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Effect of graded level of nutrients on tree mulberry and its influence on cocoon parameters of FC1 and FC2 breeds of silkworm *Bombyx mori* L

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Abstract
This study assessed the influence of various agronomic treatments on tree mulberry and it's impact on silkworm related parameters such as cocoon shell ratio, filament length, filament weight, and denier in silkworm breeds FC 1 and FC 2. Applying farmyard manure (FYM) at 40 t/ha/yr achieved the highest cocoon shell ratio, with values of 20.13% in FC 1 and 22.56% in FC 2. The optimal treatments also enhanced filament length, with the maximum measurements of 1147.36 m in FC 1 and 1320.07 m in FC 2 observed under the combination of 40 t FYM/ha/yr, 125% RDF, and foliar spray. Filament weight was similarly highest with these treatments. Denier values were notably high, reaching 3.35 in FC 1 and 2.69 in FC 2 under the most effective treatments. The results underscore the significant benefits of combining FYM, RDF, and foliar sprays for improving silk production, with notable differences in the response between the two breeds.

Keywords: Bivoltine, tree mulberry, farmyard manures, micronutrients, graded level of nutrients

Introduction
Sericulture plays a vital role in India's agricultural economy, with the country being the second-largest producer of mulberry raw silk in the world. India contributes a significant portion of global silk production, with mulberry silk being particularly important. The cultivation of mulberry trees, which provide the primary nutrition for silkworms, is crucial to this industry. This interdependence between mulberry cultivation and silk production emphasizes the agricultural and economic significance of sericulture in India. Proper nutrition is essential for enhancing silkworm health, growth, development, feed intake, silk production, and cocoon quality. Therefore, it is crucial to apply the recommended amount of fertilizer to mulberry plants to support the growth and development of silkworms and ensure successful cocoon production (El-Kayat *et al*., 2013) [2].

Sericulture, the ancient practice of rearing silkworms for silk production, relies heavily on the production of high-quality cocoons, which are essential for generating superior silk. The quality of the parental seed cocoons directly impacts the filament quality, length, weight, and denier of the silk produced. High-quality cocoons result in silk filaments that are uniform in diameter, with optimal length and weight, contributing to the overall denier, which measures the thickness and fineness of the silk thread. This, in turn, enhances the commercial value of the silk, ensuring consistent and sustainable production. The emphasis on producing high-quality cocoons is crucial for improving the efficiency, resilience, and sustainability of sericulture, as it directly influences the characteristics and quality of the mulberry silk obtained.

Materials and Methods
A study was conducted during 2022 at Krishi Vignana Kendra Haradanahalli farm, Chamarajanagara in well-established tree mulberry garden (Variety V-1) with spacing of 6 x 6 feet under irrigated condition. The experiment was conducted using RBD with Factorial concept consisted of sixteen treatments with three replications.

After top pruning, the below listed fertilizers were applied and the cultural practices were followed as per the recommended standards.

Treatment details

Factor (A) organicmanures	Factor(B) Macronutrients	Factor(C) Micronutrients
A_1- without FYM 20t ha^{-1}	B_1–No RDF	C_1 – without micronutrients
A_2- with FYM at 40 t ha^{-1}	B_2-75% RDF	C_2 - with foliar spray ofmicronutrients(POSHAN)
	B_3- 100% RDF	
	B_4- 125% RDF	

Treatment combinations

T_1	$A_1B_1C_1$	T_9	$A_2B_1C_1$
T_2	$A_1B_1C_2$	T_10	$A_2B_1C_2$
T_3	$A_1B_2C_1$	T_11	$A_2B_2C_1$
T_4	$A_1B_2C_2$	T_{12}	$A_2B_2C_2$
T_5	$A_1B_3C_1$	T_13	$A_2B_3C_1$
T_6	$A_1B_3C_2$	T_{14}	$A_2B_3C_2$
T_7	$A_1B_4C_1$	T_15	$A_2B_4C_1$
T_8	$A_1B_4C_2$	T_{16}	$A_2B_4C_2$

Experimental details for silkworm rearing

To know the effects of feeding leaves from V-1 tree mulberry raised through the application graded level of nutrients on silkworm growth and yield, FC1 and FC2 silkworm hybrid was reared on these leaves by following standard silkworm rearing practices outlined by Dandin and Giridhar (2014) [1].

Silkworm feeding and bed cleaning

The late age silkworms were reared in shelf reared separately as per treatments by feeding three times a day with matured mulberry leaves of V-1 variety raised under different treatments. Bed cleaning was done twice during IV and V instars, by lifting unfed leaves and excreta of the silkworm. Optimum spacing was provided according to the age of the silkworms. After each bed cleaning and when all the silkworms settled for moulting, lime powder was dusted on silkworms following standard rearing practices Dandin and Giridhar (2014) [1].

Mounting and harvesting

Plasticcollapsiblemountageswereusedintheexperiment.Theri pewormswerehand-picked from each treatment and replications were mounted separately treatment wise on theplastic collapsible mountages. Later on, the cocoons were harvested manually on the seventh day of mounting.

Cocoon shell ratio (%)

Shell ratio indicates the total quantity of silk available from single cocoon and is expressed in percentage. It was calculated for each treatment, replication wise by using the following formula.

$$\text{Cocoon shell ratio (\%)} = \frac{\text{Weight of cocoon shell}}{\text{Weight of whole cocoon}} \times 100$$

Cocoon filament length (m)

It is the total length of silk filament unwound from single cocoon and measured in meters. A sample of five cocoons per treatment and replication wise were randomly drawn and stifled in a hot air oven at 70 °C for three hours. The cocoons were cooked in boiling water for five minutes to soften the sericin layer. These cooked cocoons were reeled on an eprouvette with a wheel circumference of 1.125 m. The length of the silk filament was determined by the number of revolutions recorded and converted into meters by the formula:

$$L = R \times 1.125 \text{ m}$$

Where,
L = Length of the silk filament (m)
R = Number of revolutions

Denier

The raw silk filament was taken out from the epprouvette was dried using hot air oven at 70 ºC to 80 ºC and weighed to determine the denier using the standard formula.

$$\text{Denier} = \frac{\text{Weight of single cocoon filament}}{\text{Length of single cocoon filament (m)}} \times 100$$

Results and Discussion

Cocoon shell ratio (%)

The study revealed that the application of FYM at 40 t/ha/year resulted in the highest cocoon shell ratio, with 20.13% in the FC 1 breed and 22.56% in the FC 2 breed. Similarly, the application of NPK at zero percent RDF yielded a cocoon shell ratio of 21.29% in FC 1 and 24.39% in FC 2. Treatments without foliar spray recorded higher cocoon shell ratios of 20.55% and 22.53% in FC 1 and FC 2, respectively. In two-factor interactions, the highest cocoon shell ratios were observed in the combination of FYM and NPK (A1×B1) with 21.85% for FC 1 and 24.99% for FC 2, and in the interaction between NPK and foliar spray (B1×C1) with 21.93% in FC 1 and 25.31% in FC 2. The three-factor interaction showed significant results in FC 1 but not in FC 2. The highest cocoon shell ratio was achieved in T_8 (20 t FYM/ha/year + 125% RDF + foliar spray of POSHAN) with 22.85% in FC 1 and 26.50% in FC 2, while the lowest ratios were recorded in T_1 (20 t FYM/ha/year) at 15.90% for FC 1 and in T2 (20 t FYM/ha/year + foliar spray of POSHAN) at 17.79% for FC 2.

Kamel (2014) [4] studied the effect of balanced fertilization of mulberry plantations with NPK on the development and productivity of silkworm. Treated mulberry (*Morus indica*) leaes were offered to two races of silkworm *Bombyx mori* L. larvae four times per day.

Cocoon filament length (m)

The study found that applying FYM at 40 t/ha/year resulted in the highest filament lengths of 1009.02 m in the FC 1 breed and 1177.53 m in the FC 2 breed. Similarly, the application of NPK at 125% RDF produced filament lengths of 1073.73 m in FC 1 and 1272.60 m in FC 2. Treatments with foliar spray also enhanced filament lengths, achieving 1003.81 m in FC 1 and 1168.82 m in FC 2. The interaction between FYM and NPK (A2×B4) recorded the highest filament lengths of 1104.72 m in FC 1 and 1309.97 m in FC 2, while the combination of NPK and foliar spray (B4×C2) showed significant lengths of 1106.70 m in FC 1 and 1301.48 m in FC 2. Overall, T_{16} (40 t FYM/ha/year + 125% RDF + foliar spray of POSHAN) recorded the highest filament lengths of 1147.36 m in FC 1 and 1320.07 m in FC 2, followed by T_8 with 1066.04 m in FC 1 and 1300.88 m in

FC 2. The lowest filament lengths were observed in T_1 (20 t FYM/ha/year), with 857.79 m in FC 1 and 988.79 m in FC 2 (Table 1).

When silkworms were fed with mulberry leaves raised by the application of higher doses of nitrogen and potassium (400:120:200 kg NPK ha^{-1} yr^{-1}) in PM × NB4D2, significantly higher cocoon weight (1.642 g), shell weight (0.278 g), pupal weight (1.37 g), shell ratio (16.35%), filament length (888.10 m) and fecundity (469.71) were recorded (Rangaswamy, 1997) [10]. Rangaswamy *et al*. (1999) [11] found that applying NPK at 400:120:200 kg/ha/yr in five splits to mulberry and silkworms fed with such mulberry leaves had greater cocoon (1.649 g), pupal (1.370 g), shell (0.278 g) weight and filament length (880.0 m).

Present study is in agreement with the result of Mancha Shetty (1979) [5] who found that, foliar application of 0.5 per cent urea increased the number of cocoons, weight of cocoons, weight of shells, weight of pupae, filament length and weight of silk filament. Mahmood *et al*., (2002) [7] recorded better cocoon and reeling parameters when silkworms were fed with nitrogen supplemented mulberry leaves. Maqbool, (1991) [6] reported that, feeding mulberry leaves treated with nitrogen significantly increased the quality of cocoons, filament length and weight of silk filament.

Table 1: Influence of graded level of nutrients on Cocoon shell ratio (%) and Filament length (m) of FC 1 and FC 2 bivoltine silkworm breeds

Treatment	Cocoon shell ratio (%)		Filament length (m)	
	FC 1	FC 2	FC 1	FC 2
Farm yard manure (A)				
A_1: FYM @ 20 t ha^{-1}	19.99	21.57	965.88	1129.43
A_2: FYM @ 40 t ha^{-1}	20.13	22.56	1009.02	1177.53
SEm±	-	-	0.443	0.654
CD @ 5%	NS	NS	1.281	1.888
NPK(B)				
B_1: No RDF	21.29	24.39	897.95	1045.10
B_2:75% RDF	20.88	22.41	966.13	1134.74
B_3: 100% RDF	20.09	21.60	1012.00	1161.50
B_4: 125% RDF	17.99	19.86	1073.73	1272.60
SEm±	0.449	0.562	0.887	0.925
CD @ 5%	1.298	1.624	2.561	2.671
Foliar spray (C)				
C_1: No Foliar spray	20.55	22.53	971.09	1138.14
C_2: Foliar spray	19.57	21.60	1003.81	1168.82
SEm±	0.318	-	0.887	0.654
CD @ 5%	0.918	NS	2.561	1.888
Interaction (A×B)				
$A_1 \times B_1$	21.85	23.79	877.13	1005.46
$A_1 \times B_2$	20.86	20.16	952.00	1120.09
$A_1 \times B_3$	19.88	21.65	991.67	1156.96
$A_1 \times B_4$	17.37	20.68	1042.74	1235.23
$A_2 \times B_1$	20.72	24.99	918.78	1084.74
$A_2 \times B_2$	20.90	24.66	980.26	1149.38
$A_2 \times B_3$	20.31	21.55	1032.33	1166.05
$A_2 \times B_4$	18.61	19.04	1104.72	1309.97
SEm±	-	0.795	0.887	1.308
CD @ 5%	NS	2.296	2.561	3.777
Interaction (B×C)				
$B_1 \times C_1$	21.93	23.48	885.56	1030.20
$B_1 \times C_2$	20.64	25.31	910.35	1060.00
$B_2 \times C_1$	21.00	24.06	960.43	1128.68
$B_2 \times C_2$	20.76	20.76	971.83	1140.80
$B_3 \times C_1$	20.81	21.94	997.62	1158.98
$B_3 \times C_2$	19.37	21.26	1026.38	1164.03
$B_4 \times C_1$	18.46	20.66	1040.75	1234.73
$B_4 \times C_2$	17.52	19.07	1106.70	1310.48
SEm±	-	0.795	0.887	1.308
CD @ 5%	NS	2.296	2.561	3.777
Interaction (A×C)				
$A_1 \times C_1$	20.66	22.07	952.74	1106.71
$A_1 \times C_2$	19.32	21.08	979.02	1152.16
$A_2 \times C_1$	20.44	23.00	989.44	1169.58
$A_2 \times C_2$	19.82	22.12	1028.61	1185.49
SEm±	-	-	0.627	0.925
CD @ 5%	NS	NS	1.811	2.671
Interaction (A×B×C)				
T_1: $A_1B_1C_1$	22.85	23.47	857.79	988.79
T_2: $A_1B_1C_2$	20.84	24.11	896.47	1022.12

T_3: $A_1B_2C_1$	21.35	21.76	945.06	1112.01
T_4: $A_1B_2C_2$	20.37	18.57	958.94	1128.17
T_5: $A_1B_3C_1$	19.57	22.01	988.69	1156.45
T_6: $A_1B_3C_2$	20.18	21.30	994.64	1157.46
T_7: $A_1B_4C_1$	18.84	21.03	1019.43	1169.58
T_8: $A_1B_4C_2$	15.90	20.34	1066.04	1300.88
T_9: $A_2B_1C_1$	21.02	23.48	913.33	1071.61
T_{10}: $A_2B_1C_2$	20.43	26.50	924.23	1097.87
T_{11}: $A_2B_2C_1$	20.64	26.36	975.80	1145.34
T_{12}: $A_2B_2C_2$	21.15	22.96	984.73	1153.42
T_{13}: $A_2B_3C_1$	22.05	21.87	1006.54	1161.50
T_{14}: $A_2B_3C_2$	18.56	21.23	1058.11	1170.59
T_{15}: $A_2B_4C_1$	18.07	20.29	1062.08	1299.87
T_{16}: $A_2B_4C_2$	19.14	17.79	1147.36	1320.07
SEm±	0.899	-	1.254	1.849
CD @ 5%	2.596	NS	3.622	5.341

Note: (NS– Non-Significant)

Factor(A)	Factor (B)	Factor(C)
Organicmanures	Macronutrients	Micronutrients
A1– with FYM @ 20 tha^{-1}	B1–No RDF	C1– No micronutrients
A2– with FYM @ 40 tha^{-1}	B2– 75% RDF	C2–with foliar spray of
	B3– 100% RDF	micronutrients(POSHAN)
	B4– 125% RDF	

Filament weight (g)

Filament weight is a key indicator of silk quality. In this study, the application of FYM at 40 t/ha/year resulted in the highest filament weight, with 0.35 g in the FC 1 breed and 0.32 g in the FC 2 breed. The application of NPK at 125% RDF further increased filament weight to 0.38 g in FC 1 and 0.35 g in FC 2. Foliar spray treatments also enhanced filament weight, with FC 1 recording 0.35 g and FC 2 recording 0.31 g. Notably, the interaction between NPK and foliar spray (B4×C2) yielded the highest filament weights of 0.39 g in FC 1 and 0.35 g in FC 2. Overall, the T_{16} treatment (40 t FYM/ha/year + 125% RDF + foliar spray of POSHAN) produced the highest filament weights, with 0.40 g in FC 1 and 0.35 g in FC 2, followed by T_8 (20 t FYM/ha/year + 125% RDF + foliar spray of POSHAN) with 0.39 g in FC 1. The lowest filament weights were observed in T_1, with 0.27 g in FC 1 and 0.26 g in FC 2. After drying, raw silk is capable of absorbing 30% of its weight in moisture under standard conditions, with a moisture regain coefficient of 11% at 65% relative humidity and 27 ºC, which is used to determine the actual conditioned weight of the silk.

Kamel (2014) [4] studied the effect of balanced fertilization of mulberry plantations with NPK on the development and productivity of silkworm. Treated mulberry (*Morus indica*) leaves were offered to two races of silkworm *Bombyx mori* larvae four times per day. Results recorded that feeding of larvae on leaves of fertilized trees increased filament weight and size. However, such feeding led to decreased total larval duration and larval mortality percentages.

Denier

Denier, a measure of the linear mass density of fibers, is crucial for assessing silk strength. In this study, FYM application at 40 t/ha/year produced the highest denier values of 3.18 in the FC 1 breed and 2.47 in the FC 2 breed. NPK application at 125% RDF further increased denier to 3.24 in FC 1 and 2.57 in FC 2. Foliar spray treatments resulted in the highest denier of 3.19 in FC 1, while non-sprayed treatments recorded 2.49 in FC 2. The interaction between FYM and NPK (A2×B4) yielded a denier of 3.24 in FC 1 and 2.62 in FC 2 (A2×B3), whereas the interaction between NPK and foliar spray (B4×C2) recorded a denier of 3.27 in FC 1 and 2.62 in FC 2 (B4×C3). The highest denier overall was observed in T_8 (20 t FYM/ha/year + 125% RDF) with 3.35 in FC 1 and in T_{14} (40 t FYM/ha/year + 100% RDF + foliar spray of POSHAN) with 2.69 in FC 2. The lowest denier values were 2.88 in FC 1 (T_1) and 2.41 in FC 2 (T_3 and T_{12}). The results showed significant differences across all treatment combinations for both FC 1 and FC 2 breeds (Table 2).

Highest single cocoon weight, denier, and filament length were recorded at 150 kg N /ha/ yr when applied to mulberry (Narayanan *et al.*, 1966) [8]. Application of 300 kg N /ha/ yr to M-5 mulberry resulted in slightly increased cocoon yield, silk percentage, and filament length, but had no effect on mature larval weight, single cocoon weight, shell weight, or denier (Kasiviswanathan and Iyengar, 1970) [3]. Nagaraju (1997) [9] found that plants fertilized with potassium sulphate had considerably higher single cocoon weight (1.778 g), shell weight (0.307 g), filament length (792.8 m), and denier under rainfed conditions (2.33).

Table 2: Influence of graded level of nutrients on Shell weight (g) and pupal weight (g) of FC 1 and FC 2 bivoltine silkworm breeds

Treatment	Filament weight (g)		Denier	
	FC 1	FC 2	FC 1	FC 2
Farm yard manure (A)				
A_1: FYM @ 20 t ha^{-1}	0.33	0.31	3.14	2.50
A_2: FYM @ 40 t ha^{-1}	0.35	0.32	3.18	2.47
SEm±	0.00043	0.00018	0.00125	0.00121
CD @ 5%	0.00125	0.00052	0.00362	0.00349
NPK(B)				
B_1: No RDF	0.30	0.27	3.11	2.41
B_2 :75% RDF	0.33	0.30	3.14	2.43
B_3: 100% RDF	0.34	0.32	3.15	2.57
B_4: 125% RDF	0.38	0.35	3.24	2.53
SEm±	0.00061	0.00025	0.00177	0.00171
CD @ 5%	0.00177	0.00073	0.00512	0.00493
Foliar spray (C)				
C_1: No Foliar spray	0.33	0.31	3.13	2.49
C_2: Foliar spray	0.35	0.31	3.19	2.48
SEm±	0.0004	0.0002	0.0013	0.0012
CD @ 5%	0.0013	0.0005	0.0036	0.0035
Interaction (A×B)				
$A_1 \times B_1$	0.29	0.27	3.03	2.44
$A_1 \times B_2$	0.32	0.30	3.13	2.44
$A_1 \times B_3$	0.34	0.32	3.14	2.52
$A_1 \times B_4$	0.37	0.35	3.25	2.59
$A_2 \times B_1$	0.32	0.28	3.19	2.39
$A_2 \times B_2$	0.33	0.30	3.16	2.42
$A_2 \times B_3$	0.35	0.33	3.15	2.62
$A_2 \times B_4$	0.39	0.35	3.24	2.47
SEm±	0.0009	0.0004	0.0025	0.0024
CD @ 5%	0.0025	0.0010	0.0072	0.0070
Interaction (B×C)				
$B_1 \times C_1$	0.29	0.27	3.05	2.43
$B_1 \times C_2$	0.31	0.28	3.17	2.40
$B_2 \times C_1$	0.33	0.30	3.15	2.42
$B_2 \times C_2$	0.33	0.30	3.14	2.43
$B_3 \times C_1$	0.34	0.32	3.12	2.52
$B_3 \times C_2$	0.35	0.33	3.17	2.62
$B_4 \times C_1$	0.36	0.35	3.21	2.59
$B_4 \times C_2$	0.39	0.35	3.27	2.47
SEm±	0.0009	0.0004	0.0025	0.0024
CD @ 5%	0.0025	0.0010	0.0072	0.0070
Interaction (A×C)				
$A_1 \times C_1$	0.32	0.30	3.07	2.50
$A_1 \times C_2$	0.34	0.31	3.20	2.49
$A_2 \times C_1$	0.34	0.31	3.19	2.47
$A_2 \times C_2$	0.35	0.32	3.17	2.48
SEm±	0.0006	0.0003	0.0018	0.0017
CD @ 5%	0.0018	0.0007	0.0051	0.0049
Interaction (A×B×C)				
T_1: $A_1B_1C_1$	0.27	0.26	2.88	2.43
T_2: $A_1B_1C_2$	0.31	0.27	3.17	2.44
T_3: $A_1B_2C_1$	0.32	0.29	3.10	2.41
T_4: $A_1B_2C_2$	0.33	0.30	3.15	2.46
T_5: $A_1B_3C_1$	0.34	0.31	3.15	2.48
T_6: $A_1B_3C_2$	0.34	0.32	3.13	2.56
T_7: $A_1B_4C_1$	0.35	0.34	3.15	2.69
T_8: $A_1B_4C_2$	0.39	0.35	3.35	2.49
T_9: $A_2B_1C_1$	0.32	0.28	3.21	2.42
T_{10}: $A_2B_1C_2$	0.32	0.28	3.17	2.36
T_{11}: $A_2B_2C_1$	0.34	0.30	3.19	2.42
T_{12}: $A_2B_2C_2$	0.33	0.30	3.12	2.41
T_{13}: $A_2B_3C_1$	0.34	0.32	3.10	2.55
T_{14}: $A_2B_3C_2$	0.37	0.34	3.20	2.69
T_{15}: $A_2B_4C_1$	0.38	0.35	3.28	2.49
T_{16}: $A_2B_4C_2$	0.40	0.35	3.19	2.45
SEm±	0.0012	0.0005	0.0035	0.0034
CD @ 5%	0.0035	0.0015	0.0102	0.0099

Note: (NS– Non-Significant)

Factor(A)	Factor (B)	Factor(C)
Organicmanures	Macronutrients	Micronutrients
A1– with FYM @ 20t ha-1	B1–No RDF	C1– No micronutrients
A2– with FYM @ 40t ha-1	B2– 75% RDF	C2–with foliar spray of
	B3– 100% RDF	micronutrients(POSHAN)
	B4– 125% RDF	

Conclusion

The study revealed significant variations in cocoon shell ratio, filament length, filament weight and denier across different treatment combinations in both FC1 and FC2 silkworm breeds. The FC1 breed exhibited significant differences in cocoon shell ratio specifically within the A×B×C treatment combinations, while the FC2 breed showed notable variations in the A×B and B×C interactions. Filament length differences were significant across all interactions for both breeds. Denier, an important indicator of silk strength, also varied significantly in all treatment combinations, with the highest values recorded in T_15 (A2B4C1 – 40 T FYM/ha/year + 125% RDF) for FC1 and in T_{14} (A2B4C2 – 40 T FYM/ha/year + 100% RDF + Foliar spray of POSHAN) for FC2. These findings highlight the impact of specific treatment combinations on the quality parameters of silk, offering valuable insights for optimizing sericulture practices.

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