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Full Length Research Paper

Alterations in the biochemical components and photosynthetic pigments of mulberry (*Morus* Spp.) attacked by leaf – roller (*Diaphania pulverulentalis*) pest

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Leaf roller (*Diaphania pulverulentalis* Hampson) is a serious pest of mulberry (*Morus alba* L.), which is the sole food for silkworm – *Bombyx mori* L. It attacks the tender leaves of the host causing considerable damage which alters the leaf quality. An attempt was made to know the changes in the biochemical components (free amino acids, total soluble proteins, total reducing sugars, total soluble sugars, starch and total phenols) and photosynthetic pigments (total chlorophyll, chlorophyll – a, chlorophyll – b, chlorophyll – a/b ratio and carotenoids) in six popular indigenous mulberry varieties (M_5, MR_2, Mysore local, S_{36}, S_{54} and V_1) under infestation by leaf – roller pest. The results revealed that the biochemical components were reduced in almost all the varieties chosen. Though, there was no reduction in free amino acids in S_{36}; total soluble proteins in V_1; total reducing sugars in MR_2; total soluble sugars in S_{36} and S_{54}; starch contents in Mysore local and S_{54}; total phenols in MR_2. The MR_2 variety showed no alteration in the free amino acids. Total chlorophyll, chlorophyll – a, and chlorophyll – b were reduced drastically in all the varieties. The chlorophyll – a/b ratio was lowered in Mysore local, S_{36} and S_{54}. However, it was increased in M_5 and MR_2 and V_1 due to pest injury. Except Mysore local, the remaining varieties showed reduction in the carotenoid content. The alterations in biochemical components of mulberry foliage will adversely influence the health, growth and development of silkworm. This inturn results in the production of low quality silk.

Key words: Biochemical components, leaf roller, Mulberry, photosynthetic pigments.

INTRODUCTION

Mulberry (*Morus* spp.) is the exclusive source of feed for the silkworm – *Bombyx mori* L. in commercial sericulture. It is a deep rooted, perennial, found globally in almost all types of agro-climates with high biomass producing, proteins rich foliage plant (Ullal and Narasimhanna, 1981). Mulberry plays an important role in the quantity and quality of silk production, contribute to 38.20% for the success of cocoon crop (Miyashita, 1986). Silkworms feed on mulberry leaves during their entire larval period and utilize the leaf protein for the biosynthesis of silk. It is therefore clear that mulberry plays a dominant role in cocoon production as a source of nutrition to the silkworms. However, Mulberry foliage is prone to depredation by disease causing organism such as pathogens and pests. Among the several pests known to attack mulberry, the lepidopteron leaf roller, *Diaphania pulverulentalis* (Hampson) (family; Pyralidae) has attained a serious status in the Southern India. The leaf roller collected from mulberry gardens and agricultural fields are the potential carriers of microsporidia *Nosema bombycis*, a detrimental pathogen causing a pebrine disease to the silkworm. Thus constitute a potential threat of gaining access to silkworm rearing through contaminated mulberry leaf and perpetuate infection

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despite routine care taken in mother moth examination and sanitation thereby may have an adverse impact on the sericulture industry (Ifat et al., 2011).

Leaf roller infestation is high during the rainy and winter season (Geethabai et al., 1997). It attacks the crop throughout the year but, peak during January to October. The pest caused 66% reduction in the leaf yield of M_5, followed by MR_2 (65%), V_1 (52%) and S_{54} (30%) mulberry varieties (Reddy and Narayanaswamy, 2003). The early larval stage inhabits the apical part (unopened leaves) of the mulberry shoot and feed by scraping the tender leaf tissue, resulting in drying of the terminal portion. The infested leaves are brought together and bound through silk web formed by the larva. Sometimes, a single leaf is rolled into folded shape with the web from the larva inside and hence the pest is called as leaf roller. Occasionally, the larva also bores into the soft apical stem resulting in the drying of the shoot. The pest-infested plants show stunted growth. Heavily infested fields show considerable amount of webbing over the leaves. Such leaves are completely eaten up by late-age larva, resulting in considerable decline in the leaf yield (Siddegowda et al., 1995). The damage caused by leaf roller to mulberry is to an extent of 20 to 40% in some traditional regions of Karnataka (Veeranna, 1997). The literature available on the nutritive status of the leaf roller infested mulberry leaves in very scanty (Narayanaswamy, 2003). Therefore, an attempt was made to know the influence of leaf roller infestation on the biochemical components and photosynthetic pigments of mulberry leaves.

MATERIALS AND METHODS

The healthy and leaf roller infested leaves of six popular indigenous mulberry varieties viz., M_5, MR_2, Mysore local, S_{36}, S_{54} and V_1 were collected from plantations in and around Tumkur, Kanakapura taluk and Ramanagara districts (Karnataka, India). The leaves were oven dried and processed to analyse the free amino acid, total soluble proteins, total soluble sugars, starch, reducing sugars and total phenols. Fresh mulberry leaves were utilised to estimated the photosynthetic pigments (total chlorophyll, chlorophyll – a, chlorophyll – b, chlorophyll – a/b ratio and carotenoids).

Estimation of total free amino acids

Total free amino acids were determined by Ninhydrin method (Moore and Stein, 1948). 50 mg of dried mulberry leaf powder was ground in 5 ml of 80% methanol. The methanol layer (2 ml) was taken in a test tube and 1 ml of ninhydrin reagent (4% ninhydrin in methyl cellosolve and 0.2 M acetate buffer in the ratio of (1:1) was added to it. The samples were boiled for 20 min and cooled; the volume was made up to 10 ml with distilled water. Absorbance was noted at 570 nm.

Total soluble proteins

Protein content was determined using the method of Lowry et al. (1951). To 1 ml of sample (leaf extract), 5 ml of alkaline copper reagent (1% $CuSO_4$ + 1% Na-K-tartarate + 2% Na_2CO_3 in 1 N NaOH) was added and incubated at room temperature for 10 min. For this, 0.5 ml of folin-phenol reagent was added and allowed to stand for 30 min. The OD was measured at 750 nm by UV-spectrophotometer.

Total soluble sugars and starch

The total soluble sugars and starch contents were determined as described by Yemm and Willis (1954) (Anthrone method). 100 mg of leaf powder was ground in 20 ml of 80% ethanol and incubated at 95°C for 10 min from. To 1 ml of the supernatant sample, 4 ml of anthrone reagent was added. The reaction mixture was shook gently and kept over a boiling water bath for 10 min and allowed to cool down. The OD of blue green solution was measured at 625 nm. Glucose was used for plotting a standard curve.

For starch estimation, 5 mL sample was treated with 52% perchloric acid for 30 min. The samples were centrifuged at 6000 rpm for 15 min. 1 mL supernatant was mixed with 2 mL of cold anthrone reagent in ice bath. The samples were then boiled for 10 min at 100°C in water bath, cooled and recorded the absorbance at 630 nm. The starch concentration was calculated by multiplying with 0.9 to the values obtained from the standard curve.

The reducing sugars

The reducing sugars were estimated by Dinitro salicylic acid (DNS) method explained by Miller (1972). 500 mg of dried leaf powder was ground in 10 ml of 80% methanol. To 3 ml aliquot of the extract, 3 ml of di-nitrosalicylic acid (DNS) reagent was added and the mixture was boiled for 5 min in a water bath. 1 ml of 40% sodium potassium tartarate was added and OD was measured at 575 nm. Glucose was used as a standard.

Total phenols

Folin-ciocalteu was used to determine the total phenols (Bray and Thorpe, 1954). 500 mg of dried mulberry leaf powder was ground with 5 ml of methanol. The residue was re-extracted twice with the same volume of the solvent and the pooled supernatants was evaporated to dryness. The residue thus obtained was dissolved in 5 ml of distilled water and used for the estimation of total phenols. To 1 ml of sample, 1 ml of Folin's reagent (1:2) and 2 ml of 20% sodium carbonate was added. The reaction mixture was shook and heated over a boiling water bath for exactly one minute. The OD was measured at 650 nm. Caffeic acid was used for standard graph.

The photosynthetic pigments

100 mg of fresh mulberry leaf tissue was placed in a vial containing 7 ml of dimethyl sulphoxide (DMSO) and chlorophyll was extracted into the fluid without grinding at 65°C, incubated for three hours. Liquid was transformed to graduated tube and made up to a total volume of 10 ml with DMSO and absorption spectra were recorded at 663 and 645 nm using DU-40 spectrophotometer immediately. The content of total chlorophyll, chlorophyll-a and chlorophyll-b were estimated using the method suggested by Arnon (1949). The chlorophyll content was calculated by using the formula:

Total chlorophyll (mg/ml) = (0.0202) × (O.D. 645) + (0.00802) × (O.D. 663)
Chlorophyll 'a' (mg/ml) = (0.0127) × (O.D. 663) – (0.00269) × (O.D. 645)

Chlorophyll 'b' (mg/ml) = (0.0229) × (O.D. 645) – (0.00468) × (O.D. 663)

The carotenoid content was estimated using the formula of Kirk and Allen (1965) and expressed in milligrams per gram fresh weight.

Total carotenoids (µg/ml) = O.D. 480 + (0.114 × O.D. 663 – 0.638 × O.D. 645)

Data obtained were analyzed by student's t - test according to the equation of Dixon and Massay (1957). Significant differences were established at P<0.05 and P<0.01 levels. The information was also subjected to percentage of changes (decrease/increase) in the infested and healthy leaves and was calculated as:

$$\% \text{ decrease/increase} = \frac{(\text{Values of healthy leaves} - \text{values of infested leaves})}{(\text{Values of healthy leaves})} \times 100$$

RESULTS AND DISCUSSION

Biochemical components

Free amino acids

The free amino acid was decreased noticeable in leaf roller infested leaves of M_5, Mysore local, S_{54} and V_1 varieties. But, the free amino acid was increased (17.65%) in S_{36} variety and there was no alteration in MR_2 variety. The reduction was in the range of 8.07 (V_1 variety) to 71.12% (M_5 variety) (Table 1). Raman et al. (1994) observed an increased total free amino acids content in mealy bugs (*Maconellicoccus hirsutus* Green) infested mulberry varieties viz., M_5, MR_2, BC_{259}, Tr4, S_{13} (indigenous), Kosen, Ichinose and Goshoerami (exotic). Mahadeva and Shree (2003) reported a reduction in free amino acid content in M_5, MR_2, S_{36} and it was increased in the V_1 mulberry variety infested by Jassids (*Empoasca flavescenes* F.). Shree and Mahadeva (2005) observed a significant increase in the free amino acids of Mysore local variety. Whereas, it decreased significantly in the S_{54} due to jassids infestation. The amino acid content was increased (Kurangi, Thysong-3, Vietnam and Thailand) as well as decreased (M_5, Kajali, Hakkikalu and *Morus nigra*) in the leaves of mulberry varieties when they were infested by thrips – *Pseudodendrothrips mori* (Niwa) (Latha, 1999).

Total soluble proteins

The total soluble protein was decreased significantly in M_5, Mysore local, S_{36}, $S_{54,}$ non-significantly in MR_2. It was non-significantly increased in the V_1 (0.64%) mulberry variety infested by *D. pulverulentalis*. The reduction was in the range of 0.70 (MR_2) to 13.51% (Mysore local) (Table 1). Narayanaswamy (2003) also observed reduced protein content (15.31%) in the leaf roller infested M_5 variety. Shree et al. (1989) have noticed 10.50% reduction and 40.00% increase in the total soluble proteins of tukra affected leaves in Kajali and Kanva-2 mulberry varieties, respectively. Shree and Umesh (1989) noticed decrease in the protein content of *Morus macroura* and *Morus nigra*; the reduction was, however, negligible in *M. nigra*. But it was increased in *Morus australis* and *Morus cathayana*. Umesh et al. (1989) found an increase in the total soluble proteins of tukra affected mulberry leaves (variety; Vietnam) compared to healthy ones. Bose et al. (1992) investigated a statistically significant reduction in the water soluble proteins in the mealy bugs infested leaves of six mulberry varieties (K_2, S_{30}, S_{36} S_{41} and S_{54}). Raman et al. (1994) recorded the effect of tukra disease on the total soluble proteins in eight mulberry varieties. The total proteins decreased (9 to 26%) in all the mulberry varieties except MR_2. Veeranna (1997) reported an increase in the total proteins due to tukra in M_5 and DD varieties. Narayanaswamy et al. (1999) revealed that the crude protein contents were drastically reduced in spiralling whitefly (*Aleurodicus dispersus* Russell) infested leaves of M_5 mulberry variety. The total soluble proteins were more in the four mulberry cultivars (M_5, MR_2, S_{36} and V_1), when they were infested by jassids (Mahadeva and Shree, 2003).

The total soluble proteins were significantly increased in Mysore local and decreased in S_{54} due to Jassids infestation (Shree and Mahadeva, 2005). Latha (1999) reported enhanced protein content in M_5, Kurangi, Kajali, Vietnam, Thailand and *M. nigra*. It was decreased in Hakkikalu and Thysong mulberry varieties infested by thrips (*P. mori*). The crude protein contents significantly decreased in thrips infested tender leaves in all the varieties (K_2, S_{13}, S_{34}, S_{36} and V_1) considered, maximum decrease was in the variety S_{13} followed by S_{34}, K_2, V_1 and least in S_{36}. Also, a significant decrease in the protein content of medium leaves was recorded in all the varieties except V_1. The highest decrease was observed in S_{13} followed by S_{34}, K_2 and least in S_{36}. The decrease in the crude protein contents may be attributed to the damage caused by the insect, thus altering the metabolic functions leading to either decline in protein synthesis or mobilization of proteins for repair of the damaged tissues in order to develop resistance to insect bite. Increase in the protein content may be due to changes in the protein synthesis pattern to overcome the injury and develop resistance (Sathya et al., 2002a).

Total reducing sugars

The total reducing sugar was reduced in all mulberry varieties, except MR_2 where it showed significant increase (55.88%). The reduction was maximum in the *D. pulverulentalis* infested leaves of M_5 (65.01%) and minimum in Mysore local (1.51%) (Table 1). Shree and Umesh (1989) have noticed a significant increase in the

Table 1. Changes in the biochemical components of leaf roller infested mulberry leaves.

Mulberry varieties	Free amino acids (µg/g)		Total soluble proteins (mg/mg)		Total reducing sugars (mg/g)		Total soluble sugars (mg/g)		Total starch (mg/g)		Total phenols (mg/g)	
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested
M_5	7.48	2.16** (-71.12)	109.85	101.40* (-7.69)	113.20	39.60** (-65.02)	1.87	1.76 (-5.93)	1.38	1.28** (-7.14)	2.88	1.82** (-36.81)
MR_2	11.16	11.16 -	184.60	183.30 (-0.70)	40.80	63.60** (+55.88)	2.14	2.06 (-3.70)	1.53	1.13** (-26.32)	4.44	4.32 (-2.70)
Mysore local	15.36	12.24** (-20.31)	72.15	62.40** (-13.51)	185.20	182.40* (-1.51)	2.52	2.38 (-5.66)	1.05	0.86** (-17.68)	4.04	4.41 (+2.48)
S_{36}	8.16	9.16** (+17.65)	85.15	77.35* (-9.16)	191.60	182.40** (-4.80)	2.31	2.00** (-13.70)	1.31	1.42** (+8.16)	3.66	3.25* (-11.29)
S_{54}	16.68	15.20** (-8.87)	109.85	99.45** (-9.47)	43.20	37.20* (-13.89)	1.90	1.98 (+4.17)	1.50	1.55** (+2.98)	2.50	2.76** (+10.40)
V_1	19.84	18.24** (-8.07)	101.40	102.05 (+0.64)	45.20	43.20** (-4.43)	1.76	1.52** (-13.51)	1.34	1.28** (-4.67)	4.96	3.20** (-35.48)

**Significant at 1% level; * Significant at 5% level, ; Values in the parenthesis indicate % difference over healthy (+ = more than; - = less than; ---- = not altered).

tukra affected *M. macroura* and *M. australis* but it was negligible in latter variety. In *M. cathayana* and *M. nigra*, it was unaltered. Similar reductions were observed in the Vietnam mulberry variety infested by mealy bugs (Umesh et al., 1989). Bose et al. (1992) found significant reduction in the non-reducing sugars and total reducing sugars in the leaves of K_2, S_{30}, S_{36}, S_{40} and S_{54} mulberry varieties infested by *M. hirsutus.* There was a drastic decrease in the sugar contents of M_5 mulberry leaves infested by leaf roller (Narayanaswamy, 2003). The reducing sugars were decreased in M_5 and V_1. But, it was increased in MR_2 and S_{36} due to hopper burn (Mahadeva and Shree, 2003). Similar reductions of sugar contents were observed in jassids infested Mysore local and S_{54} mulberry varieties by Shree and Mahadeva (2005). Latha (1999) showed a drastic increase in the total reducing sugars of thrips infested leaves in four indigenous (M_5, Kurangi, Kajali and Hakkikalu) and four exotic (Thysong-3, Vietnam, Thailand and *M. nigra*) mulberry varieties. Sathya et al. (2002b) observed changes in the reducing and non-reducing sugars in the leaves of K_2, S_{13}, S_{34} and S_{36} and V_1 due to thrips infestation. But, it was least in the K_2 and S_{36} varieties. Alteration in the reducing sugars may be due to reduction in leaf lamina and malformation of leaves in pest affected plants resulting in less productivity (Shree and Umesh, 1989).

Total soluble sugars

The total soluble sugar was decreased in leaf roller infested leaves of M_5, MR_2 (3.70%), Mysore local, and it was significant in S_{36} (13.70%) and V_1. But it increased (4.17%) non-significantly in S_{54} mulberry variety (Table 1). Narayanaswamy (2003) observed a 31.34% increase in the sugar contents of M_5 mulberry leaves due to leaf roller infestation. The total soluble sugars were increased by 35% and 36% in the Kajali and Kanva-2 mulberry varieties, respectively. Similar

variations were observed in various other cases due to pest attack. The sugar content was marginally decreased in tukra affected *M. australis, M. cathayna* and *M. nigra* varieties. However, there was an increase in *M. macroura* (Shree and Umesh, 1989). Umesh et al. (1989) have noticed a reduction in the leaves of Vietnam variety due to mealy bugs infestation. Umesh et al. (1990) have studied the changes in sugar contents of mealy bugs infested leaves of four indigenous (Berhampore, S_{30}, S_{36} and S_{31}) and six exotic (Kosen, *M. multicaulis*, Philippine, Okinawa-2, Tsukasaguwa and Italian) mulberry varieties. The sugar content showed an increase in Berhampore, Okinawa-2 and Philippine varieties. Whereas, it decreased in Italian, Kosen, *M. multicaulis*, S_{30}, S_{36} and S_{41} varieties. No difference was observed in Tsukasaguwa.

Raman et al. (1994) observed increased soluble sugar content in the tukra affected leaves of M_5, MR_2, BC_{259}, S_{13}, Kosen, Goshoerami. However, in Tr4 and Ichinose, it was decreased. Veeranna (1997) found a high level of soluble carbohydrates in M_5 and DD varieties due to tukra. Sugars were drastically reduced in M_5 due to spiralling whitefly infestation (Narayanaswamy et al., 1999). Chandramohan et al. (2002) have noticed 43.75% reduction in the total sugars of spiralling whitefly infested mulberry leaves. Mahadeva and Shree (2003) noticed a reduction in the soluble sugars of Jassids (*E. flavescenes*) infested leaves of M_5, MR_2, S_{36} and V_1 mulberry varieties. Similar reduction was noticed in Mysore local and S_{54} by Shree and Mahadeva (2005) due to hopper burn. Latha (1999) noticed an increase in the total sugars of thrips infested leaves of M_5, Kurangi, Hakkikalu, Thysong-3, Vietnam, Thailand and *M. nigra*. But, it was decreased in Kajali.

Starch

The starch content was decreased significantly in M_5, MR_2, Mysore local and V_1. It was increased significantly in S_{36} (8.16%) and S_{54} (2.98%) varieties due to *D. pulverulentalis* infestation. The highest reduction was detected in MR_2 (26.32%) and the lowest was in V_1 (4.67%) variety (Table 1). Shree et al. (1989) observed 27 and 36% increase in starch content of mealy bugs affected Kajali and Kanva-2 mulberry varieties. The starch content was increased in the *M. macroura* and *M. nigra*. The increase was significant in *M. macroura*. There was only a negligible reduction in *M. australis* and *M. cathayana* due to *M. hirsutus* infestation (Shree and Umesh, 1989). Umesh et al., (1989) found a significant increase in the starch content in the leaves of Vietnam mulberry variety due to mealy bugs infestation. There was a significant decrease in the starch content of K_2, S_{30}, S_{36}, S_{41} and S_{54} affected by tukra (Bose et al., 1992). Raman et al. (1994) observed variation in starch contents of five indigenous (M_5, MR_2, BC_{259}, Tr4 and S_{13}) and three exotic mulberry varieties (Kosen, Ichinose and Goshoerami) due to tukra. Shree and Mahadeva (2005) observed significant reduction in the starch content of Jassids infested Mysore local and S_{54} mulberry varieties.

Total phenols

The total phenol was decreased significantly in M_5, S_{36}, V_1 and non-significantly in MR_2; but it increased significantly in S_{54} and non-significantly in Mysore local. The leaf roller infested M_5 variety showed maximum reduction (36.81%) and it was minimum in MR_2 (2.70%). The increase was 10.40 and 2.48% in S_{54} and Mysore local varieties, respectively (Table 1). Shree and Umesh (1989) reported a decreased phenolic level in tukra affected varieties. However, there was a significant increase in *M. australis* and *M. cathayana*. Umesh et al. (1989) found that increased total phenols in the leaves of Vietnam variety due to *M. hirsutus* infestation. Muthegowda et al. (1990) noticed that the pattern of phenol accumulation varied depending upon the positional status of leaves in the tukra affected C_{15} (Conoor series) variety. There was an initial increase followed by a sudden decrease from the leaf of the 2^{nd} to 10^{th} order. The tukra affected leaves had more phenolics as a result of insect bite. This clearly shows that the pests certainly altered phenolic metabolism in the host leading to biochemical changes.

Raman et al. (1994) observed a lower content of total phenol in M_5, Kosen, Ichinose, Goshoerami, BC_{259} and S_{13} varieties due to mealy bugs attack. However, it was increased in MR_2 and Tr4. Mahadeva and Shree (2003) showed a decreased phenolic content in the Jassids infested leaves of M_5, MR_2, S_{36} and V_1 varieties. Similar results were also noticed by Shree and Mahadeva (2005) in Mysore local and S_{54} varieties. Latha (1999) studied the changes in the biochemical composition of leaves of four indigenous and four exotic mulberry varieties infested by thrips. M_5, Hakkikalu and *M. nigra* varieties showed a drastic increase in the total phenolic content; while in the other varieties, it was significantly reduced. The accumulation of phenolics in the host may inactivate the enzyme which inhibits the further advance of the pathogenic organism by limiting its source of nutrients (Uritani, 1961).

The most important phenolic compounds implicated in the defense mechanism of plants against pathogens are coumaric acid, phloretin, umberlliferons, caffeic acid, chlorogenic acid and ferulic acid (Agrios, 1969). When such substances are ingested by the phytophagous insects along with the food, they get access to the natural defense mechanism.

Photosynthetic pigments

The leaf roller infested mulberry leaves of six indigenous

Table 2. Changes in the photosynthetic pigments (mg/g. fresh weight) of leaf roller infested mulberry leaves.

Mulberry varieties	Total chlorophyll		Chlorophyll – a		Chlorophyll – b		Chlorophyll – a/b		Carotenoids	
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested
M_5	1.31	1.13** (-13.40)	1.12	0.97** (-13.37)	0.19	0.16* (-14.13)	5.90	5.93 (+0.49)	0.90	0.67** (-26.02)
MR_2	2.52	2.11** (-16.29)	1.99	1.68** (-15.46)	0.53	0.42** (-19.24)	3.80	3.98* (+4.66)	1.26	0.93** (-26.01)
Mysore local	2.36	1.52** (-35.53)	1.92	1.22** (-36.40)	0.44	0.30** (-31.97)	4.35	4.06* (-6.60)	1.05	1.64** (+39.01)
S_{36}	1.34	0.82** (-39.03)	1.06	0.63** (-40.63)	0.28	0.19** (-33.57)	3.77	3.38 (-10.48)	0.72	0.38** (-47.50)
S_{54}	1.95	1.21** (-38.07)	1.56	0.94** (-39.41)	0.40	026** (-33.84)	3.94	3.61* (-8.43)	0.90	0.57** (-36.99)
V_1	3.79	3.31** (-12.74)	2.98	2.64** (-11.70)	0.81	0.67** (-16.71)	3.69	3.91** (+5.93)	1.43	1.08 (-24.58)

** Significant at 1% level; * Significant at 5% level, ; Values in parenthesis indicate % difference over healthy (+ = more than; - = less than; ---- = not altered).

(M_5, MR_2, Mysore local S_{36}, S_{54} and V_1) varieties showed almost significant changes in the photosynthetic pigments (total chlorophyll, chlorophyll – a, chlorophyll – b, chlorophyll – a/b ratio and carotenoids). There was a significant decrease in the total chlorophyll, chlorophyll – a and chlorophyll – b in the leaves of all six varieties infested by *D. pulverulentalis.* S_{36} variety showed maximum reduction in the total chlorophyll, chlorophyll – a and chlorophyll – b by 39.03, 40.63 and 33.57%, respectively. Total chlorophyll and chlorophyll – a were reduced by 12.74 and 11.70% in V_1 variety respectively; chlorophyll – b by 14.13% in M_5 mulberry variety (Table 2).

Narayanaswamy (2003) observed a reduced amount of total chlorophyll, chlorophyll – a and chlorophyll – b by 32.40, 31.98, 32.87%, respectively in the leaf roller infested mulberry plants (Variety; M_5). In the present study, the chlorophyll – a/b ratio was lowered significantly in Mysore local, S_{54} and non-significantly in S_{36}. It was increased significantly in MR_2, V_1 and non-significantly in M_5. The reduction was least (6.60%) in Mysore local but maximum (10.46%) in S_{36} variety. Similarly, the least (0.49%) increase was in M_5 and maximum reduction (5.93%) was in V_1 variety. The carotenoids were decreased significantly in M_5, MR_2, S_{36}, S_{54} and non-significantly in V_1 mulberry varieties attacked by leaf roller pest. But, there was a drastic increase in the Mysore local variety. The decrease in carotenoids was found to be maximum (47.50%) in S_{36} and minimum (24.58%) in V_1 variety. The Mysore local showed an increase of 39.01% compared to healthy ones (Table 2). Mahadeva and Shree (2003) showed a decrease in the photosynthetic pigments (total chlorophyll, chlorophyll – a, chlorophyll – b, chlorophyll – a/b ratio and carotenoids) due to *E. flavescenes* infestation (M_5, MR_2, S_{36} and V_1), except the chlorophyll – a/b ratio in M_5, which showed an increase. Similar trend was noticed in Mysore

local and S_{54} varieties by Shree and Mahadeva (2005). The photosynthetic pigments (total chlorophyll, chlorophyll – a, chlorophyll – b, chlorophyll – a/b ratio and carotenoids) were reduced because of pest (Jassids) injury.

However, in the Mysore local variety, the chlorophyll – a/b ratio was increased. Similar observations were made in other cases when mulberry leaves were infested by various pests such as mealy bugs (Umesh et al., 1989), thrips (Das et al., 1994) and giant African snails (Ravi, 1997). Thus, the content of photosynthetic pigments varied depending upon the intensity of pest-infestation, extent of damage and mulberry varieties. The altered chlorophyll content adversely affected the photosynthetic activity (Heldt, 1997), productivity which ultimately leads to reduce protein synthesis (Burd and Elliot, 1996). Consequently, the mulberry foliage suffers from nutritional inferiority.

Pest attacks generally set in motion or accelerate a complicated series of metabolic disturbances in the host, rather than effecting a simple change in a unique process. Malformation of leaves due to pests will affect the photosynthesis by the crop in 3 ways: by lowering light interception, by reducing photosynthetic efficiency, or by altering normal distribution of assimilates within the plant. Ultimately results in the variation of net availability of plant productivity (Hewett, 1977). Obviously, the foliage suffers from nutritional inferiority. Therefore, the pest attacked leaves when fed to silkworms will have an adverse impact of their growth and development, leading to cocoon crop failures (Pradeep et al., 1992; Ravi and Shree, 1998; Doureswamy and Chandramohan, 1999; Mahadeva and Shree, 2004a). The pest attacked and diseased mulberry leaves should not be used for silkworm feeding as they are known to affect the commercial characters of cocoons (Ravi and Shree 1998; Chandramohan et al., 2000; Mahadeva and Shree, 2004b). Necessary arrangements must be made to manage the pests and diseases of mulberry plant as it is the only source of food for silkworms.

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