. The genotypic differences were significant at 1% probability level in
rainy, winter and summer seasons. Similar results were reported by Tikader et al. (2004) and Banerjee et al. (2007) (Table 3, 4, 5, 6, 7 and 8).

5.1.4 Pest and disease incidence

Sucking pest incidence was observed maximum during summer season followed by winter and rainy season (Appendix 3, 6 & 9). This might be due to higher temperature, lower relative humidity and lower rainfall (Abiotic factors) which are favourable for pest multiplication in the garden. Further, mealy bugs and other sucking pests are washed out by heavy rainfall. These results are in conformity with the findings of Hemalatha and Shree (2008) who reported that maximum infestation of Pink mealy bugs in pre-monsoon season. The results of present study are also in line with findings of Vasudha Prabhakar and Neelu Nangia (2012), who 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%).

In the present study, mulberry accessions in rainy, winter and summer seasons, the diseases such as leaf spot and leaf rust were noticed in different cultivars. Earlier several authors have also reported the diseases in different seasons Phillip et al. (1996) and Mala et al. (2007).

5.1.5 Types of leaf venation

In the present study, three types of leaf venations were observed viz., reticulate, palmate and pinnate. These findings are in parallel with the results of Penkov (1979) (Table 2) (Fig. 1).

5.1.6 FRUIT TRAITS

Maximum number of fruits were recorded in accession Surat local, whereas ME-18 had longer fruit length, fruit diameter and fruit weight (Table 9) (Plate 6).
These results are on par with the findings of Chikkalingaiah et al. (2009) who also reported that accession ME-18 had maximum fruit length.

5.1.7 Genetic variability for different growth and yield parameters in 80 different mulberry accessions

Studies on genetic variability in rainy season revealed that all the sixteen traits exhibited wide range of variations indicating the presence of sufficient genetic variability in the mulberry accessions (Table 10, 11 and 12).

5.1.7.1 Co-efficient of variation

The range in mean values does not reflect the total variance in the materials studied. Hence, actual variance has to be estimated for the characters to know the extent of existing variability. The genotypic variance measures the magnitude of genetic variability present in the crop and phenotypic variance indicates the amount of variation which is due to the phenotypic values. The absolute values of phenotypic and genotypic variance cannot be used for interpreting the degree of variability in different characters because the characters differ in the unit of measurement. Hence, the coefficient of variation (PCV and GCV) which is calculated by considering the respective means has been used for the comparisons. High values of these parameters indicate wider variability and vice-versa. In the same context narrow differences between the phenotypic co-efficient of variation (PCV) and genotypic coefficient of variation (GCV) implies lesser effect of environment of these traits.

The results on evaluation of eighty mulberry accessions for the sixteen growth parameters during rainy season revealed that phenotypic variation was wide in respect of plant height, total shoot length, number of leaves per plant, single leaf area, 100 fresh leaf weight, and leaf yield per plant. Same trend was noticed in winter and summer season (Table 10, 11 &12) (Fig. 2, 3 & 4). This may
infer that considerable improvement in mulberry could be achieved through selection based on these parameters. The results of the present study is in conformity with the findings of Bari *et al.* (1988a), Bhat (1989), Patil (1998) and Patil *et al.* 1999), Tikader *et al.* (2004), Ram Rao *et al.* (2006) and Banerjee *et al.* (2007).

The parameters *viz.*, internodal distance, number of branches per plant, stem girth and number of trichomes per mm, moisture per cent, moisture retention at 3 h, 6 h, 9 h, 12 h and 24 h showed lower phenotypic variability and the same trend was also noticed in winter and summer season. Therefore, accessions with genetic variations for these parameters can be used as parents to provide enough variability to exercise selection in the desired direction. These results are in agreement with the findings of Bari *et al.* (1988a), Bhat (1989), Patil (1998), Patil *et al.* 1999), and Ram Rao *et al.* (2006).

Phenotypic variability is not very much reliable since it encompasses both genetic and environment effects and does not reveal as to which factor is showing higher degree of variability (Johnson *et al.*, 1955) and it is inevitable to split the overall variation into genetic and non genetic components and standardize these by obtaining the co-efficients of genotypic and phenotypic variation. The PCV was higher than the GCV, and this clearly shows that environment greatly influence the expression of the studied characters.

The difference between PCV and GCV for plant height, number of branches per plant, total shoot length, number of leaves per plant, single leaf area, leaf yield per plant, 100 fresh leaf weight, stem girth, number of trichomes, moisture percentage, moisture retention at 3 h, 6 h, 9 h, 12 h and 24 h, were very less. Thus, the influence of environment on these parameters is considered to have less effect and hence selections can be made based on these traits.
High PCV and GCV were found for number of branches, total shoot length, number of leaves per plant, single leaf area, leaf yield per plant, 100 fresh leaf weight and number of trichomes per mm indicating greater diversity among accessions for these traits in rainy season, winter and summer season (Fig 2, 3&4).

Almost similar trend of results was observed in three seasons. Higher estimates of PCV and GCV was also reported for number of branches per plant Bari et al. (1988b), Tikader et al. (1999), Tikader et al. (2004) and Ram Rao et al. (2006), total shoot length, Tikader (1999) and Tikader et al. (2004), number of leaves, Masilamani and Kamble (1998) and Ram Rao et al. (2006), single leaf area Tikader et al. (1999) and Ram Rao et al. (2006), 100 fresh leaf weight Masilamani and Kamble (1998), Patil et al. (1999), Tikader et al. (2004), leaf yield per plant, Bari et al. (1988a), Masilamani and Kamble (1998), Tikader and Roy (1999) and Jyoti Biradar (2010).

Plant height, internodal distance, stem girth, moisture retention capacity at 24 hours recorded moderate PCV and GCV values in the germplasm accessions in rainy season and almost similar trend was observed in winter and summer season also. While moisture retention at 12 h recorded moderate PCV and GCV during rainy and summer season.

Moderate estimates of PCV and GCV was also reported for internodal distance by Bari et al. (1989), Tikader et al. (1999) and Tikader et al. (2004) for leaf yield per plant by Ram Rao et al. (2006).

Moisture percentage, moisture retention at 3 h, 6h and 9 h exhibited low PCV and GCV indicating a narrow range of variation for these traits in rainy, winter and summer season, thereby restricting the scope for selection. While moisture retention at 12 h recorded low PCV and GCV during winter season.
These results are in agreement with Tikader et al. (1999), Masilamani et al. (2000), Tikader et al. (2004), Ram Rao et al. (2006).

The high magnitude of GCV for different traits revealed the greater extent of variability present in these parameters thereby suggesting good scope for improvement through selection. Low values of GCV indicated the need to create variability either by hybridization or mutation, followed by selection (Bhat, 1989 and Patil, 1998).

5.1.7.2 Heritability for different growth and yield parameters in 80 different mulberry accessions

Broad sense heritability gives an idea about portion of observed variability attributable to genetic differences. The difference between PCV and GCV estimates indicates the relative influence of environment on the character, which in turn decides the extent of their heritability. If the difference is low for a character then the influence of environment is less coupled with heritability. Wide differences indicate considerable influence of the environment, thus resulting in low heritability estimates.

High heritability estimates were obtained for plant height, number of branches per plant, total shoot length, number of leaves per plant, single leaf area, leaf yield per plant, 100 fresh leaf weight, internodal distance, stem girth, number of trichomes per mm, moisture content, moisture retention capacity at 6 h, 12 h, 24 h and leaf yield per plant (Table 10, 11 &12). Similar trend of results were observed during winter and summer season. High heritability estimates suggest the major role of genetic constitution in the expression of the parameters and such parameters are considered to be dependable from the breeding point of view (Patil, 1998). These results are comparable with the findings of Bari et al. (1989), Masilamani and Kamble (1998), Patil et al. (1999), Tikader and Roy (1999) and Chikkalingaiah et al. (2008).

5.1.8 Character association for different growth and yield parameters in mulberry accessions

Although variability estimates provide information on the extent of improvement possible in different characters, they do not throw light on the extent and nature of relationship prevalent between the contributory characters and economically important characters. Leaf yield being a complex polygenic character, direct selection based on these traits would not yield fruitful results without giving due importance to their genetic background. The association of yield and its component traits reflects the nature and degree of relationship between them.

The correlation analysis helps in examining the possibility of improving yield through indirect selection of its components traits which are highly correlated as done by Prakash and Halaswamy (2006) in mulberry. In the present investigation, correlation analysis was carried out for eighty different mulberry accessions. Significant and positive association at both phenotypic and genotypic levels was observed for leaf yield per plant with number of branches per plant, internodal distance, plant height, 100 fresh leaf weight, single leaf area, total shoot length, number of leaves per plant and moisture content (Table 13 &14). Thus these traits can be relied upon as important parameters for screening and selection
of superior mulberry genotypes. The results of Das and Krishnaswamy (1969), Rangaswami et al. (1978), Sarkar et al.(1987), Susheelamma et al. (1988), Bari et al. (1988b), Bindroo et al. (1990), Rahman et al.(1994), Tikader and Roy (1999), Tikader and Roy (2003), Rahman et al. (2004), Tikader and Dandin (2005), Ram Rao et al. (2006) and Tikader and Roy (2006) were in conformity with the present results. 100 fresh leaf weight exhibited positive and significant association with single leaf area and leaf yield per plant at phenotypic and genotypic levels was observed.

Single leaf area was associated significant and positively with leaf yield per plant at phenotypic and genotypic levels. The association was non-significant and negative with total shoot length, number of leaves per plant, MRC at 3 h, MRC at 6 h, MRC at 9 h, MRC at 12 h, MRC at 24 h and number of trichomes per mm at both phenotypic and genotypic levels (Table 13 &14). These results are in conformity with the findings of Bhat (1989), Masilamani and Kamble (1998) and Banerjee et al. (2007).

Number of leaves per plant had positive association with moisture content and leaf yield per plant both at phenotypic and genotypic levels which were significant. Number of branches per plant has positive and significant association with leaf yield per plant, plant height, total shoot length, number of leaves per plant, moisture content, moisture retention capacity (MRC) at 6 h, MRC at 9 h, MRC at 12 h and MRC at 24 h at phenotypic and genotypic levels. The present results supports the findings of several authors, Sarkar et al.(1987), Bari et al. (1989), Rahman et al. (1994), Tikader and Roy (2001), Tikader and Dandin (2005) and Banerjee et al. (2007). Total shoot length association was significant and positive with number of leaves per plant, moisture content, MRC at 6 h, MRC at 9 h, MRC at 12 h, MRC at 24 h and leaf yield per plant at phenotypic and genotypic levels.
Among growth attributing traits, plant height was associated positively and significantly with total shoot length, number of leaves per plant and leaf yield per plant at phenotypic and genotypic levels. These results supports the findings of several authors, Sarkar et al. (1987), Bari et al. (1989), Rahman et al. (1994), Vijayan et al. (1997), Tikader and Roy (2001), Tikader and Dandin (2005) and Banerjee et al. (2007).

5.2 BIOCHEMICAL COMPOSITION OF 13 ELITE MULBERRY ACCESSIONS

TB-21 accession had higher nitrogen (4.23%) followed by ME-27 (4.16%) and MI-79 (4.06%) and it was significantly lower in Srinagar local (3.13%) and the next best ones were C-776 (3.27%) and Karanahalli (3.32%) (Table 21) (Fig. 13). 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).

Crude protein content was significantly maximum in leaves of accession TB-21 (26.43%) followed by ME-27 (25.97%) and MI-79 (25.38%). However, Srinagar local had significantly minimum crude protein content of 19.58 per cent and the next best ones were C-776 (20.44%) and Karanahalli (20.77%). Protein content was significantly maximum in TB-21 (22.67%) followed by ME-27 (22.15%) and both were on par with each other. Whereas, it was significantly low in Srinagar local (15.44%) and C-776 (16.96%). 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). Machii and Katagiri (1991) opined that increased protein content beyond the optimal level in mulberry leaves leads to a marginal improvement in cocoon productivity. Total amino acids content was found to be significantly maximum in leaves of accession TB-21 (315.57 mg/g) followed by
MI-27 (305.54mg/g) and it was significantly minimum in Srinagar local (241.65 mg/g) and C-776 (253.10 mg/g).

Significantly higher starch and sugar content was 11.92 and 15.24 per cent, respectively, obtained from the leaves of accession TB-21, followed ME-27 (11.49 and 15.09 % of starch and sugar, respectively) MI-79 (11.11 and 14.85 % of starch and sugar respectively). Whereas, it was lowest in Srinagar local (8.91 and 10.94% of starch and sugar, respectively) and the next best one was C-776 (9.23 and 11.09% of starch and sugar, respectively. TB-21 had significantly higher content of total carbohydrates (24.75 %) followed by ME-27 (23.89%) and it was significantly lower in leaves of Srinagar local (17.17%) (Table 21). Carbohydrate 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, silkworm gain more energy and inturn may enhance the synthesis of silk protein.

Total chlorophyll content was significantly maximum in leaves of accession TB-21 (3.39 mg/g) followed by ME-27 (3.27 mg/g) and MI-79 (3.21 mg/g). However, it was significantly minimum in leaves of MI-506 (2.51 mg/g) and the next best ones were C-776 (2.61 mg/g) and ME-144 (2.66 mg/g) (Table 21) (Fig. 15). 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 (Sujathamamma and Dandin, 2000).

Significantly higher crude fibre content was observed in leaves of ME-27 (13.07%) followed by ME-144 (12.77%) and M. indica (12.71%) which were on par with each other. Crude fibre content was significantly minimum in leaves of Srinagar local (9.84%) and the next best ones were C-776 (10.01%) and Karanahalli (10.49%). Total ash content was significantly maximum in leaves of
TB-21 (12.65%) followed by MI-79 (12.57%) and ME-27 (12.16%) and it was significantly minimum in Karanahalli (9.72%) and the next best ones were C-776 (10.37%) and Srinagar local (10.78%) (Table 21) (Fig. 16). These results are in conformity with the results of Ramachandra et al. (2008), who reported that leaf quality of five selected varieties of mulberry viz., S₃₆, S₅₄, M₅, DD and V₁ showed significant differences among the varieties with respect to leaf moisture content, protein, sugar and total chlorophyll. Jalaja Kumar and Ram Rao (2008) reported that the leaf quality characters viz., leaf moisture, moisture retention (after 6 h of harvest), protein, nitrogen, carbohydrate and amino acid contents were found to be high in mulberry genotypes 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) found significant variation among twenty five improved mulberry varieties with respect to leaf protein, sugar, phenol, moisture content. Among them, the variety, C2017, 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%). Likewise, in the present study also the accessions TB-21, ME-27, MI-79 and M. indica exhibited better values for bio-chemical parameters.

5.3 REARING PERFORMANCE OF PM×CSR₂ FED WITH THE LEAVES OF DIFFERENT ELITE MULBERRY ACCESSIONS

5.3.1 Rearing parameters

5.3.1.1 Mature larval weight (g)

Significantly maximum mature larval weight was registered when the PM×CSR₂ worms were fed with leaves of accession TB-21 (32.63 g/10 larvae)
followed by ME-27 (30.62 g/10 larvae) and MI-79 (29.55 g/10 larvae). Whereas, significantly minimum mature larval weight was recorded in silkworm fed with leaves of Srinagar local (21.16 g/10 larvae) and the next best ones were C-776 (21.87g/10 larvae) and Karanahalli (22.26g/10 larvae). The variation in larval weight may be due to the difference in nutritional composition of the leaf. Larval weight was maximum during fifth instar (Table 22) (Fig. 17). This may be due to maximum food consumption and growth rate during fifth instar. The present results are comparable with the findings of Tayade et al. (1988), who observed significant differences in weight of larvae when the silkworm larvae were fed on mulberry varieties viz., Kanav-2, Kosen, LM-1, LM-2, Mysore Local, S-30, S-36, S-41 and S-54. Khan et al. (2007) reported that yield/ 10,000 larvae by weight was maximum in genotypes SKM-27 and SKM-48 which occupied 3rd and 4th rank as their performance. Sujathamma et al. (2001) reported that the nutritive quality of leaves Tr-10 and MR-2 varieties were found superior, as larvae fed on these two varieties have shown higher values larval weight. Khan et al. (2007) evaluated seven mulberry genotypes and concluded SKM-27 recorded the highest larval weight (52.59 g). Krishnaswami et al. (1970), Verma and Kushwaha (1970) observed better larval growth with different mulberry varieties. Patil et al. (2001) reported that higher levels of leaf water content, total soluble sugars, soluble proteins, total chlorophyll and leaf water retention increased larval weight. Leaf moisture content and water retention positively influenced the silkworm larval growth and development (Chaluvachari and Bongale, 1995). The performance of silkworm B. mori is known to vary much depending on varieties of mulberry used as food source, thereby, implying that certain varieties are comparatively better for the optimum growth and development of silkworm (Sujathamma et al., 2001).

5.3.1.2 Single cocoon weight (g)

Accession TB-21, recorded significantly maximum cocoon weight (1.79g) followed by accession ME-27 (1.78g) and MI-79 (1.77g). However, significantly
minimum cocoon weight was recorded when PM×CSR$_2$ worms were reared on leaves of accession Srinagar local (1.61g) and the next best ones were C-776 (1.65g) and Karanahalli (1.665g) (Table 22) (Fig. 18) (Plate 10). These results are in parallel to the findings of Sujathamma et al. (2001) who evaluated the feed quality of 25 mulberry varieties utilizing two popular silkworm races viz., the crossbreed PM×CSR$_2$ and PM×NB$_3$D$_2$. Significant differences were observed for cocoon weight when the larvae were fed on different mulberry varieties. Jalaja Kumar and Ram Rao (2008) reported 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. 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 increased cocoon weight. Growth and development of silkworm (Bombyx 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 and Krishnaswami et al., 1970). Saratchandra et al. (1992) also reported varietal effect on the yield of cocoons by number and weight.

5.3.1.3 Shell weight (g)

Significantly maximum shell weight was obtained when larvae were fed with leaves of accession TB-21 (0.36g) followed by accession ME-27 (0.35g) and MI-79 (0.35g). However, significantly minimum shell weight was observed when silkworms were reared on leaves of accession Srinagar local (0.25g) and the next best ones were C-776 (0.26g) and Karanahalli (0.27g) (Table 22) (Fig. 18). These results are parallel with the findings of Talebi Esfandarani et al. (2002) who reared the fourth and fifth instars larvae of silkworm (B. mori L.) on leaves of varied moisture content and observed there was improvement in cocoon weight, shell weight and pupal weight. But, the shell ratio was less with higher moisture content 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 leaves
moisture on some parameters was determined. The male cocoon, cocoon shell and pupal weights were significantly increased in 72.48 per cent and female cocoon shell and pupal weights also significantly increased in high moisture group.

5.3.1.4 Shell ratio (%)

Significantly higher shell ratio was registered when PM×CSR₂ worms were reared on leaves of accession TB-21 (19.98%), followed by ME-27 (19.85%) which were on par with each other, in the present investigation. While, it was significantly low when worms were fed on leaves of accession Srinagar local (15.24%) and the next best ones were C-776 (15.24%) and Karanahalli (15.63%) (Table 22) (Fig. 19). This variation may be due to varied nutritional composition of leaves of different accessions which also affected the shell ratio. These results are in conformity the findings of Sujathamma et al. (2001) who evaluated the feed quality of 25 mulberry and observed significant differences in shell ratio when the larvae were fed on different mulberry varieties. Patil et al. (2001) higher levels of leaf water content, total soluble sugars, soluble proteins, total chlorophyll and leaf water retention resulted in increased shell ratio. Bari et al. (1983) and Dar et al. (1988) indicated that the varieties of mulberry had a significant effect on different cocoon characters.

5.3.1.5 Silk quality parameters

The silk productivity was significantly maximum in TB-21 (3.97 cg/day) followed by ME-27 (3.92 cg/day) and MI-79 (3.85 cg/day). It was significantly minimum in Srinagar local (2.73 cg/day) and the next best ones were C-776 (2.86 cg/day) and Karanahalli (3.01 cg/day) (Table 22) (Fig. 20).

Silkworms fed on mulberry leaves of accession TB-21 recorded significantly longer filament length (823.65m) followed by the accessions MI-27 (817.64m) and MI-79 (811.95m). However, the silk filament length was
significantly shorter (718.82m) in Srinagar local and the next best ones were C-776 (732.81m) and Karanahalli (741.93m) (Table 23).

Significantly maximum filament weight was found when silkworms were reared on accession TB-21 (0.27g) followed by ME-27 (0.26g) and MI-79 (0.26g). However, it was significantly minimum when silkworms were reared on Srinagar local (0.223g) and the next best ones were C-776 (0.23g) and Karanahalli (0.23g) (Table 23).

Significantly maximum denier was recorded when PM×CSR$_2$ worms were reared on leaves of SB-21 (2.96) followed by V-1 (2.94), M. indica (2.93) and TB-21 (2.92). Whereas, it was significantly minimum in case of Srinagar local (2.79) and the next best ones were C-776 (2.80) and ME-144 (2.83) (Table 23).

Significantly higher raw silk per cent was obtained when PM×CSR$_2$ worm were fed with leaves of TB-21 (14.94%) followed by ME-27 (14.72%) and MI-79 (14.71%) which were on par with each other. However, it was significantly low in case of silkworms fed with leaves of Srinagar local (13.78%) and the next best one was C-776 (13.82%). (Table 23).

Renditta was significantly low when PM×CSR$_2$ worms were reared upon the leaves of TB-21 (6.69) followed by ME-27 (6.79) which was on par with MI-79. While, it was significantly high when silkworms were fed with leaves of Srinagar local (7.26) and the next best one was C-776 (7.24) (Table 23).

Differences in silk quality parameters between the accessions might be due to difference in the nutritional contents in leaves of different accessions and larval duration during fifth instar. These results are in conformity with the findings of Sujathamma et al. (2001) who reported significant differences in all the characters viz., cocoon weight, shell weight, shell ratio, average filament length and filament denier, when the larvae were fed on different mulberry varieties. The food quality
influences the weight of the cocoon, silk yield and physicochemical properties of silk thread. Khan et al. (2007) evaluated seven mulberry genotypes through bio-assays and reported that the highest filament length was recorded in Ichinose (1206m). Sujathamma and Dandin, (2000) reported that 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.

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.

5.3.2 Consumption indices

5.3.2.1 Consumption (g/50 larvae)

Consumption of leaf during fifth instar was observed to be increasing upto eighth day and it gradually decreased on ninth day among the accessions. The present findings are in close conformity with those of Chomhuen (1973), who reported that the amount of mulberry leaves fed per worm in the fifth instar increased upto eighth day and then decreased. Anantharaman et al. (1993) reported the higher ingesta in fifth instar, which is necessary for the larvae to maintain metabolic demand during the transformation of larva to pupa, pupa to moth and also for the secretion of silk.

Food consumption was observed to be significantly maximum among the silkworms fed with leaves of accession TB-21 (464.82g/50 larvae) followed by silkworms fed with leaves of ME-27 (461.95g/50 larvae) and MI-79 (457.38 g/50 larvae). Silkworms fed with leaves of Srinagar local consumed significantly minimum food (425.99 g/50 larvae) and the next best ones were C-776 (430.46g/50 larvae) and Karanahalli (433.74g/50 larvae) (Table 24). The present findings are in conformity to those of Prabhakara et al. (1992), who reported that
leaf consumption increased during fifth instar from first to eighth day, later showing decreasing trend when worms were fed with leaves of Mysore Local, M5 and S54 varieties of mulberry. Das and Sikdar (1970) reported that the consumption of leaf by the larvae of *B. mori* differed according to mulberry varieties, which have varied biochemical composition. Ito (1972) observed that nutritional quality of mulberry leaves had greater impact on quantum of ingested food. Koul *et al.* (1994) observed that leaf consumption values in fifth instar larvae differed in different mulberry varieties. According to Prabhakara *et al.*, (1992) the consumption of leaf by larvae during fifth instar varied according to the mulberry variety, being lowest among the improved varieties and highest in conventional variety. Reddy *et al.* (1997) recorded varied quantum of leaf consumption when the larvae of PM×NB4D2 reared on S-54, S-41 and Mysore local.

The preference of the food depends on the nutritional value and also by the presence of non-nutritional stimulus / taste as suggested by House (1962). The variation in food consumption may also be due to variation in moisture content of the leaves of different accessions, since, there exists a correlation between the food consumption and moisture content of food (Basaiah, 1988). The greater consumption rate could be attributed as a means to meet the requirement of different nutrients for the body growth.

### 5.3.2.2 Digestion (g/50 larvae)

The amount of food digested indicates the amount of nutrient passed through the digestive system for utilization. The digestion mainly governed by the physiology of insect, its nutritional requirement and nutritional value of the food. The chemical compound that stimulates the consumption may not be digested mainly due to its chemical complexity to digest. Hence, the digestion indicates the amount of digestible nutrient of the food. The amount of food digestion during
fifth instar increased from first day to sixth day and thereafter decreased irrespective different accessions. The decrease in digestion rate in silkworms during later stages of fifth instar may be attributed to reduced metabolic activities, coinciding with increased silk synthesis in silk glands.

Silkworms fed with leaves of accession TB-21 (216.34g/50 larvae) recorded significantly highest food digestion followed by silkworms fed with leaves of accession ME-27 (212.92 g/50 larvae) and MI-79 (209.05 g/50 larvae). Significantly less food digestion was recorded among the silkworms fed with leaves of accession Srinagar local consumed (179.39/50 larvae) and the next best ones were C-776 (182.81 g/50 larvae) and Karanahalli (185.63 g/50 larvae) (Table 25). According to Prabhakara et al. (2000), the rate of digestion in silkworm differed when fed on different varieties of mulberry, which are in line with the current observations.

### 5.3.2.3 Consumption index

Comparison of consumption index is a better measure of consumption rather than the bulk food eaten, as it measures the rate at which the food enters the digestive system. Waldbauer (1968) suggest that consumption index is a better measure of behavior of response to food. Since, the rate of food intake is a response of bulk, water content and other physico-chemical properties of whole fresh food and the rate of dry matter intake is largely a function of this response.

The consumption index (CI) was found to be decreased from first to seventh day of fifth instar and thereafter increased among accessions. This is attributed to the decrease in efficiency of larvae to convert food into body weight as the age of the larvae advanced eventhough they consume more food.

Consumption index was significantly minimum when silkworm were fed with leaves of accession TB-21 from first to ninth day fifth instar (0.667) followed
by accession ME-27 (0.677). However, CI was significantly maximum when silkworms were reared on accession Srinagar local (0.779) and C-776 that recorded CI of 0.769 (Table 26). This variation might be due to variation in biochemical constituents of different mulberry varieties, which play major role on gain in body weight of silkworm. Prabhakara et al., (2000) observed that CI was maximum when silkworms reared on Local variety compared to M-5 and S-54 (i.e., improved mulberry varieties). Dutta et al (1996) observed that when Saruput and Nistari silkworm breeds reared on Jatimani variety of mulberry recorded higher CI compared to K-2 mulberry variety.

5.3.2.4 Growth rate

Growth rate (GR) explains how much of dry matter increases in the larvae per gram of body weight per day. It directly influences the speed of development, which depends on the quality of host and physiology of silkworm, etc.

During fifth instar, the GR decreased gradually from first to seventh day and it became negative from eighth day onwards among the accessions. The decrease in GR towards the end of larval stage is attributed to reduced weight gain by the larvae due to reduced efficiency of digestive system, conversion of body substances into fat and the utilization for silk synthesis.

The larvae fed on TB-21 recorded higher growth rate (0.189) followed by ME-27 (0.179) and MI-79 for which the GR was 0.177. Significantly minimum GR was recorded when silkworms were reared on Srinagar local (0.148) and the next best ones were C-776 and Karanahalli (0.154) (Table 27). The variation of GR among mulberry accessions might be due to difference in biochemical constituents present in them. Similar differences were noticed on by Dutta et al. (1996), who reported that the larvae reared on Jatimani had higher GR compared to silkworms reared on K-2 mulberry variety. Prabhakara et al. (2000) reported that the larvae reared on S-14 leaves resulted in maximum GR compared to M-5.
Krishnaswami et al. (1971) opined that the growth rate in *B. mori* depends on the nutritional content of the mulberry leaves. Mehta and Saxena (1973) reported that the growth rate depends on the utilization of nutrients.

### 5.3.2.5 Efficiency of conversion of ingested food (ECI)

The ECI is an overall measure of an insect’s ability to utilize the consumed food after digestion for growth. The ECI mainly depend on digestibility (approximate digestibility), which on one hand, converted into body substance and on the other hand metabolized for energy to maintain life.

The ECI increased from first to third day of fifth instar and thereafter, it decreased gradually as the age of the larvae advanced among accessions. The increased rate of ECI upto third day of fifth instar is attributed to maximum consumption and digestion during early stages of fifth instar. However, the reduction in ECI towards the advancement of fifth instar might be due to less digestion and also to utilize body substances for the development of silkglands.

When silkworms were fed with leaves of accession TB-21, they recorded significantly maximum ECI of 39.58 per cent, which was followed by ME-27 (38.36%) and MI-79 (37.48%). However, it was significantly minimum when silkworms were reared upon leaves of accession Srinagar local (26.73%) and C-776 (28.11%) (Table 28). The variation in ECI among accessions may be due to the varied rate of metabolism, which on the other hand is governed by the nutritional value of the food. The increase in metabolism may be due to its higher amount of complex constituents, to break down such compounds the large amount of energy is utilized. Similar differences was observed when larvae reared on improved (i.e., MR-2 and S-54) and conventional varieties of mulberry (M-5 and Mysore local) (Periaswamy and Radhakrishnan, 1985). Dutta et al. (1996) reported that ECI values of the worms differed significantly on Jatimani and K-2 mulberry varieties, being maximum in case of K-2. Prabhakara et al. (2000)
reported that larvae reared on M-5 variety had maximum ECI compared to Local variety of mulberry.

5.3.2.6 Efficiency of conversion of digested food (ECD %)

ECD explains the ability of insect to utilize the portion of food that is digested for growth and development.

The ECD increased from first to fifth day of fifth instar and thereafter it decreased as the age of the larvae advanced among the accessions. The change in ECD of different days of fifth instar might be due to changes in the midgut activity of the silkworm. Similarly, Sumioka et al. (1982) reported that ECD decreased with larval growth.

Significantly maximum (67.88%) ECD was noticed when the larvae were fed with leaves of TB-21 followed by ME-27 (67.27%), MI-79 (66.84%) and V-1 (66.38%). However, it was significantly minimum in case of silkworms fed with leaves of accession Srinagar local for which ECD was 61.90 per cent and the next best one was C-776 (62.57%) (Table 29). Similar difference was observed with respect to ECD among varieties by Anantharaman et al., (1993). According to Dutta et al. (1996), K-2 exhibited significantly higher ECD compared to Jatimani mulberry variety. Prabhakara et al. (2000) observed that silkworms reared on M5 mulberry variety showed better ECD compared to Local variety of mulberry, which may be due to low nutrient status of mulberry leaves of Local variety compared to M-5 and S-54.

5.3.2.7 Approximate digestibility (AD %)

Approximate digestibility is a precise measure of digestibility to evaluate the best food compared to the amount of food digested. It measures the digestible portion of the food that is ingested.
During fifth instar, the AD increased from first to fourth day, thereafter it decreased gradually as the age of the silkworm advanced among the accessions. The reduction in AD during later part of fifth instar might be due to less efficiency of digestion and more silk synthesis in silkglands.

AD was significantly maximum when the silkworms were fed with leaves of accession TB-21 (47.66%) followed by silkworms reared on leaves of accession ME-27 (47.20%). Significantly minimum AD was observed on accession Srinagar local (43.24%) and C-776 (43.54%) (Table 30). This variation may be due to nutritional differences of the food and also moisture content in the food and excreta. The present results are in conformity with those of Prabhakara (1988), who reported that the silkworms reared on Local variety showed higher AD compared to improved mulberry varieties M-5 and S-54. Dutta et al. (1996) also reported that Jatimani variety of mulberry recorded higher AD compared to K-2.

5.3.2.8 Reference ratio (RR)

Reference ratio is an indirect expression of absorption and assimilation of food. It also expresses the ingesta requirement per unit excreta production.

Significantly highest reference ratio was registered when silkworms were reared on accession TB-21 (1.95) followed by accession ME-27 (1.93). However, it was significantly minimum in case of silkworms fed with leaves of accession Srinagar local (1.79). The RR values was high in larvae fed on TB-21, because it had more nutrients which are required for better growth and development, hence larvae produce less excreta (Table 31). These results are in conformity with those of Anantharaman et al. (1994), who reported that RR values depend on quality of food.
5.3.3 Correlation between biochemical constituents and cocoon and shell weight

Cocoon weight had highly significant positive association with biochemical constituents like nitrogen, protein, total amino acids, total carbohydrates and total chlorophyll content (Table 32). Shell weight had significantly positive association with biochemical constituents like nitrogen, total amino acids and total carbohydrates and non-significant positive association with protein and total chlorophyll content (Table 33). These results are on par with the findings of Patil et al. (2001) who reported that 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) 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 Katagiri, 1991). Sudo et al. (1981) found a significant correlation between the nitrogen content in the leaf, silkworm body weight and cocoon shell weight.

CONCLUSION

Study of growth and yield parameters revealed that during rainy, winter and summer seasons, SB-21, ME-144, C-776, ME-18, M. indica, M. multicaulis, MI-224, MR-2, ME-03 and ME-52 were found to be superior with respect to leaf yield per plant among the eighty accessions. High PCV and GCV were recorded for number of branches, total shoot length, number of leaves, single leaf area, leaf yield per plant and 100 fresh leaf weight indicating greater diversity among accessions for these traits in rainy season, winter and summer season. High heritability in broad sense was recorded for plant height, number of branches per plant, total shoot length, number of leaves per plant, single leaf area, leaf yield per
plant, 100 fresh leaf weight, stem girth, number of trichomes per mm, moisture percentage, moisture retention capacity at 6, 12 and 24 h.

Thirteen accessions were selected based upon their performance for growth parameters, leaf yield, moisture content and moisture retention capacity. These thirteen accessions were evaluated through biochemical analysis and silkworm rearing performance. Among the 13 accessions TB-21, ME-27 and MI-79 had maximum moisture content, moisture retention capacity, nitrogen, protein, carbohydrates, amino acids, which are essential for growth and development of silkworm and cocoon production. TB-21, ME-27 and MI-79 were also superior with respect to economic traits of silkworm.

Maximum number of fruits were recorded in accession Surat local, whereas ME-18 had longer fruit length and fruit diameter.

**FUTURE LINE OF WORK**

1. Accessions TB-21, ME-27 and MI-79 can be further evaluated in preliminary yield trials for leaf yield, growth parameters and rearing performance studies on the mulberry silkworm.

2. Hybridization programme could be done with involvement of top ten best performing mulberry accessions and progenies could be evaluated further.

3. Screening of drought tolerant mulberry accessions in the germplasm and their impact on economic traits of silkworm is necessary.

4. Biochemical analysis / constituents and value added products of mulberry fruits are needed to be explored.