Mysore J. Agric. Sci., 56 (4) : 94-104 (2022)

Leaf Quality Evaluation of Mulberry (*Morus* Sp.) Variety V1 Trained as Small Tree under Different Spacing and Stump Height

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Received : May 2022
Accepted : July 2022

Abstract

A study was undertaken with the objective of understanding the performance of V1 mulberry cultivar as small tree under different spacing and stump height. Field experiment was laid out in split plot design having three spacing [(S1-2.4 x 1.2 m), (S2 - 2.4 x 1.8 m), (S3- 2.4 x 2.4 m)] and three stump heights [(H1-0.5 m), (H2 -1.0 m), (H3-1.5 m)] under irrigated condition during 2016-2021 at College of Sericulture, Chintamani. In chemoassay of leaf, all the nine treatments showed very good content of moisture (73.13 - 79.71%), crude protein (25.56 - 29.53%), total sugars (16.34 - 17.37%), total chlorophyll (3.076 - 3.266 mg/g), total minerals (9.79 - 10.67%) and crude fibre (11.07 - 11.77%). In bioassay also, they exhibited better rearing performance with optimal range of mature larval weight (39.40 - 43.29g), effective rate of rearing (93.24 - 96.40%), cocoon yield / 100 DFLs (87.29 - 89.49 kg), cocoon weight (1.836 - 1.885 g), cocoon shell weight (0.397 - 0.433 g), cocoon filament length (1080 - 1230 m) with reduced larval duration (547 - 589 hr) and lower denier (2.828 - 3.018). In all the treatments, majority of chemoassay and bioassay parameters were found marginally better during monsoon, followed by winter and summer. Highly significant positive correlations were noticed between four biochemical parameters *viz.,* crude protein, total sugars, total chlorophyll and total minerals and six bioassay parameters *viz.,* mature larval weight, effective rate of rearing, cocoon yield, single cocoon weight, single cocoon shell weight and filament length. Three treatments *viz.,* S3H3, S2H3 and S3H2 showed better performance ranking first, second and third in both chemoassay and bioassay. However, the superiority of any of the nine treatments studied has to be judged by considering the leaf yield, Leaf- Cocoon ratio and Benefit - Cost ratio under variable intensity of cultivation.

Keywords : Tree mulberry, Leaf quality, Spacing, Bivoltine silkworm, Bioassay, V 1 variety

In sericulture, growth and development of silkworm (*Bombyx mori* L.) larvae and subsequent cocoon yield and quality are mainly influenced by nutritional quality of mulberry (*Morus* Spp.) leaves as feed. To organize sericulture on sound economic lines, maximization of quality leaf production per unit area of land and cocoon production per unit quantity of leaf are essential. Mulberry leaf quality is largely determined by assaying the content of its major biochemical constituents (chemoassay) such as, moisture, protein, carbohydrates, chlorophylls, fibre, minerals and ultimately judged based on the silkworm rearing performance (bioassay). In southern plains of India, bush form of mulberry cultivation under assured irrigation is most common and V1 variety is most popular with high yield potential of good quality leaf in different seasons. In recent years, sericulturists of this area are facing the problem of scarcity of irrigation water due to scanty and erratic rainfall which implies on potential leaf yield and leaf quality, as a

consequence of which the cocoon productivity is declining.

It is an established fact that, tree roots respond well to drought condition (Brunner *et al.*, 2015) and mulberry being a tree species thrives well as high bush / small tree in drought situation by developing deeper and extensive root system (Dandin and Sengupta, 1988). Sericulturists who faced the problem of severe scarcity of irrigation water, to save their mulberry bushes from collapse, are converting their bush plantations into tree type. Thereby, in southern plains of India, the concept of tree mulberry cultivation was originated under rainfed condition and more recently extended under irrigated condition. In due course, a few studies have established the better performance of tree form over bush form in different mulberry cultivars namely, V1 (Vanitha, 2018), BSRM-5 (Quader *et al.*, 1991) and BM-3 (Hossain *et al.,* 2016). However, there is only scanty information on the performance of V1 cultivar as small tree with different spacing and stump height in irrigated condition.

Since, there is no recommended package of practices for the cultivation of V1 as tree under irrigated condition from the research institutes, sericulturists have adopted different spacing, pruning height, training method, doses of manure and fertilizer as per their own experience and convenience which resulted in varied cocoon productivity. Even now, this situation of tree mulberry cultivation in Karnataka has remained unchanged. Meanwhile, many researchers have suggested for standardization of agronomical practices for tree mulberry cultivation (Ahalya, 2021 and Megharaj *et al.,* 2021) and recently, Central Sericultural Research and Training Institute (CSR&TI), Mysore has taken up a research work on the development of an agronomical package for tree mulberry cultivation (Anonymous, 2021). Keeping this prevailing situation of tree mulberry cultivation in view, field experiments were undertaken to investigate the leaf and cocoon yield with V1 variety trained as small tree under nine of treatment combinations of three spacings and three stump heights at College of Sericulture, Chintamani (UAS, Bangalore) during 2016 - 2021.

Material and Methods

An experiment was undertaken at College of Sericulture, Chintamani which falls under South Eastern Dry Zone of Karnataka in the year 2016-2021. The experiment was laid out with mulberry variety V1 in split plot design having two factors *viz.*, spacing (S) as main plot treatment with three levels S1 (2.4 x 1.2 m), S2 (2.4 x 1.8 m), S3 (2.4 x 2.4 m) and stump height (H) as sub plot treatment with three levels *viz*., H1 (0.5 m), H2 (1.0 m), H3 (1.5 m). Accordingly, there were nine combinations of treatments (S1H1, S1H2, S1H3, S2H1, S2H2, S2H3, S3H1, S3H2, and S3H3) with three replications each.

Collection and Preservation of Mulberry Leaf Samples for Chemoassay

Mulberry leaves were collected from plants after 60 days growth from previous harvest / pruning at morning hours (8 to 9 am) randomly from all the treatments. The composite leaf samples were air dried for two days and kept in oven at 70ºC for 1hr to dry further. The dried leaf samples were grounded into fine powder and preserved in butter paper bags for chemical analysis of crude protein (CP), total sugars (TS), total minerals (TM) and crude fibre (CF). Fresh leaves were used for the estimation of leaf moisture (M) and total chlorophyll (TC) content. Analysis were conducted in three crops of the year - first crop (August 3rd to October 4th week), second crop (January 2nd to March 3rd week) and third crop (March 4th to May 4th week) which nearly represents monsoon, winter and summer seasons, respectively.

Estimation of Bio-chemical Constituents of Leaf Samples

The biochemical constituents for six parameters were analysed by adopting standard chemical analytical methods - crude protein by microkjeldhal method (Jackson, 1973); total soluble sugars (Dubois *et al.,* 1956); chlorophyll content (Arnon, 1949), moisture content, total minerals and crude fibre (AOAC, 1984).

Bioassay Studies

To assess the quality of leaf harvested from small tree forms of V1 variety, cultivated under nine treatments,

silkworm rearing with bivoltine hybrid (FC2 x FC1) was conducted following the standard rearing technique (Srinivasa Babu *et al*., 2010). For every treatment, three replications each with freshly hatched 500 silkworms were maintained and worms were fed with the leaves of the experimental plot replication-wise of each treatment. Ten larval weight (TLW), total larval duration (TLD), effective rate of rearing (ERR), cocoon weight (CW), cocoon shell weight (CSW), cocoon filament length (CFL), and denier (D) were recorded and cocoon yield per 100 DFLs (CY) was calculated. Three rearing corresponding to the three crops of chemoassay representing three seasons were conducted in a year and in three consecutive years (3rd, 4th and 5th year of plantation).

The observations of both biochemical and bioassay studies of a particular season of three years are pooled and the pooled data are subjected for statistical analysis of variance using the standard SPSS package version 26. Further, the effect of treatments in respect of each biochemical constituent and bioassay parameter were judged by ranking them based on the mean values of overall seasons.

Results and Discussion

Chemoassay Studies

Statistically analysed seasonwise pooled data of three years on three biochemical constituents *viz*., moisture, crude protein and total sugars and other three constituents *viz*., total chlorophyll, total minerals and crude fibre, along with ranking on the performance of V1 tree mulberry under various treatments are presented in Table 1 and Table 2, respectively.

Main Effects of Spacing and Stump Height

The data (Table 1 and Table 2) indicated that both, spacing and stump height have significant effect on all the six biochemical constituents of leaf in all the three seasons studied. It is also observed that, irrespective of the seasons, all the six constituents increased with the increase in spacing. Similarly, except moisture content, other five constituents also increased with the increase in stump height. But, the moisture content was found to decrease with the increase in stump height in all the seasons.

Interaction effect of treatments

All the nine treatments have showed significant effect on all the biochemical constituents of leaf studied in all the three seasons (Table 1 and Table 2). All the biochemical constituents were maximum in higher spacing and stump height (S3H3) treatment. In mulberry, literature pertinent to tree cultivation is very few compared to that of bush cultivation.

All the six biochemical constituents are major determinants of mulberry leaf quality as it is reported that, moisture content (for enhancing ingestion), leaf protein (as major source of raw silk protein), carbohydrates (as energy source), higher chlorophyll (for enhancing photosynthetic efficiency of plant), mineral content (for balancing physiological alkalinity of feed) and crude fibre (for improving palatability of silkworms) play major roles in silkworm nutrition.

The moisture content was found to vary between 73.13 and 79.71 per cent in different treatments which is above the optimum requirement of silkworm as Dandin and Kumar (1989) have suggested that, more than 73 per cent of moisture in leaf is optimum for silkworm growth and development. In a similar study, with 8' x 3', 8'x 5' and 10' x 10' spacing with a common stump height of 3', Sudhakar *et al.* (2018a & b) have recorded 78.56, 80.34 and 80.31 per cent of moisture content, respectively. All the treatments also showed good percentages of crude protein (25.56 to 29.53%), total sugars (16.34 to 17.37%), total minerals (9.79 to 10.67 %), crude fiber content (11.07 to 11.77 %) and also total chlorophyll (3.076 to 3.266 mg/g) content. All these quality parameters are found at desirable levels for better growth and development of silkworm. As observed for the growth and yield parameters, the treatment with higher spacing and higher stump height (S3H3) recorded maximum values for most of the growth parameters and leaf yield per tree (Bharathi and Basavaiah, 2022), the same treatment also showed higher contents of biochemical constituents. While studying the biochemical contents

TABLE 1

Effect of spacing and stump heights on moisture, crude protein and total sugars content in leaves of V-1 mulberry trained as small tree

Treatment	Moisture (%)				Crude protein (%)				Total sugars (%)			
	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR
Main plot treatment Spacing (S)												
S_1 (2.4 x 1.2 m)	77.15	74.32	75.76	3	27.64	25.97	26.86	3	16.87	16.50	16.76	3
S_2 (2.4 x 1.8 m)	77.46	74.60	76.27	2	28.05	26.37	27.43	2	16.98	16.70	16.96	2
S_3 (2.4 x 2.4 m)	77.57	74.95	76.15	1	28.51	26.89	27.57	1	17.04	16.85	17.10	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.06	0.05	0.02		0.03	0.01	0.02		0.01	0.01	0.01	
CD at 5%	0.23	0.21	.0.07		0.10	0.06	0.09		0.03	0.02	0.02	
Sub plot treatment Stump height (H)												
H_1 (0.5 m)	79.10	76.11	77.64	1	26.90	26.10	26.58	3	16.71	16.48	16.66	3
H_2 (1.0 m)	77.42	74.46	76.14	2	28.15	26.41	27.41	2	16.99	16.68	16.98	2
H_3 (1.5 m)	75.67	73.30	74.42	3	29.15	26.73	27.88	1	17.19	16.88	17.18	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.07	0.05	0.07		0.04	0.03	0.02		0.01	0.01	0.01	
CD at 5%	0.21	0.14	0.22		0.12	0.08	0.05		0.02	0.03	0.03	
Interaction (S x H)												
$S_1 H_1$	78.42	75.67	77.15	3	26.60	25.56	26.15	9	16.64	16.34	16.44	9
$S_1 H_2$	77.11	74.16	75.54	6	27.54	26.13	26.85	7	16.90	16.49	16.85	6
$S_1 H_3$	75.93	73.13	74.60	8	28.78	26.24	27.59	4	17.08	16.66	16.99	4
$S_2 H_1$	79.19	75.97	77.57	2	26.82	26.21	26.67	8	16.73	16.49	16.72	8
$S_2 H_2$	77.41	74.34	76.52	5	28.18	26.35	27.59	5	17.02	16.71	16.99	5
$S_2 H_3$	75.78	73.50	74.72	7	29.15	26.56	28.02	2	17.19	16.89	17.16	2
$S_3 H_1$	79.71	76.69	78.18	1	27.29	26.54	26.90	6	16.77	16.60	16.81	7
$S_3 H_2$	77.72	74.88	76.34	4	28.71	26.75	27.79	3	17.06	16.84	17.10	3
$S_3 H_3$	75.29	73.28	73.94	9	29.53	27.38	28.04	1	17.29	17.09	17.37	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.12	0.08	0.12		0.07	0.04	0.03		0.01	0.02	0.02	
CD at 5%	0.36	0.25	0.38		0.21	0.14	0.08		0.04	0.06	0.05	
Overall Mean	77.40	74.62	76.06		28.07	26.41	27.29		16.96	16.68	16.94	

(The data are mean of three years) (OR - Overall ranking based on average of three seasons)

of V1 tree mulberry with 6'x 6' spacing under rainfed condition, Ahalya and Chiklingaiah (2022) have recorded lower levels of crude fibre, total minerals, crude protein, sugar and chlorophyll content (9.33%, 9.65%, 22.67%, 14.13 % and 2.41 mg/g), respectively, compared to the levels recorded in the present study.

Seasonal Variations

In all the three seasons, considerable differences in the leaf biochemical constituents of all the treatments are recorded. During monsoon, the contents of moisture, crude protein, total sugars, total chlorophyll

TABLE 2

Effect of spacing and stump heights on total chlorophyll, total minerals and crude fibre content in leaves of V-1 mulberry trained as small tree

Treatment	Total chlorophyll (mg/g)				Total Minerals (%)				Crude fibre (%)			
	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR
Main plot treatment Spacing (S)												
S_1 (2.4 x 1.2 m)	3.135	3.105	3.146	3	10.28	9.95	10.05	3	11.27	11.36	11.20	3
S_2 (2.4 x 1.8 m)	3.233	3.123	3.161	2	10.41	10.05	10.18	2	11.32	11.41	11.23	2
S_3 (2.4 x 2.4 m)	3.222	3.138	3.172	1	10.48	10.14	10.30	1	11.43	11.52	11.29	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.004	0.001	0.001		0.02	0.01	0.02		0.01	0.01	0.00	
CD at 5%	0.014	0.006	0.004		0.07	0.03	0.07		0.04	0.04	0.02	
Sub plot treatmentStump height (H)												
H_1 (0.5 m)	3.161	3.096	3.126	3	10.21	9.88	10.03	3	11.15	11.28	11.20	3
H_2 (1.0 m)	3.199	3.118	3.161	2	10.37	10.04	10.16	2	11.35	11.39	11.23	2
H_3 (1.5 m)	3.230	3.152	3.193	1	10.59	10.23	10.35	1	11.52	11.62	11.29	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.002	0.001	0.001		0.01	0.01	0.01		0.01	0.01	0.00	
CD at 5%	0.008	0.003	0.004		0.04	0.03	0.04		0.02	0.03	0.01	
Interaction (S x H)												
$S_1 H_1$	3.101	3.076	3.114	9	10.13	9.79	9.92	9	11.07	11.24	11.17	8
$S_1 H_2$	3.125	3.103	3.150	8	10.24	9.94	10.03	7	11.26	11.32	11.18	6
$S_1 H_3$	3.178	3.136	3.175	5	10.47	10.13	10.22	4	11.49	11.53	11.23	2
$S_2 H_1$	3.203	3.095	3.127	7	10.20	9.87	10.07	8	11.16	11.27	11.19	7
$S_2 H_2$	3.251	3.118	3.163	4	10.38	10.07	10.17	5	11.35	11.40	11.22	4
$S_2 H_3$	3.245	3.156	3.195	2	10.67	10.20	10.31	2	11.45	11.55	11.27	2
$S_3 H_1$	3.178	3.117	3.136	6	10.31	9.98	10.09	6	11.23	11.34	11.23	5
$S_3 H_2$	3.222	3.133	3.170	3	10.48	10.09	10.28	3	11.43	11.46	11.29	3
$S_3 H_3$	3.266	3.163	3.210	1	10.64	10.34	10.52	1	11.63	11.77	11.36	1
F test	*	*	*		*	*	*		*	*	*	
SEm±	0.004	0.002	0.002		0.02	0.02	0.02		0.01	0.01	0.01	
CD at 5%	0.013	0.005	0.006		0.06	0.05	0.08		0.04	0.04	0.02	
Overall Mean	3.197	3.122	3.160		10.39	10.05	10.18		11.34	11.43	11.24	

(The data are mean of three years) (OR - Overall ranking based on average of three seasons)

and total minerals were recorded maximum followed by summer and winter. Only, crude fibre content was maximum in winter followed by summer and monsoon. In bush mulberry, Bongale and Chaluvachari (1995) have recorded higher biochemical constituents in crop of post-winter to pre-summer (Jan-March) compared to crops of pre-monsoon (Jun-Aug) and monsoon (Aug-Oct), which is slightly different from the present study.

Overall, the treatments S3H3, S2H3 and S3H2, performed better over other treatments and ranked

uniformly first, second and third, respectively for all the constituents except moisture content. This clearly indicated that wider spacing treatment of 2.4 x 2.4 m with stump height of either 1.5 or 1.0 m is most suitable for obtaining better quality leaves. The superiority in quality of leaves in wider spacing treatments may be attributed to the reduced competition for nutrients between the plants. In bush mulberry also, higher moisture content and moisture retention capacity have been recorded in wider spacings (9' x 3') than narrow (3' x 3') spacing (Ananya *et al.*, 2015).

Bioassay Studies

Season wise pooled data of three years of various treatments on four rearing parameters *viz.,* ten mature larval weight, total larval duration, effective rate of rearing and cocoon yield per 100 DFLs and also, four cocoon parameters *viz.*, cocoon weight, cocoon shell weight, cocoon filament length and denier along with ranking on the performance of treatments are presented in Table 3 and Table 4, respectively. The cocoons harvested from different treatments are depicted in Fig.1.

Fig. 1 : Cocoons of bivoltine hybrid silkworm harvested by rearing with V-1 mulberry cultivated as small tree under nine treatments of spacing and stump heights.

Main Effects of Spacing and Stump Height

ANOVA on pooled data (Table 3 and Table 4) indicated that both, spacing and stump height have significant effect on all the rearing and cocoon parameters studied for all the three seasons. Further, falling in line with the trend recorded in biochemical contents in all the bioassay parameters also, the effect of widest spacing (S3) and highest stump height (H3) were found maximum and the effect of narrowest spacing (S1) and least stump height (H1) were minimum.

Interaction Effect of Spacing and Stump Height

In the present study, significant differences between the nine treatments in all the rearing parameters (Table 3) and cocoon parameters (Table 4) are recorded. The differences were also almost of same degree and thereby exhibiting identical ranks for almost all the eight parameters. Further, the effects of all the treatments on the bioassay parameters are in line with the trend observed with biochemical contents also, thereby they exhibited almost identical rankings in both chemoassay and bioassay.

The perusal of the data clearly indicated that, all the treatments studied, have better effect on rearing performance with optimal range of TLW (39.40 - 43.58 g), ERR (93.24 - 96.27 %), CY (87.29 - 89.31 kg per 100 DFLs), SCW (1.853 - 1.885 g), SCSW (0.397 - 0.433 g) and FL (1080 - 1230 m) with reduced LD (589 - 547 h) and lower D (3.018 - 2.828). Treatment with maximum spacing and stump height (S3H3) showed top performance while treatment with minimum spacing and stump height (S1H1) showed least performance in all the parameters studied. While evaluating V1 tree mulberry with three spacings of 8' x 3', 8' x 5' and 10 x 10' with 3' stump height in common, Sudhakar *et al*. (2018a & b) have recorded non-significant differences in ERR, single cocoon weight, single cocoon shell weight and cocoon shell ratio between the spacings. In comparative leaf quality evaluation studies also, better rearing performances were recorded with mulberry tree cultivation over bush cultivation (Hossain *et al*., 2016; Vanitha and Narayanaswamy, 2019). Further, many comparative studies on the performance of bush mulberry under different spacing have established better rearing performance under wider spacing over narrow spacing (Ananya, 2014; Vinod Kumar *et al*. 2020).

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TABLE 3

Effect of V-1 mulberry trained as small tree with different spacing and stump heights on bivoltine (FC_2 x FC_1) silkworm rearing parameters

Treatment	Mature larval weight (g/10)				Total larval duration (hr)				Effective rate of rearing (%)				Cocoon yield / 100 DFLs (kg)			
	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR
Main plot treatment Spacing (S)																
S_1 (2.4 x 1.2 m)	42.77	39.71	41.56	3	575	587	556	3	95.57	93.39	95.39	3	88.58	87.48	87.61	3
S_2 (2.4 x 1.8 m)	43.19	39.91	41.69	2	574	585	554	2	95.99	93.50	95.83	2	88.75	87.79	88.06	2
S_3 (2.4 x 2.4 m)	43.25	39.95	41.84	1	571	584	550	1	96.20	93.54	96.23	1	89.19	87.97	88.51	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.01	0.01	0.01		0.49	0.27	0.55		0.024	0.003	0.06		0.02	0.005	0.05	
CD at 5%	0.05	0.05	0.02		1.93	0.85	2.17		0.094	0.01	0.22		0.06	0.019	0.19	
Sub plot treatment Stump height (H)																
H_1 (0.5 m)	42.97	39.48	41.47	3	575	587	556	3	95.72	93.34	95.70	3	88.72	87.51	87.89	3
H_2 (1.0 m)	43.06	39.93	41.67	2	573	585	553	2	96.00	93.50	95.81	2	89.05	87.75	88.05	2
H_3 (1.5 m)	43.17	40.16	41.94	1	571	584	551	1	96.03	93.58	95.93	1	89.09	87.97	88.23	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.01	0.02	0.01		0.106	0.17	0.11		0.023	0.003	0.02		0.09	0.01	0.02	
CD at 5%	0.03	0.06	0.02		0.326	0.51	0.33		0.071	0.01	0.05		0.27	0.02	0.05	
Interaction (S x H)																
$S_1 H_1$	42.60	39.40	41.36	9	578	589	558	9	95.44	93.24	95.26	9	88.33	87.29	87.44	8
$S_1 H_2$	42.75	39.85	41.55	7	575	587	555	6	95.56	93.42	95.36	8	88.67	87.41	87.59	7
$S_1 H_3$	42.95	39.88	41.77	5	572	585	554	5	95.69	93.49	95.54	7	88.84	87.74	87.82	5
$S_2 H_1$	43.10	39.47	41.48	8	576	587	557	8	95.79	93.36	95.77	6	88.67	87.52	87.95	6
$S_2 H_2$	43.19	39.94	41.62	4	574	585	554	7	96.04	93.54	95.82	4	89.16	87.86	88.07	5
$S_2 H_3$	43.28	40.31	41.96	2	572	584	552	2	96.17	93.61	96.08	2	89.37	87.59	88.17	2
$S_3 H_1$	43.23	39.56	41.57	6	573	585	553	4	95.92	93.42	95.88	5	89.15	87.74	88.30	4
$S_3 H_2$	43.24	40.00	41.85	3	571	584	551	3	96.14	93.54	96.25	3	89.37	87.98	88.50	3
$S_3 H_3$	43.29	40.29	42.09	1	569	582	547	1	96.40	93.64	96.36	1	89.49	88.19	88.72	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.02	0.04	0.01		0.18	0.37	0.19		0.040	0.005	0.03		0.05	0.014	0.03	
CD at 5%	0.05	0.11	0.03		0.56	1.14	0.58		0.123	0.01	0.09		0.16	0.042	0.08	
Overall Mean	43.07	39.86	41.70		573	585	554		95.92	93.47	95.81		89.00	87.75	88.06	

(The data are mean of three years) (OR - Overall ranking based on average of three seasons)

TABLE 4

Effect of V-1 mulberry trained as small tree with different spacing and stump heights on bivoltine (FC_2 x FC_1) cocoon parameters

Treatment	Cocoon weight (g)				Cocoon shell weight (g)				Cocoon filament length (m)				Filament denier			
	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR	Monsoon	Winter	Summer	OR
Main plot treatment Spacing (S)																
S_1 (2.4 x 1.2 m)	1.876	1.838	1.859	3	0.427	0.399	0.419	3	1219	1092	1193	3	2.842	2.995	2.930	3
S_2 (2.4 x 1.8 m)	1.878	1.839	1.861	2	0.429	0.401	0.420	2	1222	1117	1199	2	2.839	2.966	2.918	2
S_3 (2.4 x 2.4 m)	1.881	1.840	1.863	1	0.430	0.403	0.421	1	1227	1128	1209	1	2.833	0.000	2.914	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.0004	0.0001	0.0002		0.0001	0.0002	0.0004		0.27	0.89	0.63		0.0002	0.0004	0.001	
CD at 5%	0.001	0.0003	0.001		0.0002	0.001	0.001		1.05	3.48	2.48		0.001	0.0012	0.004	
Sub plot treatment Stump height (H)																
H_1 (0.5 m)	1.874	1.838	1.856	3	0.427	0.399	0.418	3	1218	1101	1193	3	2.843	3.003	2.930	3
H_2 (1.0 m)	1.879	1.840	1.862	2	0.430	0.400	0.420	2	1223	1114	1201	2	2.838	2.989	2.921	2
H_3 (1.5 m)	1.883	1.841	1.866	1	0.431	0.402	0.422	1	1226	1123	1207	1	2.834	2.976	2.911	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.0003	0.0001	0.0003		0.0001	0.0002	0.0001		0.53	0.59	0.33		0.0005	0.0004	0.001	
CD at 5%	0.001	0.0003	0.001		0.0003	0.001	0.0005		1.62	1.81	1.01		0.001	0.001	0.003	
Interaction (S x H)																
S_1 H_1	1.870	1.836	1.853	9	0.425	0.397	0.416	9	1212	1080	1187	9	2.846	3.018	2.940	9
S_1 H_2	1.876	1.838	1.860	7	0.428	0.398	0.419	8	1221	1093	1192	8	2.842	3.004	2.931	7
S_1 H_3	1.881	1.839	1.865	5	0.429	0.401	0.422	5	1224	1104	1198	5	2.839	2.996	2.926	5
S_2 H_1	1.874	1.838	1.856	8	0.427	0.399	0.418	7	1218	1104	1191	7	2.843	3.008	2.920	8
S_2 H_2	1.879	1.839	1.861	4	0.430	0.402	0.420	4	1222	1121	1200	4	2.839	2.994	2.921	6
S_2 H_3	1.882	1.840	1.866	2	0.432	0.403	0.422	2	1228	1128	1206	2	2.836	2.983	2.906	2
S_3 H_1	1.877	1.839	1.859	6	0.428	0.401	0.421	6	1224	1118	1202	6	2.840	2.982	2.922	4
S_3 H_2	1.882	1.840	1.863	3	0.431	0.403	0.422	3	1226	1128	1210	3	2.832	2.984	2.912	3
S_3 H_3	1.885	1.842	1.867	1	0.433	0.405	0.424	1	1230	1139	1215	1	2.828	2.948	2.907	1
F test	*	*	*		*	*	*		*	*	*		*	*	*	
SEm±	0.0005	0.0002	0.0005		0.0001	0.0004	0.0003		0.91	1.02	0.57		0.001	0.001	0.002	
CD at 5%	0.002	0.001	0.001		0.0005	0.001	0.001		2.80	3.13	1.74		0.002	0.002	0.006	
Overall Mean	1.878	1.839	1.861		0.429	0.401	0.420		1223	1113	1200		2.838	2.989	2.921	

(The data are mean of three years) (OR - Overall ranking based on average of three seasons)

Seasonal Variations

Among the seasons, in monsoon crop majority bioassay parameters of V1 performed better with all the treatments. The parameters *viz.,* TLW, CW, CSW, CFL ERR, CY and D showed maximum values during monsoon followed in order by summer and winter. However, the LD was shortest in summer, shorter in monsoon and short in winter. This observation is in conformity with that of Ahalya *et al.* (2020), who have recorded better performance of V1 tree mulberry with 5' x 5' spacing and 5' crown height under rainfed condition, in rainy season followed in order by summer and winter. In bush mulberry also, Bongale and Chaluvachari (1995) have reported higher larval weight, single cocoon weight, single shell weight and shell ratios in crop of post-monsoon (October - November) followed by crop of monsoon (July - Aug) which differed significantly with crop of summer (April - May).

Correlation of Biochemical and Bioassay Parameters

Correlation coefficients among and between six biochemical constituents and eight bioassay parameters in nine treatments are presented in Table 5. The biochemical constituents *viz.*, crude protein, total sugars, total chlorophyll and total minerals have highly significant and positive correlation among them and also showed non-significant positive correlation with crude fibre. Quader (1991) has also recorded significant positive correlation between soluble carbohydrate and protein. Moisture content showed highly significant negative correlation with crude fibre (r = -0.9820**), significant negative correlation for CP (r = -0.710*) and TS (r = -0.696*) and non-significant negative correlation with TC (r = -0.583) and TM (r = -0.5655). The bioassay parameters *viz.,* MLW, ERR, CY, CW, CSW and CFL exhibit highly significant and positive correlations among them, while they showed highly significant and negative correlations with TLD and D.

The moisture content showed varied type of relation with bioassay parameters also, as it showed with biochemical parameters. M had significant and

TABLE 5

Correlation coefficients among and between chemo-assay and bioassay parameters of V-1 mulberry trained as small tree under different spacing and stump height

	M	CP	TS	TC	TM	CF	MLW	TLD	ERR	CY	CW	CSW	CFL	D
M	1	-0.7104 *	-0.6957 *	-0.5833	-0.5655	-0.9820 **	-0.5909	0.5323	-0.1788	-0.2366	-0.7187 *	-0.4878	-0.3565	0.4818
CP		1	0.9966 **	0.9632 **	0.9715 **	0.6434	0.9823 **	-0.9182 **	0.8130 **	0.8320 **	0.9860 **	0.9493 **	0.9065 **	-0.9009 **
TS			1	0.9677 **	0.9758 **	0.6206	0.9785 **	-0.9276 **	0.8241 **	0.8456 **	0.9865 **	0.9557 **	0.9156 **	-0.9178 **
TC				1	0.9523 **	0.4992	0.9677 **	-0.9150 **	0.8626 **	0.8984 **	0.9485 **	0.9718 **	0.9412 **	-0.8700 **
TM					1	0.4945	0.9786 **	-0.9616 **	0.8918 **	0.9107 **	0.9765 **	0.9798 **	0.9602 **	-0.9513 **
CF						1	0.5225	-0.4547	0.0819	0.1335	0.6538	0.3963	0.2710	-0.3747
MLW							1	-0.9236 **	0.8763 **	0.8848 **	0.9582 **	0.9712 **	0.9516 **	-0.9146 **
TLD								1	-0.8454 **	-0.9104 **	-0.9479 **	-0.9649 **	-0.9357 **	0.9289 **
ERR									1	0.9783 **	0.7895 *	0.9295 **	0.9699 **	-0.8908 **
CY										1	0.8311 **	0.9610 **	0.9794 **	-0.9003 **
CW											1	0.9463 **	0.8932 **	-0.9703 **
CSW												1	0.9843 **	-0.9409 **
CFL													1	-0.9252 **
D														1

Significant level at 5% r = 0.6664 Significant level at 1% r = 0.7977

negative correlation with CW while showed non-significant and positive correlation with TLD and D, and non-significant, negative correlation with MLW, ERR, CY, CSW and CFL. Highly significant positive correlations were noticed between four biochemical parameters *viz*., CP, TS, TC and TM and six bioassay parameters *viz*., MLW, ERR, CY, CW, CSW and CFL. Further, the correlations between CF and these six bioassay parameters were non-significant and positive, while, CF was negative and highly significant with other two parameters *viz*., TLD and D. Vanitha and Narayanswamy (2019) have also recorded negative correlation between moisture content of leaf and larval weight, cocoon weight, shell weight and shell ratio of crossbreed silkworm. Highly significant positive correlation between four biochemical parameters (CP, TS, TCH and TM) and six bioassay parameters (MLW, ERR, CY, CW, CSW, and CFL) and also negative and highly significant correlation with LD and FD recorded in the present study clearly indicated that, better quality of leaf could be obtained from all the treatments. Raghavendra *et al*. (2017) have also reported the improvement of grainnage parameters in silkworm breed 'Pure Mysore' with the increase in leaf biochemical content.

In the present study, all the treatments showed above 93 per cent ERR with more than 87 kg per 100 DFLs CY in all the seasons, which clearly indicated the superior rearing performance by all of them. Further, the differences in rearing performances recorded between the treatments were only marginal. As observed under chemoassay, in bioassay also, the treatment combinations S3H3, S2H3 and S3H2 in sequence performed better over other treatments in all the eight parameters. But, the study on the leaf yield of the said nine treatments revealed that, the performance of other three treatments S1H3, S1H2 and S1H1 was superior as first, second and third highest leaf yielders and the differences in leaf yield among these treatments is marginal (Bharathi and Basavaiah, 2022).

In sericulture, maximization of both leaf quality and leaf yield are equally important to achieve the goal of maximizing the profit per unit area of mulberry garden. Further, in different treatments of the present study, cost of labor for intercultural operations, fertilizer application, irrigation, harvesting etc., vary to some extent depending on the intensity of cultivation. Hence, the superiority of any of the nine treatments studied has to be judged by considering the leaf yield, Leaf- Cocoon ratio and Benefit - Cost ratio under variable intensity of cultivation. Efforts are being made to identify the suitable treatment for different situations by working out the economics.

References

A.O.A.C., 1984, *Official methods of Analysis. Association of official Analytical Chemists, Inc.,USA,* pp. : 152 - 153, 160.

AHALYA, B. N., 2021, Genotype × environmental interaction for growth and yield parameters of tree mulberry genotypes in different seasons and bioassay studies of silkworm *Bombyx mori* L. *Ph.D. Thesis*, Univ. Agric. Sci., Banglaore.

AHALYA B. N., CHIKKALINGAIAH, FATIMA SADATULLA AND MURALI, K., 2020a, Bioassay studies of silkworm *Bombyx mori* L. on tree mulberry genotypes in different seasons. *Inl. J. Curr. Micro. and Appl. Sci.*, **9** (9) : 133 -141**.**

AHALYA, B. N. AND CHIKKALINGAIAH, 2022, Genotype × environmental interaction for growth and yield parameters of tree mulberry genotypes in different seasons and bioassay studies of silkworm *Bombyx mori* L. *Mysore J. Agric. Sci*., **56**(1) : 458.

ANANYA, N. C., 2014, Impact of spacing in mulberry on leaf quality and silk cocoon yield. *M.Sc. Thesis,* Univ. Agric. Sci., Banglaore, pp. : 59.

ANANYA, N. C., VIJAYENDRA, M., SWATHI, H. C., CHANDRASHEKAR, S., MANJUNATH GOWDA AND RAMAKRISHNA NAIKA, 2015, The impact of spacing on growth, yield and moisture retention capacity of leaves in mulberry, *Morus alba*. *Biosci. Biotech. Res. Comm.,* **8** (1) : 20 - 24.

ANONYMOUS, 2021, Annual Report (2020-21). CSR&TI, Myosre, pp. : 54.

Arnon, D. I., 1949, Copper enzymes in isolated chloroplasts. Polyphenol oxidase in *Beta vulgaris*. *Plant Physiology*, **24** : 1 - 15.

Bharathi, V. P. and Basavaiah, 2022, Growth and yield performance of mulberry (*Morus* spp.) cultivar V-1 as small tree in Karnataka. *Mysore J. Agric Sci*., **56** (2) : 83 - 91.

Bongale, U. D. and Chaluvachari, C., 1995, Evaluation of four mulberry varieties by leaf biochemical analysis and bioassay with *Bombyx mori* L. *J. Indian Bot. Soc.,* **72** : 59 - 62.

Brunner, I., Herzog, C., Dawes, M. A., Arend, M. and Sperisan, C., 2015, How tree roots respond to drought. *Frontiers in Plant science*, **6** (article 547) : 1 - 16.

Dandin, S. B. and Sengupta, K., 1988, Mulberry cultivation as high bush and small tree in hilly regions. CSR&TI, Mysore.

Dandin, S. B. and Kumar, R., 1989, Evaluation of mulberry genotypes for different growth and yield parameters. In : Genetic resources of mulberry and utilisation, [(Eds.)], K. Sengupta and S.B. Dandin, CSR&TI, Mysore, pp. : 143-152.

Dubois, M. K., Giller, K. A., Hamilton, K., Relers, P. A. and Smith, F., 1956, Colorimetric method for determination of sugars and related substances. *Annal. Chem.,* **28** : 350 - 356.

Jackson, M. L., 1973, Nitrogen determination for soil and plant tissue. *In: Soil Chemical Analysis,* Prentice- Hall of India, Pvt. (Ltd.), New Delhi, pp. : 183 - 204.

Hossain, Md. Shakhawat, Saiful Islam and Haque, Md. Moinul, 2016, Influence of different cultivation forms of mulberry variety BM-3 (*Morus alba*) on leaf nutrition, yield and economic traits of silkworm. *Elixir Applied Chemistry*, **95** : 41169 - 41172.

Megharaja, Harishkumar, J., Chaithra K. C., Likhithgowda, M. and Manjunatha, H. B., 2021, Diverse tree mulberry geometry and cultural practices adopted by the farmer's and its optimization. *Acta Scientific Agriculture*, **5** (6) : 85 - 91.

Qader, M. A., 1991, Varietal differences and correlation studies in the nutritional composition of the mulberry. *Sericologia,* **31** (3) : 449 - 453.

Qader, M. A., Sarkar, A. and Ahmed, S. U., 1991, Comparative study on the nutritive value of bush, low cut and tree mulberry leaves at different maturity stages. *Sericologia,* **31** (3) : 429 - 437.

Raghavendra, J., Banuprakash, K. G., Narayanareddy, R. and Narayanaswamy, K. C., 2017, Validation of performance of silkworm race pure Mysore reared on different mulberry varieties for graninage parameters. *Mysore J. Agric. Sci.,* **51** (3) : 699 - 705.

Srinivasa Babu, G. K., Singh, G. B. and Chandrakanth, K. S., 2010, Silkworm rearing. In : Handbook of Sericulture Technologies, [(Eds.)], S.B. Dandin and K. Giridhar, Pub: CSB, Bangalore, pp. : 335 - 385.

Sudhakar, P., Hanumantharayappa, S. K., Sudhakar Rao, P., Jalaja S. Kumar and Sivaprasad, V., 2018a, Influence of tree mulberry (*Morus alba* L.) in varied geometries on mulberry leaf and silkworm rearing. *Intl. J. Curr. Res. Life Sci.*, **97** (3) : 1381 - 1386.

Sudhakar, P., Hanumantharayappa, S. K., Sudhakar Rao, P., Jalaja S. Kumar and Sivaprasad, V., 2018b, Tree mulberry - sustainable and economically viable sericultural farming for southern tropical zones. *Intl. J. App. Pure Sci. & and Agri.,* **4** (6) **:** 13-23.

Vanitha, C., 2018, Assessment of productivity of tree mulberry, *Morus alba* L. *M.Sc. Thesis*, Univ. Agric. Sci., Bangalore.

Vanitha, C. and Narayanaswamy, K. C., 2019, Performance of silkworm on tree mulberry, *Morus alba* L. *Int. J. Curr. Microbiol. App. Sci*., **8** (4) : 2020 - 2025.

Vinod Kumar Yadav, M., Noble Morrison, Arunkumar, G. S., Dhaneshwar Padhan, Praveen Kumar, K., Sivaprasad and Pankaj Tewary, 2020, Comparative study on different mulberry spacing and its impact on mulberry leaf yield and silkworm rearing. *Journal of Entomology and Zoology Studies,* **8** (1) : 1110 - 1115.