Original Research Article

Exploring silkworm litter as a liquid manure: A key to boost mulberry growth and productivity

Abstract

Mulberry (*Morus spp.*) is the primary food source for silkworm, *Bombyxmori* L. Mulberry growth and nutritional quality are critical for successful sericulture. With the increasing demand for sustainable agricultural practices particularly in rearing silkworms with chemical free mulberry leaves, the use of organic inputs has gained attention as an alternative to synthetic fertilizers. Silkworm litter, a by-product of silkworm rearing is rich in organic matter and essential nutrients, making it a potential resource for recycling into organic manure. This study explores the effectiveness of silkworm litterbased liquid organic manure (SLLM) at different doses along with Recommended Dose of Fertilizers (RDF)in improving the growth, yield and nutritional quality of mulberry. The treatment RDF + Soil drenching of 250 l acre^{-1} of 20 % SLLM at 10 Days after pruning (DAP) + Foliar spray of 150 l acre^{-1} of 10 % SLLM at 25 DAP (T_9) recorded longest shoot length(89.36 cm and 133.28cm), maximum shoots per plant (16.53and 23.80), leaves per shoot (22.17 and 32.02), maximum leaf area (153.44 cm^2 and 226.56 cm^2) at 45 and 60 DAP, respectively and leaf yield (67.31 Tonnes ha^{-1} year^{-1}). Leaf quality parameters such as total chlorophyll (2.37 mg g^{-1}), crude protein (21.56 %) and carbohydrate content (20.26 %) were also found superior in T_9.This shows that SLLM being liquid manure contained nutrients in readily available form which has supplied the nutrients that are required for mulberry growth and development. Indicating enhanced mulberry growth, yield along with improved quality parameters.

Keywords: *Silkworm litter; Liquid organic manure; Mulberry growthand quality; Leaf yield*

1. Introduction

Mulberry (*Morus spp.*) is a deep-rooted high biomass producing foliage crop which is the sole food source for silkworm, *Bombyxmori*L. Rearing of 100 Disease free layings (dfls) require 1000 kg of mulberry leaves. This produces approximately 300 kg of litter and 500 kg of leftover mulberry waste (Mala and Chandrashekhar., 2020). One hectare of mulberry farm produces 15 MT of sericultural waste annually. It is equivalent to 280-300 kg of nitrogen, 90-100 kg of phosphorus and 150-200 kg of potash (Dandin&Giridhar, 2014).Utilization of these byproducts reduces reliance on chemical fertilizers, improves soil health and nutrient availability to mulberry plants enhancing leaf quality.

The major by-products of silkworm rearing are the unfed/left over mulberry leaves and faeces, which together constitute silkworm litter. This litter can be used as excellent organic manure. Quantifying the silkworm litter,it is estimated that 45 per cent of the total leaves fed to the silkworm goes as waste in the form of unfed leaves and shoots. The silkworm ingests only 40 per cent of the leaf spread in the trays, of which only about 55 per cent is digested and the rest is converted as silkworm faeces (Majumder et al., 2000).

Application of manure produced out of silkworm litter is highly beneficial for mulberry cultivation and is much effective than conventional use of farm yard manure (Shen et al., 2024). Hence, this study was taken up to recycle the silkworm litter as an organic liquid manure to increase the mulberry leaf quality and quantity.

2. Material and Methods

The field experiments were conducted in Kharif and Rabi seasons during 2023 – 2024at the Department of Sericulture, University of Agricultural Sciences, Gandhi KrishiVigyan Kendra,Bengaluru.The field is located at latitude of 13^0 08’ N, longitude of 78^o 08’ E and at an altitude of 918 m above mean sea level in the Eastern Dry Zone (Zone-5) of Karnataka.

The experiment was carried out in well established Victory-1 (V1) mulberry garden with paired row system of planting. The design of experiment followed for statistical analysis is Completely Randomized Block Design (RCBD) with 10 treatments and 3 replications.

2.1 Preparation of silkworm litter based liquid organic manure (SLLM)

India has traditional knowledge of preparation and use of organic liquid manures since ages (Ram et al., 2019). Here, an indigenous traditional knowledge of manure preparation has been adopted.

An Indigenous Technical Knowledge (ITK) initially tried by an organic farmer was considered in this research. Wherein, silkworm litter is collected from the rearing beds of late age silkworm. 25 kg of silkworm litter is soaked in 50 liters of water for 48 hours (2 days) in 200 liters capacity drum and mixed thoroughly. The mixture was stirred well in clock wise direction and kept in shade covered with wet jute bag. Then, 10kg of *Calotropisgigantia*leaves and 10kg of *Ipomoea campanulata*leaves were added. It is left for decomposition up to 21 days. During the period the contents were digested by the microorganisms present in cow dung and silkworm litter. After 21 days the volume has been made up to 200 litres by adding water to it. Then 50 litres of cow urine was added. Finally, 250 litres of liquid manure was prepared. It was applied to soil manually and sprayed on mulberry leaves using hand sprayer as per the treatments.

Table 1:Treatment details

T_1	RDF + Soil drenching of 150 l acre^{-1} of 20 % SLLM at 10 DAP
T_2	RDF + Foliar spray of 100 l acre^{-1} of 10 % SLLM at 25 DAP
T_3	RDF + Soil drenching of 150 l acre^{-1} of 20 % SLLM at 10 DAP + Foliar spray of 100 l acre^{-1} of 10% SLLM at 25 DAP
T_4	RDF + Soil drenching of 200 l acre^{-1} of 20 % SLLM at 10 DAP
T_5	RDF + Foliar spray of 125 l acre^{-1} of 10 % SLLM at 25 DAP
T_6	RDF + Soil drenching of 200 l acre^{-1} of 20 % SLLM at 10 DAP + Foliar spray of 125 l acre^{-1} of 10 % SLLM at 25 DAP
T_7	RDF + Soil drenching of 250 l acre^{-1} of 20 % SLLM at 10 DAP
T_8	RDF + Foliar spray of 150 l acre^{-1} of 10 % SLLM at 25 DAP
T_9	RDF + Soil drenching of 250 l acre^{-1} of 20 % SLLM at 10 DAP + Foliar spray of 150 l acre^{-1} of 10 % SLLM at 25 DAP
T_{10}	RDF (PoP) (Control)

RDF – 350:140:140 kg N: P_2O_5: K_2O ha^{-1} $year^{-1}$ + 20 tonnes FYM ha^{-1} $year^{-1}$

SLLM – Silkworm litter based liquid organic manure

DAP – Days After Pruning

2.2 Manure analysis

Table 2: Methods followed for chemical analysis of SLLM

Parameters	**Methods**	**References**
pH (1:2.5)	Potentiometric method	Jackson (1973)
EC (dS m^{-1})	Conductometric method	Jackson (1973)
Total Nitrogen (%)	Microkjeldhaldigestion distillation method	Jackson (1973)
Total phosphorus (%)	Diacid digestion and vanadomolybdate method	Jackson (1973)
Total potassium (%)	Diacid digestion and Flame photometer Method	Jackson (1973)
Total Fe, Mn, Zn and Cu (ppm)	Diacid digestion and Atomic absorption spectrophotometry	Jackson (1973)

Table 3:Standard methods adopted for microbial analysis of SLLM

Parameters	**Methods**	**Reference**
Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
Fungi	Martin's rose Bengal Agar	Martin (1950)
Actinomycetes	Kuster's Agar	Kuster (1959)

2.3 Growth and yield parameters of mulberry

Observations on mulberry growth parameters were taken at 45 and 60 DAP. The observations recorded were: Growth parameters *viz.*, Length of longest shoot, number of shoots, number of leaves per shoot and leaf area. The leaf yield was recorded at 60 DAP.

2.4 Estimation of quality parameters in leaves

2.4.1 Leaf moisture content (%)

Moisture content in the mulberry leaves was estimated using standard reference of AOAC (2000) protocol. It was expressed in percentage on wet basis and it was determined by drying mulberry leaves in hot air oven at 105 °C for 3 hr and then moisture content was determined by following formula:

$$\text{Leaf moisture (\%)} = \frac{\text{Fresh weight - dry weight}}{\text{Fresh weight}} \times 100$$

2.4.2 Chlorophyll ‘a’, ‘b’ and total chlorophyll content of leaf

Chlorophyll content in mulberry leaf was determined by the following procedure described by Hiscox and Isrealstam (1979). The leaf chlorophyll ‘a’, ‘b’ and total chlorophyll contents were computed using the formula suggested by Arnon (1949).

$$\text{Total chlorophyll (mg/g)} = \frac{20.2\ (A.645) + 8.02\ (A.663)\ X\ V}{1000\ X\ W}$$

$$\text{Chlorophyll 'a' (mg/g)} = \frac{12.7\ (A.663) - 2.69\ (A.645)\ X\ V}{1000\ X\ W}$$

$$\text{Chlorophyll 'b' (mg/g)} = \frac{22.9\ (A.645) - 4.68\ (A.663)\ X\ V}{1000\ X\ W}$$

Where,

A = Absorbance at specific wavelength (645 and 663 nm)

V = Final volume of the chlorophyll extract (ml)

W = Fresh weight of the sample (g)

2.4.3 Carbohydrate content (%)

Carbohydrate content in the leaves of mulberry was quantitatively measured by Anthrone Reagent method (Ranganna, 1986). For assessment of carbohydrates content, 0.2 g of mulberry leaf sample was grinded in pestle and mortar with the help of distilled water. The samples were centrifuged at 5000 rpm for 10 minutes. The supernatant was collected in test tube and 4 ml of anthrone reagent is added to get green colour. The absorbance value of the green colour was noted to evaluate the carbohydrate content using U-V spectrophotometer at wavelength of 625 nm. Against standard sugar solution (Dextrose L) the carbohydrates content was calculated and expressed in mg/g.

2.4.4Crude protein (%)

Protein content of the leaf was assessed after determining the total nitrogen content in the leaf (0.5 g leaf sample) using Macro-Kjeldhal method. The protein content of the leaf was computed by multiplying the per cent nitrogen of the sample with the factor 6.25 (A.O.A.C., 2000).

$$\text{Crude protein (\%)} = \text{N (\%)} \times 6.25$$

2.4.5 Statistical analysis and interpretation of data

The data collected from the experimental mulberry garden from two consecutive crops were pooled and subjected for statistical analysis by using one-way RCBD for testing of significance by Fisher's method of analysis of variance. The level of significance used in F test was P=0.05. The critical difference (CD) values were computed where F test was found significant to compare the treatments.

3.Results and Discussion

3.1 Nutrient composition of Silkworm litter based liquid organic manure (SLLM)

The pH of the manure was found to be slightly alkaline (7.68). Electrical conductivity was found to be 8.10 dS m^{-1}.The manure has 3.02, 1.22 and 2.96 per cent of NPK content respectively. The micro nutrients content was 1,116.20 ppm of Iron, 73.80 ppm zinc, 14.10 ppm copper and 268.60 ppm manganese(Table 4). This 100 per cent SLLM was diluted to 20 per cent for soil drenching and 10 per cent for foliar application (Table 1) as per set treatments to know the better combinations of treatment for qualitative and quantitative results.

The findings are also supported by the results of Shanmugam et al. (2020) who recorded higher percentage of nitrogen (2.05 %), phosphorus (0.60 %), potassium (2.20 %) in silkworm litter. Xiao-ping et al. (2011) observed a significant increase in total nitrogen, phosphorus, and potassium contents by 58.0 per cent, 84.4 per cent and 29.7 per cent respectively in silkworm excreta organic fertilizer (SEOF) higher than those in the raw material after fermentation. Sangeetha et al. (2012) reported that composted manure made out of silkworm litter - Pupal waste (SLPW) was found to be rich in nutrients Nitrogen (3.11 %), Phosphorus (0.39 %) and potassium (2.48 %) which are greater than the farm yard manure and vermicompost.

Table 4: Nutrient composition of Silkworm litter based liquid organic manure (SLLM)

Nutrients	Composition
pH	7.68
EC (dS m^{-1})	8.10
Nitrogen (%)	3.02
Phosphorous (%)	1.22
Potassium (%)	2.96
Iron (ppm)	1,116.20
Zinc (ppm)	73.80
Copper (ppm)	14.10
Manganese (ppm)	268.60

Table 5: Microbial population in Silkworm litter based liquid organic manure (SLLM)

Microorganism	Population (cfu ml^{-1} of manure)
Bacteria	52.24 X 10^6
Actinomycetes	66.58 X 10^4
Fungi	3.33 X 10^2

3.2Microbial population in Silkworm litter based liquid organic manure (SLLM)

Bacterial, fungal and actinomycetes population of the manure was estimated at the time of application. Bacterial count was found to be 52.24 X 10^6 cfu ml^{-1} of manure, fungal count was 3.33 X 10^2 cfu ml^{-1} of manure, actinomycetes was 66.58 X 10^4 cfu ml^{-1} of manure. Chakraborty etal. (2019) found similar results in other liquid organic manures like *panchagavya* and *jeevamrutha*. *Panchagavya* contained 12 x 10^4cfu ml^{-1} bacteria, 9 x 10^3 cfu ml^{-1} fungi and 4 x 10^3 CFU ml^{-1} actinomycetes. *Jeevamrutha* consisted of 14 x 10^5 cfu ml^{-1} bacteria, 17 x 10^3 CFU ml^{-1} fungi and 2 x 10^3 cfu ml^{-1} actinomycetes(Table 5).

Ram (2013) reported 2.61×10^6cfu ml^{-1} bacteria, 1.8×10^4cfu ml^{-1} Fungi, 1.8×10^4cfu ml^{-1}Actinomycetes, 5.7×10^2cfu ml^{-1} P solubilzers, 2.7×10^2cfu ml^{-1} Free living nitrogen fixers in *Panchgavya* and 1.54×10^6cfu ml^{-1} bacteria, 1.05×10^4cfu ml^{-1} Fungi, 6.8×10^4cfu ml^{-}

[1]Actinomycetes, 2.7×10^2cfu ml^{-1} P solubilzers, 3.1 ×10^2cfu ml^{-1} Free living nitrogen fixers in *jeevamrutha*.

More bacterial and actinomycetes count was noticed due to slightly alkaline pH of the manure which favours the growth of bacteria and actinomycetes. Fungi require acidic pH (5 - 6) for its growth (Basu et al., 2015). Hence, less fungal population was observed in the manure.

3.3 Influence of Silkworm litter based liquid organic manure (SLLM) on mulberry growth and yield:

All the treatments were found to be effective in significantly enhancing growth and yield of mulberry than control.

3.3.1 Length of longest shoot: The longest shoot length of 89.36 cm and 133.28cm was recorded in T_9 at 45 DAP and 60 DAP, respectively. It was followed by T_7 which recorded longest shoot length of 88.10 cm and 127.36 cm at 45 DAP and 60 DAP, respectively. The minimum shoot length of 72.04 cm and 105.57cm was recorded in T_{10} (control) (Table 6).

These results are in conformity with Shanmugam et al. (2020) who recorded the longest shoot length of 99.00 cm with application of silkworm excreta (SE) 400 g/plant along with RDF. The increase in shoot length can be attributed to microbial and nutrient content in soil with combined effect of foliar application which enhances the growth and development of mulberry plant. It might be attributed due to application of more nitrogen content in the soil through the SLLM that in turn increased the shoot length of mulberry (Ahmed et al., 2022).

3.3.2 Number of shoots per plant: T_9 recorded maximum number of shoots per plant (16.53and 23.80) at 45 DAP and 60 DAP, respectively. This was followed by T_7 (15.50and 23.35) and T_6 (15.53 and 22.43). Less number (11.80and 18.62) was recorded in T_{10} (Table 6).

The present investigation is in line with study of Hemavathi (2021) who reported that soil application of bio digested liquid organic manure equivalent to 150 % N ha^{-1} recorded greater number of shoots (21.60 and 25.00) at 45 and 60 DAP, respectively. Similar findings were also reported by Mala and Chandrashekhar (2020) who reported that highest number of branches $plant^{-1}$ of 13.32 was recorded in mulberry plot treated with 50 % of seri bio-digester effluent + 25 % bio-digester effluent + 25 % RDF.

This could be due to presence of numerous nutrients, enzymes and plant growth promoting hormones (Yang and Zhu., 2002) in silkworm litter manure, which aided the plant's rapid growth and resulted in increased number of shoots.

Table 6: Influence of Silkworm litter based liquid organic manure (SLLM) on mulberry growth

Treatments	Length of longest shoot (cm)		Number of shoots per plant		No. of leaves per shoot		Leaf area (cm^2)	
	45 DAP	60 DAP	45 DAP	60 DAP	45 DAP	60 DAP	45 DAP	60 DAP
T1	80.61^{bcd}	113.24^{de}	14.02^{bc}	20.32^{cde}	19.73^{bc}	28.44^{de}	111.52^{de}	191.71^{d}

T2	78.22^{de}	110.86^{ef}	13.37^{cd}	20.04^{de}	18.80^{cd}	27.54^{e}	108.55^{de}	182.54^{e}
T3	79.96^{cd}	114.21^{de}	15.33^{ab}	21.79^{abcd}	19.67^{bc}	29.01^{cde}	124.34^{cd}	201.12^{c}
T4	84.83^{abcd}	117.14^{cde}	14.83^{abc}	21.82^{abcd}	21.07^{ab}	29.94^{bcd}	130.40^{bc}	212.94^{b}
T5	81.12^{bcd}	118.98^{cd}	14.20^{bc}	21.16^{bcd}	19.63^{bc}	29.08^{cde}	126.54^{cd}	199.76^{c}
T6	83.88^{abcd}	122.45^{bc}	15.53^{ab}	22.43^{ab}	21.10^{ab}	30.44^{abc}	135.10^{bc}	205.60^{c}
T7	88.10^{ab}	127.36^{ab}	15.50^{ab}	23.35^{a}	21.83^{a}	31.67^{ab}	146.70^{ab}	221.14^{a}
T8	86.51^{abc}	123.92^{bc}	14.93^{abc}	22.24^{abc}	21.00^{ab}	29.94^{bcd}	141.11^{abc}	213.14^{b}
T9	89.36^{a}	133.28^{a}	16.53^{a}	23.80^{a}	22.17^{a}	32.02^{a}	153.44^{a}	226.56^{a}
T10	72.04^{e}	105.57^{f}	11.80^{d}	18.62^{e}	17.40^{d}	27.26^{e}	102.04^{e}	171.17^{f}
F - test	*	*	*	*	*	*	*	*
S.Em ±	2.314	2.145	0.421	0.625	0.539	0.540	6.751	2.133
C.D $_{0.05}$	6.874	6.373	1.251	1.858	1.601	1.605	20.058	6.339
C.V	4.860	3.130	4.994	5.024	4.611	3.169	9.045	1.824

* - Significant @ 0.05; Figures with same superscript are statistically on par

3.3.3 Number of leaves per shoot: Maximum number of leaves per shoot (22.17 and 32.02) was recorded in T_9. The Treatments T_7 (21.83and 31.67) and T_6(21.10 and 30.44) were on par with T_9. Less number (17.40and 27.26) was recordedin T_{10} (Table 6).

The findings are in conformity with Shanmugam et al. (2020) who recorded greater number of leaves branch^{-1} (28.15) when applied with Silkworm Excreta (SE) manure at 400 g/plant. Mala and Chandrashekhar (2020) reported maximum number of leaves branch^{-1} (18.39 and 33.00) when applied with 50 % Seri Bio-digester effluent+25% Bio-digestor effluent + 25% RDF at 45 and 60 DAP.

More the shoot length and number of shoots per plantmore will be the number of leaves per shoot. Shivakumaret al. (2000) observed similar results in their studywhere they found that, the combination of organic manures and inorganic fertilizers helped to increase the number of branches and leaves.

3.3.4 Leaf area (cm^2): Maximum leaf area (153.44 cm^2 and 226.56 cm^2) was recorded in T_9.The treatments T_7 (146.70 cm^2 and 221.14 cm^2)was on par with T_9. This was followed by T_8 which recorded leaf area of 141.11cm^2 and 213.14 cm^2) at 45 DAP and 60 DAP, respectively. Minimum leaf area (102.04 $cm^2$and 171.17 cm^2) was recorded in T_{10} (Table 6).

The results are in accordance with Sudhakar et al. (2018) found that the V-1 mulberry plot treated with N_{175} P_{70} + 20 kg seri azo + 25 kg seriphos + 10/5 MT farm yard manure recorded the maximum leaf area at 192.5 cm^2 and vermicast spray + 7 % panchagavya spray recorded 191.80 cm^2. Hemavathi (2021) reported highest leaf area of 122.91 cm^2 and 165.20

cm^2 when applied with Bio digested liquid organic manure equivalent to 150 % N ha^{-1} at 45 and 60 DAP.

The findings are also in conformity with Mala and Chandrashekhar (2020) who reported that the highest leaf area of 208.33 dm^2 in 50 % of seri bio-digestor effluent + 25 % bio-digestor effluent + 25 % RDF compared to control (184.50 dm^2). The application of SLLM might have boosted photosynthesis and transfer of photosynthates, leading to production of larger leaves.

3.3.5 Leaf yield: Application of silkworm litter based liquid manure to mulberry plants had significantly and effectively increased leaf yield in all the treatments than control.

The highest yield of 969.43 g plant^{-1}(67.31 tonnes/ha/year) was recorded in T_9 (RDF + Soil drenching of 250 l acre^{-1} of 20 % SLLM at 10 DAP + Foliar spray of 150 l acre^{-1} of 10 % SLLM at 25 DAP). The treatment RDF + Soil drenching of 250 l acre^{-1} of 20 % SLLM at 10 DAP (T_7) which recorded933.73g plant^{-1}(64.83 tonnes/ha/year)was on par with T_9. The lowest yield of 700.56g plant^{-1} was recorded in T_{10} [RDF (PoP) (Control)](Fig. 1 & Fig. 2)].

The present findings are in line with the study of Devamani (2018) who reported that highest leaf yield of 1680.30 g plant^{-1} was recorded in 3 MT vermicompost + 12 litres *panchagavya* at 3 per cent level acre^{-1} year^{-1}.

The results are also in conformity with Shanmugam et al. (2020) who recorded highest leaf yield of 12935.4 (kg /ha/harvest) when applied with Silkworm Excreta (SE) manure at 400 g/plant. Ahmed et al. (2021) showed that seri-waste compost performed better in terms of leaf yield (52.23 MT/ha/year). Hemavathi (2021) recorded highest yield of 826.66 g plant^{-1} when applied with Bio digested liquid organic manure equivalent to 150 % N ha^{-1} and 706.99 g plant^{-1} in 100 % RDF (as per POP) control.

Silkworm litter manure contains more amount of plant nutrients like macro and micro nutrients which contribute to increased production (Ahmed et al., 2021). Mulberry growth and production might be enhanced by the accumulation of beneficial microorganisms in the liquid organic manure at the treatment site or rhizosphere which improves nutrient absorption in the soil. Organic manure increases humus content in soil which improves nutrient retention and soil fertility that enhances vegetative growth and in turn leaf yield (Bharadwaj et al., 2014).

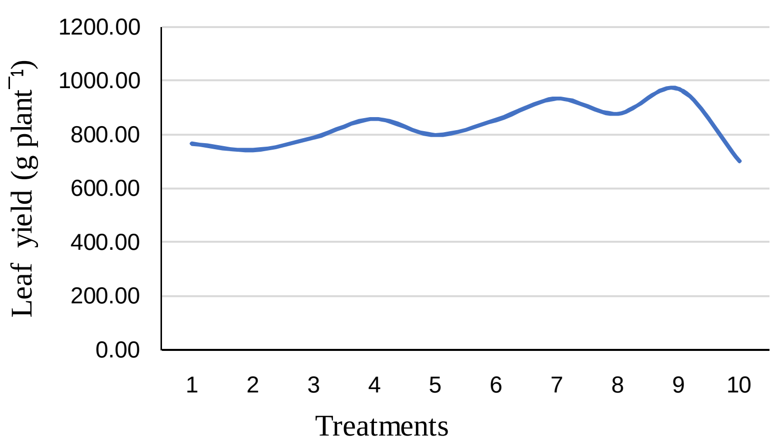

Fig. 1: Mulberry yield (g plant^{-1}) as influenced by different treatments of SLLM

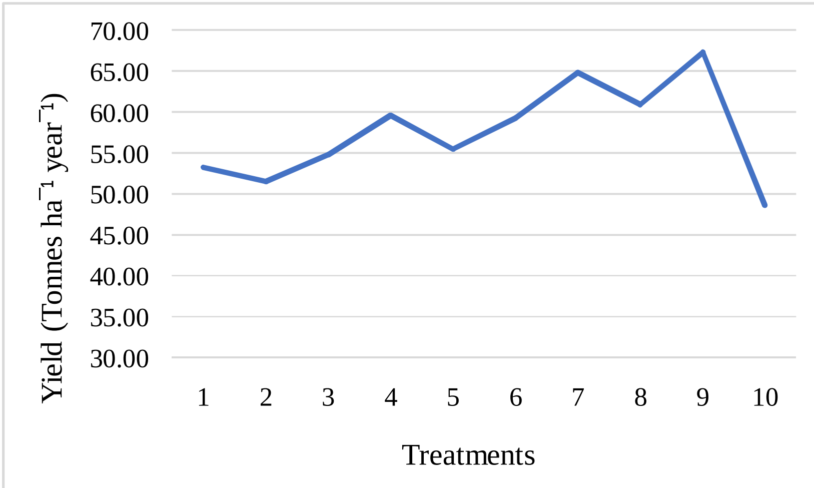

Fig. 2: Mulberry yield (Tonnes ha^{-1} year^{-1}) as influenced by different treatments of SLLM

Table 7: Influence of SLLM on quality parameters of mulberry

Treatments	Chlorophyll a (mg g $^{-1}$)	Chlorophyll b (mg g $^{-1}$)	Total chlorophyll (mg g $^{-1}$)	Leaf moisture content (%)	Crude protein content (mg g^{-1})	Carbohydrate content (mg g^{-1})
T1	$1.36^{b\,de}$	0.83^{ab}	2.20^{de}	71.44^{cd}	19.11^{d}	18.44^{ef}
T2	1.39^{bcd}	0.84^{ab}	2.24^{cde}	71.30^{cd}	18.95^{d}	18.24^{f}
T3	1.39^{bcd}	0.84^{ab}	2.26^{cd}	72.37^{bcd}	19.35^{cd}	18.98^{de}
T4	1.39^{bcd}	0.85^{ab}	2.25^{cd}	73.25^{abc}	20.19^{b}	19.20^{cd}
T5	1.42^{ab}	0.85^{ab}	2.28^{bcd}	73.00^{abcd}	19.87^{bc}	19.14^{cd}
T6	1.42^{abc}	0.85^{ab}	2.30^{abc}	73.47^{abc}	20.26^{b}	19.30^{cd}
T7	1.42^{ab}	0.86^{ab}	2.29^{abc}	75.34^{a}	21.14^{a}	19.96^{ab}
T8	1.46^{a}	0.87^{a}	2.35^{ab}	73.98^{ab}	20.95^{a}	19.60^{bc}
T9	1.47^{a}	0.86^{ab}	2.37^{a}	74.69^{ab}	21.56^{a}	20.26^{a}
T10	1.32^{e}	0.80^{c}	2.16^{e}	70.56^{d}	18.65^{d}	18.16^{f}
F - test	*	*	*	*	*	*
S.Em ±	0.012	0.007	0.023	0.742	0.227	0.188
C.D $_{0.05}$	0.036	0.022	0.069	2.205	0.674	0.558
C.V	1.512	1.499	1.767	1.762	1.966	1.702

* - Significant @ 0.05; Figures with same superscript are statistically on par

3.4 Influence of SLLM on quality parameters of mulberry:

3.4.1 Chlorophyll content: All the treatments with SLLM were found to be effective in significantly increasing chlorophyll content of leaf than control. Highest chlorophyll ‘a’ and total chlorophyll content (1.47mg g^{-1} and 2.37 mg g^{-1}) was found in T_9.The treatment T_8 which recorded chlorophyll ‘a’ and total chlorophyll content of 1.46mg g^{-1} and 2.35mg g^{-1} was on par with T_9(Table 7).

T_8 recorded highest chlorophyll ‘b’ content (0.87 mg g^{-1}). The treatment T_9which recorded chlorophyll ‘b’ content of 0.86mg g^{-1} was on par with T_8. The lowest values for chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll (1.32 mg g^{-1}, 0.8 mg g^{-1}, 2.16 mg g^{-1}, respectively) was recorded in T_{10} (Control)(Table7).

Similar results were obtained by Narayanaswamyet al. (2006), who reported that the highest total chlorophyll content of 2.12 and 2.20 mg/g of fresh weight was recorded in both S36 and DD (Vishwa) mulberry varieties by the foliar application of Phalada mulberry organic liquid at 5 ml/litre, respectively. Mala and Chandrashekhar (2020) reported highest chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll (1.46 mg g^{-1}, 0.87 mg g^{-1}, 2.44 mg g^{-1}, respectively) at 60 DAP with application of 25 % Seri Bio-digester effluent+25 % Bio-digester effluent+25 % Vermicompost + 25 % Compost.

The result shows that foliar application of SLLM resulted in quicker absorption of nutrients.Adequate supply of nutrients through silkworm litter liquid manure might be resulted in increased chlorophyll content of leaves (Suresh Kumar et al., 2011).

3.4.2 Leaf moisture content (%): All the treatments with silkworm litter liquid manure significantly increased the leaf moisture content at 60 DAP than control. Maximum moisture content of 75.34per cent was found in T_7. It was followed by T_9which recorded 74.69 per cent moisture content. Lowest moisture content of 70.56per cent was recorded in T_{10} (Control) (Table 7).

The current study is supported by Mala and Chandrashekhar (2020) who reported that highest moisture content was recorded in mulberry plot applied with 50 % seri bio-digestor effluent + 25 % bio-digestor effluent + 25 % RDF (74.46 %) over control (70.32 %). It is also supported by study of Hemavathi (2021) who reported maximum moisture content of 74.33 per cent in mulberry leaves when applied with Jeevamrutha equivalent to 150 % N ha^{-1}, 73.54 per cent when applied with Bio digested liquid organic manure equivalent to 125 % N ha^{-1}.

Similar results were also observed by Narayanaswamy et al. (2006)and Sudhakar et al. (2018). Increase in moisture content of leaves might be due to water retention capacity, slow and steady supply of moisture from silkworm litter liquid organic manure.

3.4.3 Crude protein content (%): Crude protein content of mulberry leaves was significantly influenced by soil application and foliar spray of silkworm litter liquid manure. Maximum crude protein content of 21.56 per centwas recorded in T_9.It was followed by T_7which recorded crude protein content of 21.14 per cent. T_8 recorded 20.95 per cent crude protein.T_7 and T_8were on par with T_9. Lowest value of 18.65 per cent was recorded in T_{10} (Control) (Table 7).

The results are in accordance with findings of Hemavathi (2021) who reported higher crude protein content of 22.72 per cent in mulberry plot applied with bio digested liquid organic manure equivalent to 150 % N ha^{-1} that was on par with bio digested liquid organic manure equivalent to 125 % N ha^{-1} (21.33 %) and the lowest was registered in amritpani equivalent to 100 % N ha-1 (18.35 %) treated plot.

Similar results were found by Thangaroja et al. (2018) who reported that the highest soluble protein 32.45 mg/g fresh weight was recorded in V-1 mulberry garden with organic foliar application of 1 % effective microbes compared to control (29.06 mg/g of fresh weight). The results are also in conformity with Narayanaswamy et al. (2006), Rani and Evanjaline (2015) and Mala and Chandrashekhar (2020). The rise in crude protein could be attributed to an increase in the nitrogen content of leaves.

3.4.4 Carbohydrate content (%): Carbohydrate content of mulberry leaves was significantly influenced by soil application and foliar spray of silkworm litter liquid manure. Maximum carbohydrate content (20.26 %) was recorded in T_9 which was followed by T_7 having carbohydrate content of 19.96 per cent.Lowest carbohydrate content of 18.16 per cent was recorded in T_{10} (Control) (Table 7).

The findings are in accordance with Narayanaswamy et al. (2006) who found that applying 5 ml/L of phalada mulberry organic liquid spray to the DD variety resulted in a maximum decreasing sugar content of 14.41 per cent. It is also in line with Hemavathi (2021) who reported that highest carbohydrate content of 12.35 per cent in mulberry plot applied with bio digested liquid organic manure equivalent to 150 % N ha^{-1}.

Rajanna et al. (2000) reported higher total soluble carbohydrates in leaves under silkworm excreta and recommended NPK application than pupal powder (PP), sheep manure (SM), Swine waste (SW), pongamia cake (PC) application. Thangaroja et al. (2018) reported highest total carbohydrates (40.74 mg/g) in treatment with foliar spray of 1 per cent effective microorganisms (EM) on V-1 mulberry. This could be attributed to improved mulberry leaf quality due to the use of SLLM.

4. Conclusion:

Silkworm litterbased liquid organic manure (SLLM) is a nutrient rich manure which is an effective and sustainable alternative to synthetic fertilizers for mulberry cultivation. The manure application significantly enhanced plant growth, leaf yield and nutritional quality that are crucial for silkworm. All the treatments with different doses of SLLM found effective in increasing mulberry growth, yield and quality of mulberry leaves. Among the treatments, RDF + Soil drenching of 250 l $acre^{-1}$ of 20 % SLLM at 10 DAP + Foliar spray of 150 l $acre^{-1}$ of 10 % SLLM at 25 DAP (T_9) recorded maximum mulberry growth, leaf yield and superior leaf quality. This eco-friendly approach not only recyclesthe silkworm litter at farm level but also reduces dependence on chemical inputs,lowers production costs and minimizes environmental pollution. The adoption of this organic manure can strengthen the economic viability of mulberry cultivation while addressing waste management challenges in sericulture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE):

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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