Agric Res J **61** (3): 395-404, *June* 2024
DOI: 10.5958/2395-146X.2024.00051.6

ORGANIC BASED FOLIAR FORMULATIONS ON MULBERRY: A PATHWAY TO ENHANCE REARING PERFORMANCES OF DOUBLE HYBRID SILKWORM, *Bombyx mori* L.

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ABSTRACT

An investigation was conducted to assess the efficacy of organic-based foliar formulations on mulberry and their influence on the rearing performance of the double hybrid [FC_1 x FC_2] silkworm, *Bombyx mori* L. The study involved the application of organic foliar formulations—specifically Jeevamrutha, Panchagavya, and Vermiwash—at varying concentrations (5%, 7.5%, and 10%) on the V-1 mulberry variety at 25 and 32 days after pruning (DAP). These applications were made in conjunction with the recommended doses of organic manures and fertilizers. Additionally, Seriboost at a concentration of 0.25% was used as a check, along with water control and absolute control treatments. The efficacy of the organic foliar formulations on mulberry was assessed through bioassays utilizing the double hybrid silkworm. Notably, Vermiwash applied at a 10% concentration resulted in the highest mature larval weight (5.087 ± 0.061 g), effective rate of rearing (ERR) (94.18 ± 0.558%), shell weight (0.472 ± 0.002 g), shell ratio (22.13 ± 0.116%), and silk productivity (7.148 ± 0.057%). In contrast, the application of Panchagavya at 10% led to higher cocoon weight (2.140 ± 0.011 g), pupal weight (1.663 ± 0.007 g), and cocoon yield (90.61 ± 0.394 kg/100 disease-free layings (DFLs)) compared to the absolute control. Seriboost at 0.25% demonstrated improvements over both the water control and absolute control, although its effects were less significant than those of the organic formulations. Overall, the findings suggest that organic-based foliar applications have the potential to enhance the rearing and cocoon parameters of silkworms.

Key words: Jeevamrutha, Mulberry, Panchagavya, Silkworm, Vermiwash

Silk production, a cornerstone of agro-based industries, holds significant economic and cultural value. Its impact on the rural economy is profound, providing employment opportunities and helping to mitigate urban migration. The cultivation of mulberry, the primary food source for the silkworm *Bombyx mori* L., is crucial for the production and productivity of cocoons. Nutrient-rich mulberry leaves are essential for the growth and development of silkworms, directly influencing cocoon production. Therefore, adopting appropriate cultivation practices for mulberry is imperative to sustain high-quality silk production.

Mulberry leaves are fundamental to the growth and development of silkworms, directly influencing both the quality and quantity of cocoon and raw silk production. Approximately 70% of the silk proteins synthesized by silkworms are derived from the proteins found in mulberry leaves. To ensure optimal growth and high-quality cocoon production, it is essential to provide silkworms with nutritious mulberry leaves. Compared to other agricultural crops, mulberry cultivation requires relatively high quantities of manure and chemical fertilizers. In fact, mulberry contributes to over 60% of the total cost of cocoon production (Rangaswamy *et al.*, 1976). However, the rising costs and limited availability of chemical fertilizers present significant challenges, as these inputs become increasingly expensive over time. Furthermore, intensive mulberry cropping can lead to nutrient depletion in the soil, and excessive use of inorganic fertilizers negatively impacts soil health (Shashidhar *et al.*, 2009).

In modern agriculture, organic farming methods have gained significant traction due to their ecological sustainability and potential to enhance crop yields while addressing environmental concerns. Organic-based foliar formulations, applied through spraying, have emerged as a promising strategy for improving the growth and productivity of mulberry plants. These formulations, enriched with beneficial microorganisms and nutrients, not only rectify deficiencies but also enhance the biochemical composition of mulberry, promoting robust plant development that supports healthy silkworm growth and the production of high-quality cocoons. The indiscriminate use of chemical inputs in agriculture has led to ecological degradation, including soil and water resource depletion and compromised food quality. As a result, there is a growing recognition of organic farming

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Date of receipt: 21.03.2024, Date of acceptance: 28.06.2024

as a sustainable alternative to conventional chemical-based agriculture. Furthermore, increasing awareness among farmers has spurred the development of various organic formulations designed to boost crop yields (Kannaiyan, 2000).

Organic manures have increasingly replaced chemical fertilizers, while herbal extracts have taken the place of pesticides. However, there remains a lack of viable alternatives for growth-promoting hormones and immunity boosters for plants. In Vrikshayurveda, the plant growth stimulant known as Panchagavya has been identified as highly effective in enhancing the biological efficiency of crop plants (Natarajan, 2002). Recent studies have shown that the soil application of bio-digested liquid organic manures in V-1 mulberry gardens significantly influences key economic parameters, such as cocoon weight, shell weight, cocoon shell ratio, single cocoon filament length, and filament denier in double hybrid silkworms compared to cross-breed silkworms (Chandrashekar *et al*., 2022).

To promote sustainable sericulture and safeguard the environment, the implementation of eco-friendly foliar solutions is of paramount importance. Organic-based foliar formulations aim to enhance both mulberry and cocoon production, thereby increasing crop productivity while simultaneously preserving soil integrity and reducing chemical contamination. In light of these considerations, the present research assesses the effects of organic foliar formulations on V-1 mulberry and their subsequent impact on the growth and cocoon yield of double hybrid silkworms.Top of Form

MATERIALS AND METHODS

The study was conducted at the Krishi Vigyan Kendra, V.C. Farm, Mandya, situated in the Southern Dry Zone of Karnataka, India at a geographical location of 12°34'6" North latitude and 76°49'56" East longitude, with an altitude of 695 meters above mean sea level. During the experimental period, average temperature, relative humidity, and annual rainfall were recorded at 24.87°C, 73.5%, and 1302.3 mm, respectively. An established V-1 mulberry garden, five years old and planted at a spacing of 4 x 4 feet (small-sized trees with an approximate height of three feet), served as the study site. The experimental design was structured as a Randomized Block Design, consisting of 12 treatments with three replications, each plot covering an area of 96 square feet. Before initiating the experiment, the mulberry plants were pruned, and cultivation practices were implemented according to the recommended package for irrigated conditions, which included the application of farmyard manure (20 MT/ha/year in two equal splits) and chemical fertilizers (N:P:K @ 350:140:140 kg/ha/year in five equal splits) and cultural practices were carried out as per the recommended package of practices developed for irrigated condition (Dandin and Giridhar 2010).

Preparation of organic formulations

Jeevamrutha

Jeevamrutha was prepared by mixing 1.25 kg of local cow dung, 1.25 liters of cow urine, 250 g of jaggery, 250 g of pulse flour, a handful of garden soil, and 25 liters of tap water in a plastic drum. Following a 15-day incubation period with daily stirring, the mixture was filtered to yield a stock solution (Palekar, 2006). This stock solution was then diluted to create three concentrations (5%, 7.5%, and 10%) for foliar application.

Panchagavya

Panchagavya was prepared by mixing 7 kg of fresh cow dung and 1 kg of ghee in a plastic drum, which was then fermented for two days. Following this, 4 liters of cow urine diluted with 10 liters of water were added and allowed to ferment for an additional 10 days. Subsequently, 2 liters each of cow's milk and curd, along with 3 kg of jaggery, 2 liters of tender coconut water, and 12 fully ripened bananas, were incorporated and fermented for 15 days (Sutar *et al*., 2018). This solution was then used to create three concentrations (5%, 7.5%, and 10%) for foliar application.

Vermiwash

Vermiwash, a liquid extract obtained from vermicomposting, was produced by percolating water through layers of gravel, coarse sand, garden soil, and cow dung in a plastic tub fitted with a drainage valve. The setup housed a population of 250 earthworms and was regularly moistened. After a 16-day period, nutrient-rich solutions were collected by daily sprinkling with 5 liters of water. This nutrient-rich solution was then stored for further use (Ismail, 1997). The stored solution was subsequently diluted to create three concentrations (5%, 7.5%, and 10%) for foliar application.

Application of organic based foliar formulations on mulberry

Three organic-based formulations—Jeevamrutha, Panchagavya, and Vermiwash—were applied to the mulberry leaves using a knapsack sprayer on the 25^{th} and 32^{nd} days after pruning, during dusk hours. Additionally, 'Seriboost' was included as a foliar spray for comparison, as it is commonly utilized by sericulture farmers. Water control and an untreated control group were also maintained throughout the investigation.

Silkworm Rearing

Double hybrids offer significant advantages over single hybrids in terms of effective rearing rates, larval growth, vigour, and yield. As a result, the promotion of double hybrids has become essential in India. Despite Karnataka's prominence in mulberry raw silk production, only 15-20% of the yield is derived from bivoltine double hybrid silkworms. One week prior to the start of silkworm rearing, the rearing room and equipment were thoroughly disinfected, and disease-free layings (DFLs) of bivoltine double hybrid silkworms ($FC_1 \times FC_2$) were incubated. The temperature and relative humidity of the rearing room were monitored, and rearing operations were conducted following standard procedures (Dandin and Giridhar, 2010).

Silkworm rearing was carried out using the bivoltine double hybrid ($FC_1 \times FC_2$). Mulberry leaves treated with various organic-based foliar formulations at different concentrations were fed to the silkworms from the third instar until spinning. A hundred worms were maintained in each treatment, with each treatment replicated three times. Observations were made on key rearing parameters, including mature larval weight (g), fifth instar larval duration (days), total larval duration (days), effective rate of rearing (ERR, %), and cocoon yield (kg/100 DFLs). Additionally, cocoon parameters such as cocoon weight (g), shell weight (g), pupal weight (g), shell ratio (g), and silk productivity (cg/day) were recorded for each treatment. These data were analyzed to assess the efficacy of organic-based foliar formulations on mulberry.

The data from this study were analyzed using statistical methods to evaluate the efficacy of organic-based foliar formulations on mulberry leaves and their impact on the economic traits of silkworms. The results were subjected to one-way analysis of variance (ANOVA) following a completely randomized design, with significance levels set at $p \leq 0.05$ and $p \leq 0.01$ (Sundarraj *et al.*, 1972), using SPSS for Windows version 21.0. Additionally, the percentage improvement over the control was calculated using Abbott's formula (Abbott, 1925).

RESULTS AND DISCUSSION

Foliar nutrition is a method of supplying essential nutrients to plants by directly applying liquid fertilizers onto their leaves. Plants can absorb vital elements through both their stomata and epidermis, with uptake typically occurring more rapidly through the stomata; however, significant absorption also takes place through the epidermis and bark. Timely foliar applications can enhance the absorption levels of specific nutrients during critical growth and development stages (Chethan Babu, 2022). Applying organic-based foliar formulations to mulberry leaves may improve their nutritional profile, enriching them with essential nutrients and bioactive compounds. This enhancement in the nutritional quality of mulberry leaves could provide a more nourishing diet for silkworm larvae, ultimately improving the economic traits of silkworm cocoons.

Rearing parametres

Rearing parameters such as larval weight, larval duration, effective rate of rearing (ERR), and cocoon yield are vital indicators that directly influence the quality and quantity of silk production. Larval weight significantly impacts cocoon quality; heavier larvae produce more robust cocoons due to increased leaf consumption. Maintaining an optimal larval duration is essential; while longer durations can strengthen silk, they also elevate the risk of diseases and may lead to a reduction in overall yield. ERR is critical for ensuring the successful completion of the silkworm life cycle, enhancing both the quantity and quality of silk produced. Increasing ERR not only boosts silk production but also fosters sustainability and profitability in sericulture. Ultimately, cocoon yield is largely influenced by larval weight, duration, and ERR, driving the economic prosperity of sericulture farmers.

In the present investigation, organic-based foliar formulations applied to mulberry leaves significantly influenced the mature larval weight of double hybrid silkworms. Among the treatments, T_9 (Vermiwash @ 10%) resulted in the highest mature larval weight of 5.087 ± 0.061 g, followed closely by T_8 (Vermiwash @ 7.5%) with 5.030 ± 0.035 g and T_6 (Panchagavya @ 10%) at 5.020 ± 0.051 g; these results were statistically comparable. Additionally, T_3 (Jeevamrutha @ 10%) and T_2 (Jeevamrutha @ 7.5%) recorded weights of 4.977 ± 0.029 g and 4.913 ± 0.061 g, respectively, while T_{10} (Seriboost at 0.25%) showed a weight of 4.873 ± 0.027 g, all demonstrating favourable outcomes. In contrast, the lowest mature larval weights were observed in T_{12} (absolute control) at 4.510 ± 0.058 g, followed closely by T_{11} (water control) at 4.567 ± 0.039 g. These findings highlight the effectiveness of organic-based foliar formulations in enhancing the rearing performance of silkworms compared to untreated controls.

The larvae reared on mulberry leaves treated with organic-based formulations did not show significant effects on the fifth instar and total larval duration. However, the fifth instar duration ranged from 6.433 ± 0.088 to 7.000 ± 0.289 days, while the total larval duration varied from 22.00 ± 0.289 to 23.33 ± 0.601 days.

The effective rate of rearing (ERR) is critical in silkworm rearing, as it directly impacts cocoon yield and economic viability. The application of organic-based foliar formulations, such as Jeevamrutha, Panchagavya, and Vermiwash on mulberry leaves, significantly enhanced ERR. Notably, T_9 (Vermiwash @ 10%) recorded the highest ERR at 94.18 ± 0.558%, followed closely by T_6 (Panchagavya @ 10%) at 94.11 ± 0.091% and T_8 (Vermiwash @ 7.5%) at 94.01 ± 0.246%. Other treatments, including Vermiwash, Jeevamrutha, Panchagavya, and Seriboost at various concentrations, also demonstrated favourable ERR values ranging from 93.16% to 93.78%. In contrast, T_{12} (absolute control) exhibited the lowest ERR at 89.44 ± 0.268%.

Foliar application of organic-based formulations, particularly Panchagavya and Vermiwash at a 10% concentration, significantly increased cocoon yield compared to the absolute control. Specifically, T_6 (Panchagavya @ 10%) achieved the highest yield of 90.61 ± 0.394 kg/100 DFLs, followed closely by T_9 (Vermiwash @ 10%), which yielded 90.36 ± 1.160 kg/100 DFLs. In contrast, Seriboost at 0.25% recorded a cocoon yield of 86.90 ± 1.460 kg/100 DFLs, compared to T_{12} (absolute control), which yielded 79.82 ± 0.234 kg/100 DFLs. These findings highlight the efficacy of Panchagavya and Vermiwash at higher concentrations in enhancing cocoon yield (Table 1).

The improvement in the rearing performance of double hybrid silkworms due to the foliar application of Vermiwash, Panchagavya, and Jeevamrutha can be attributed to several factors. The enhanced nutritional profile of mulberry leaves resulting from these applications provides a more nourishing diet for the silkworm larvae, promoting healthier growth and leading to increased larval weight and effective rate of rearing (ERR). However, total larval duration did not exhibit significant variations, possibly due to genetic factors or the limited impact of the treatments on developmental duration. Ankalagi and Ansari (1992) demonstrated the effectiveness of the foliar spray 'Fasal' in reducing larval mortality, highlighting the potential benefits of organic-based foliar applications for improving silkworm health. Additionally, Shanti *et al.* (1997) recorded an increase in the economic traits of silkworms (PM × NB_4D_2) reared on mulberry variety MR-2 that was treated with zinc

Table 1. Effect of organic based foliar formulations on rearing parameters of double hybrid silkworm [FC_1 X FC_2]

Treatment	Matured larval weight [g]	Fifth instar larval duration [days]	Total larval duration [days]	Effective rate of rearing [%]	Cocoon yield [kg/100 DFLs]
T_1: Jeevamrutha @ 5%	4.850 ± 0.078 [7.54]	6.750 ± 0.058 [-3.57]	22.83 ± 0.167 [-1.44]	92.59 ± 0.309 [3.52]	87.07 ± 0.618 [9.08]
T_2: Jeevamrutha @ 7.5%	4.913 ± 0.061 [8.94]	6.750 ± 0.058 [-3.57]	22.67 ± 0.441 [-2.16]	92.84 ±0.444 [3.81]	88.12 ± 1.963 [10.40]
T_3: Jeevamrutha @ 10%	4.977 ± 0.029 [10.35]	6.750 ± 0.058 [-3.57]	22.75 ± 0.144 [-1.80]	93.77 ± 0.490 [4.85]	89.90 ± 2.898 [12.63]
T_4: Panchagavya @ 5%	4.867 ± 0.035 [7.91]	6.750 ± 0.058 [-3.57]	22.50 ± 0.289 [-2.88]	93.16 ±0.570 [4.16]	87.64 ±2.876 [9.80]
T_5: Panchagavya @ 7.5%	4.913 ± 0.058 [8.94]	6.433 ± 0.088 [-8.10]	23.00 ± 0.000 [-0.72]	93.78 ±0.527 [4.85]	90.49 ±1.050 [13.37]
T_6: Panchagavya @ 10%	5.020 ± 0.051 [11.31]	6.500 ± 0.058 [-7.14]	22.33 ± 0.333 [-3.60]	94.11 ± 0.091 [5.23]	90.61 ± 0.394 [13.52]
T_7: Vermiwash @ 5%	4.943 ± 0.048 [9.61]	6.500 ± 0.115 [-7.14]	22.50 ± 0.289 [-2.88]	93.18 ±0.199 [4.18]	88.05 ±0.413 [10.31]
T_8: Vermiwash @ 7.5%	5.030 ± 0.035 [11.53]	6.500 ± 0.058 [-7.14]	22.50 ± 0.577 [-2.88]	94.01 ±0.246 [5.11]	90.15 ± 0.412 [12.94]
T_9: Vermiwash @ 10%	5.087 ± 0.061 [12.79]	6.500 ± 0.153 [-7.14]	22.00 ± 0.289 [-5.04]	94.18 ± 0.558 [5.30]	90.36 ±1.160 [13.20]
T_{10}: Seriboost @ 0.25%	4.873 ± 0.027 [8.06]	6.750 ± 0.058 [-3.57]	22.50 ± 0.289 [-2.88]	92.87 ±0.543 [3.84]	86.90 ±1.460 [8.87]
T_{11}: Water control	4.567 ± 0.039 [1.26]	7.000 ± 0.252 [0.00]	23.33 ± 0.601 [0.72]	90.15 ±0.560 [0.80]	80.86 ±0.277 [1.30]
T_{12}: Absolute Control	4.510 ± 0.058	7.000 ± 0.289	23.17 ± 0.167	89.44 ±0.302	79.82 ±0.234
Mean	4.879 ± 0.031	6.682 ± 0.045	22.67 ± 0.101	92.84 ± 0.268	87.50 ± 0.683
F-value	11.96**	NS	NS	12.38**	6.011**

** : Highly significant at $p \leq 0.01$, NS: Non-significant, [ ]: % change over control

(0.5%) and iron (1.0%) on the 30th day after pruning.

Rajegowda *et al.* (1999) reported that larval and cocoon parameters of the PM × NB_4D_2 silkworm could be significantly improved by feeding them M-5 mulberry leaves sprayed with ‘Seriboost’ at a concentration of 2.5 ml/l on the 16th, 23rd, and 30th days after pruning. Additionally, Jyothi *et al.* (2000) found that rearing PM × NB_4D_2 silkworms on M-5 mulberry leaves treated with ‘Daman Penshibao’ @ 0.50 ml/10 liters resulted in significant increases in mature larval weight (32.79 g/10 worms), effective rate of rearing (ERR) (86.10%), and cocoon yield (114.73 g/100 worms), compared to unsprayed leaves, which yielded 28.70 g, 78.04%, and 99.85 g, respectively.

Foliar spray of CCC (2-Chloroethyl-trimethyl-ammonium chloride) at concentrations of 5-10 ppm on mulberry variety S-146, applied 45 days after pruning, improved silkworm survival and silk recovery by 57 to 58% compared to untreated controls (Mohan *et al.*, 2003). Singhvi *et al.* (2003) observed that silkworms fed leaves sprayed with 10 ppm of GA_3 showed enhanced effective rates of rearing (ERR). Uppar (2011) demonstrated that the foliar spray of Vermiwash significantly improved chawki larval weight, mature larval weight, and ERR, although larval duration did not show statistically significant variation due to the application of organic-based formulations. Furthermore, Purusothaman *et al.* (2012) recorded increases in larval weight and other economic traits of silkworms following the application of Vermiwash at concentrations of 10%, 25%, and 50% once a week for four weeks on tree mulberry variety MR-2.

The findings presented in this study provide evidence for the efficacy of organic-based foliar applications, particularly Vermiwash and micronutrient solutions, in enhancing the growth and development of silkworms. The results corroborate earlier research by Kumbar (2016), who highlighted the benefits of Vermiwash as a foliar spray in improving larval weight and effective rate of rearing (ERR). This consistency across studies emphasizes the role of Vermiwash in sustainable sericulture practices. The enhancement of larval weight and ERR through micronutrient application, as reported by Geetha *et al.* (2017), further supports the notion that optimized foliar nutrition can significantly influence silkworm development. The increase in larval weight to 3.55 g and ERR to 92.00 demonstrates a clear advantage in utilizing micronutrient combinations for silkworm feeding, reinforcing the need for precise nutrient management in mulberry cultivation. Ahmed *et al.* (2018b) also contribute to this discussion by presenting evidence that the application of RBD along with urea significantly increases larval weight. Their findings align with the broader trend observed across multiple studies, suggesting that targeted nutrient interventions lead to measurable improvements in silkworm growth metrics. Nithya *et al.* (2018) further add to the conversation by showcasing the positive impact of nano zinc oxide on larval performance, including shorter moulting durations and higher weights, highlighting the potential of nanotechnology in sericulture. The consistent theme throughout these studies is the critical role of foliar applications in enhancing silkworm productivity. Shafi (2019) and Bannimatii (2019) both reported significant increases in larval weight and other growth parameters through specific foliar treatments, reinforcing the potential of Vermiwash and nutrient solutions in silkworm rearing. The marked improvement in growth metrics, such as the mature larval weight observed by Shafi (46.53 g/10 larvae) compared to control groups, highlights the importance of integrating these organic practices into sericulture.

Choudhury *et al.* (2019) contribute valuable insights by demonstrating the effects of nano ZnO and nano Cu applications, which resulted in improved growth and reduced larval durations. This highlights not only the efficacy of these treatments but also the importance of timing in application, as seen in their use at specific intervals post-pruning. The studies conducted by Deepa *et al.* (2020) and Mahesh *et al.* (2020) reinforce the concept that amino acid sprays and well-balanced fertilizer applications can significantly enhance the quality of mulberry leaves, leading to improved growth rates in silkworms. Mahesh *et al.* (2020) particularly noted the importance of combining foliar and soil applications to optimize silkworm performance, a strategy that could be pivotal in developing integrated pest management systems. Finally, the recent work by Goutam *et al.* (2023) highlights the trend toward precision agriculture in sericulture. Their findings on the application of nano nitrogen, in conjunction with balanced soil nutrient management, illustrate a progressive approach to optimizing silkworm nutrition and productivity.

Thus, the integration of organic-based foliar applications, particularly Vermiwash and micronutrient treatments, has been consistently shown to enhance key growth parameters in silkworms. These findings collectively advocate for the adoption of sustainable and scientifically-informed practices in sericulture, paving the way for increased productivity and improved economic outcomes for sericulturists.

Cocoon parameters

Cocoon weight is a critical factor influencing silk quality, yield, and economic viability. Heavier cocoons indicate that they are spun by well-fed and properly developed silkworms, leading to better-quality silk.

Shell weight serves as an initial indicator of potential silk yield; heavier shells typically contain more silk and yield longer filament lengths. The shell ratio, which represents the silk filament content relative to total cocoon weight, significantly affects both the quantity and quality of silk. A higher shell ratio signifies a greater proportion of silk filament content in relation to total cocoon weight, resulting in the production of superior-quality silk. Additionally, cocoon yield per 100 disease-free layings (DFLs) directly reflects production efficiency and determines overall profitability in silk production.

In the present study, the foliar application of organic-based formulations, particularly Panchagavya and Vermiwash at higher concentrations, significantly increased cocoon weight compared to the absolute control. Specifically, T_6: Panchagavya @ 10% concentration exhibited the highest cocoon weight of 2.140 ± 0.011 g, closely followed by T_5: Panchagavya @ 7.5% (2.135 ± 0.030 g) and T_9: Vermiwash at 10% (2.132 ± 0.017 g). Additionally, T_8: Vermiwash at 7.5% (2.131 ± 0.008 g) and T_3: Jeevamrutha at 10% (2.130 ± 0.058 g) also showed comparable results. In contrast, the absolute control recorded a cocoon weight of 1.983 ± 0.003 g. Seriboost @ 0.25% (2.079 ± 0.030 g) demonstrated a significant improvement over the absolute control, further supporting the effectiveness of organic foliar applications in enhancing cocoon weight.

Organic-based foliar sprays, particularly Vermiwash and Panchagavya at higher concentrations, significantly increased shell weight compared to the absolute control. T_9: Vermiwash @ 10% exhibited the highest shell weight of 0.472 ± 0.002 g, closely followed by T_6: Panchagavya @ 10% (0.464 ± 0.003 g), T_8: Vermiwash @ 7.5% (0.455 ± 0.007 g), and T_5: Panchagavya @ 7.5% (0.449 ± 0.001 g), which showed negligible differences among them. Additionally, Seriboost at 0.25% (0.422 ± 0.012 g) also demonstrated significant improvements in shell weight. In contrast, the lowest shell weight was observed in the absolute control (0.325 ± 0.002 g), which was comparable to T_{11}: Water control (0.337 ± 0.012 g).

The application of organic-based foliar formulations, including Jeevamrutha, Panchagavya, and Vermiwash, significantly increased pupal weight compared to both the water and absolute controls. The highest pupal weight was observed in T_6: Panchagavya @ 10% (1.663 ± 0.007 g), closely followed by T_3: Jeevamrutha @ 10% and 7.5% (1.660 ± 0.055 g). Additionally, T_5: Panchagavya @ 7.5% and T_{10}: Seriboost at 0.25% exhibited pupal weights of 1.657 ± 0.007 g and 1.653 ± 0.009 g, respectively. In contrast, the lowest pupal weights were recorded in T_{11}: Water control (1.465 ± 0.009 g) and T_{12}: Absolute control (1.468 ± 0.001 g).

Foliar application of organic-based formulations, particularly Vermiwash and Panchagavya at higher concentrations, significantly increased the shell ratio compared to the absolute control. T_9: Vermiwash @ 10% exhibited the highest shell ratio of 22.13 ± 0.116%, closely followed by T_6: Panchagavya @ 10% (21.67 ± 0.047%) and T_8: Vermiwash @ 7.5% (21.34 ± 0.333%). Other treatments, such as T_5: Panchagavya @ 7.5% (20.96 ± 0.289%), T_3: Jeevamrutha @ 10% (20.93 ± 0.321%), T_2: Jeevamrutha @ 7.5% (20.83 ± 0.156%), and Seriboost @ 0.25% (20.27 ± 0.295%), also demonstrated significant improvements in shell ratio. In contrast, the lowest shell ratio was observed in the absolute control (16.38 ± 0.087%), which was comparable to T_{11}: Water control (16.89 ± 0.565%).

Foliar application of organic-based formulations, specifically Vermiwash and Panchagavya at higher concentrations, significantly increased silk productivity compared to the absolute control. T_9: Vermiwash @ 10% exhibited the highest silk productivity of 7.148 ± 0.057 cg/day, closely followed by T_6: Panchagavya @ 10% (7.134 ± 0.052 cg/day). Additionally, T_8: Vermiwash at 7.5% and T_5: Panchagavya @ 7.5% demonstrated silk productivity of 6.996 ± 0.130 cg/day and 6.988 ± 0.112 cg/day, respectively, showing close proximity in their effects. Other treatments, including T_7: Vermiwash @ 5% (6.684 ± 0.181 cg/day) and T_3: Jeevamrutha @ 10% (6.599 ± 0.110 cg/day) and 7.5% (T2) (6.510 ± 0.163 cg/day), also indicated significant improvements in silk productivity. In contrast, T_{12}: Absolute control exhibited the lowest silk productivity at 4.658 ± 0.189 cg/day (Table 2).

The improvement in cocoon parameters can be attributed to the enriched nutritional profile of mulberry leaves resulting from foliar applications, which provide a more nourishing diet for silkworm larvae. This leads to healthier, heavier larvae that spin larger and more robust cocoons, thereby increasing both cocoon weight and pupal weight. The enhancement in cocoon weight is critical, as it directly influences the quality and quantity of silk produced. Additionally, the increase in cocoon weight contributes to improvements in shell weight, shell ratio, and silk productivity, further enhancing the overall output and economic viability of silk production.

The findings of this study provide strong evidence supporting the efficacy of various foliar sprays and organic formulations in enhancing cocoon yield and quality in silkworm rearing. The consistent results observed across multiple studies highlight the critical role of nutrient supplementation through foliar application, which significantly improves key cocoon parameters such as weight, shell weight, and overall yield. Initial research by Mishra *et al.* (1993) demonstrated that the application of Vipul on mulberry (variety: K-2) resulted in a significant increase in cocoon

Table 2. Organic based foliar formulations on cocoon parameters of double hybrid silkworm [FC_1 X FC_2]

Treatment	Cocoon weight [g]	Shell weight [g]	Pupal weight [g]	Shell ratio [%]	Silk productivity [cg/day]
T_1: Jeevamrutha @ 5%	2.090 ± 0.021 [5.38]	0.423 ± 0.002 [30.15]	1.647 ± 0.030 [12.15]	20.24 ±0.148 [23.56]	6.267 ± 0.033 [34.55]
T_2: Jeevamrutha @ 7.5%	2.109 ± 0.037 [6.34]	0.439 ± 0.011 [35.18]	1.660 ± 0.006 [13.05]	20.83 ±0.156 [27.12]	6.510 ± 0.163 [39.75]
T_3: Jeevamrutha @ 10%	2.130 ± 0.058 [7.39]	0.445 ± 0.005 [37.03]	1.660 ± 0.055 [13.05]	20.93 ±0.321 [27.73]	6.599 ± 0.110 [41.66]
T_4: Panchagavya @ 5%	2.090 ± 0.056 [5.38]	0.424 ± 0.012 [30.56]	1.637 ± 0.045 [11.46]	20.30 ±0.031 [23.91]	6.289 ± 0.213 [35.02]
T_5: Panchagavya @ 7.5%	2.135 ± 0.030 [7.66]	0.449 ± 0.001 [38.26]	1.657 ± 0.007 [12.83]	20.96 ± 0.289 [27.93]	6.988 ± 0.112 [50.01]
T_6: Panchagavya @ 10%	2.140 ± 0.011 [7.91]	0.464 ± 0.003 [42.67]	1.663 ± 0.007 [13.28]	21.67 ±0.047 [32.27]	7.134 ± 0.052 [53.16]
T_7: Vermiwash @ 5%	2.100 ± 0.009 [5.88]	0.434 ± 0.012 [33.64]	1.627 ± 0.007 [10.78]	20.68 ±0.502 [26.23]	6.684 ± 0.181 [43.49]
T_8: Vermiwash @ 7.5%	2.131 ± 0.008 [7.45]	0.455 ± 0.007 [39.90]	1.628 ± 0.012 [10.87]	21.34 ±0.333 [30.23]	6.996 ± 0.130 [50.19]
T_9: Vermiwash @ 10%	2.132 ± 0.017 [7.50]	0.472 ± 0.002 [45.13]	1.643 ± 0.007 [11.92]	22.13 ±0.116 [35.06]	7.148 ± 0.057 [53.45]
T_{10}: Seriboost @ 0.25%	2.079 ± 0.030 [4.84]	0.422 ± 0.012 [29.74]	1.653 ± 0.009 [12.60]	20.27 ± 0.295 [23.72]	6.499 ± 0.297 [39.53]
T_{11}: Water control	1.993 ± 0.019 [0.50]	0.337 ± 0.012 [3.59]	1.465 ± 0.009 [-0.20]	16.89 ±0.565 [3.07]	4.815 ± 0.181 [3.38]
T_{12}: Absolute control	1.983 ± 0.003	0.325 ± 0.002	1.468 ± 0.001	16.38 ±0.087	4.658 ± 0.189
Mean	2.094 ± 0.011	0.424 ± 0.008	1.617 ± 0.013	20.22 ± 0.295	6.382 ± 0.139
F-value	3.148**	32.15**	9.509**	36.61**	26.42**

**: Highly significant [$p \leq 0.01$], [ ]: % change over control

yield compared to untreated controls. Similarly, Dorigol (1995) confirmed the effectiveness of Vipul foliar spray by reporting improved cocoon yield in silkworms fed on treated leaves. These foundational insights have been corroborated by subsequent research, including that of Rajegowda *et al.* (1999), who highlighted significant enhancements in cocoon parameters with Seriboost-sprayed mulberry. Moreover, studies such as those by Jyothi *et al.* (2000) emphasized the positive impact of 'Daman Penshibao' on PM x NB_4D_2 silkworms, showing significant increases in cocoon yield, weight, and shell ratio. The benefits of other treatments are illustrated in the work of Chikkaswamy *et al.* (2001), who noted improvements in cocoon weight and pupal weight when silkworms were reared on 'Green leaf' sprayed mulberry. Prasanna Kumar *et al.* (2001) reported similar findings, noting enhanced cocoon weight, shell weight, and shell ratio among hybrids reared on treated leaves. Further supporting these results, Singhvi *et al*. (2002, 2003) observed significant improvements in cocoon shell weight and economic traits, including cocoon weight and shell ratio, when silkworms were fed leaves treated with Seriboost and GA_3, respectively. These studies collectively suggest that targeted nutrient applications can lead to substantial benefits in silkworm productivity. The current research aligns with findings from Rajegowda and Raju (2011), who reported significant increases in cocoon weight and shell weight through the application of a specific micronutrient composition. Additionally, Uppar (2011) documented a higher cocoon yield resulting from the foliar spray of vermiwash, further establishing the efficacy of organic inputs.

Research by Purusothaman *et al.* (2012) found that weekly applications of vermiwash enhanced silk gland weight and other economic traits, corroborating the findings of Samuthiravelu *et al.* (2012), who indicated superior cocoon traits due to organic foliar applications. Similarly, Lokesh (2014) reported significant increases in commercial parameters when combining soil application of vermicompost with foliar treatments. The contributions of organic formulations continue to be validated, as highlighted by Kumbar (2016) and Geetha *et al.* (2017), who reported improved cocoon parameters through various organic treatments. Ahmed *et al.* (2018 a,b) demonstrated the effectiveness of foliar fertilizer applications, noting increases in larval weight, cocoon weight, and filament length, indicating the potential for fertilizer strategies in enhancing cocoon quality. Furthermore, studies by Sudhakar *et al.* (2018) and Nithya *et al.* (2018) showcased the benefits of organic manures and innovative applications of nano zinc, respectively, both contributing to improved cocoon metrics. Devamani (2019) similarly highlighted the effectiveness of bio-formulations like vermicompost and panchagavya. The positive impact of vermiwash was also noted by Shafi (2019) and Bannimatti (2019), who reported significant improvements in larval and cocoon weights. Recent research by Choudhury *et al.* (2019), Deepa *et al.* (2020), Sudhakar *et al.* (2018), Mahesh *et al.* (2020), Thanga Roja *et al.* (2023), and Goutam *et al.* (2023) further highlights the potential of novel interventions, including nano materials and amino acids, in enhancing cocoon quality and productivity.

Economic analysis

Liquid organic amendments are integral to traditional agriculture, often celebrated as a natural farming miracle. Rural farmers easily prepare these formulations using readily available ingredients like cow dung, cow urine, jaggery, pulse flour, crop residues, soil, and water. These amendments are praised for their cost-effectiveness, sustainability, and environmentally friendly nature. In the present study, the application of organic foliar formulations demonstrated a favourable benefit-cost ratio of 1.78:1, highlighting their economic viability. This indicates that for every unit invested in these organic practices, farmers can expect to gain significantly in return, making them an attractive option for enhancing agricultural productivity while promoting ecological balance.

CONCLUSION

In conclusion, this study highlights the significant effects of organic-based foliar formulations on mulberry (V-1) and their beneficial impact on the rearing performance of double hybrid silkworms (FC_1 X FC_2). The observed improvements in rearing and cocoon parameters over control groups highlight the potential of integrating organic foliar applications alongside conventional organic manures and chemical fertilizers to enhance silkworm productivity. While soil application remains the predominant method for nutrient supply, the ability of plants to absorb essential minerals through foliar sprays opens up new possibilities for addressing nutritional deficiencies effectively. Despite the challenges associated with foliar application, including the necessity for multiple sprays and the risk of nutrient wash-off, the advantages it offers in correcting nutritional disorders cannot be overlooked.

This research demonstrates the promising role of organic inputs in improving cocoon quality and yield, which is vital as sericulture adapts to evolving environmental and market conditions. The findings encourage further exploration into the mechanisms of nutrient absorption in mulberry leaves and the refinement of application techniques. By advancing nutrient management strategies, the sericulture industry can enhance productivity while prioritizing ecological sustainability, paving the way for more resilient agricultural practices in the future.

Authors' contribution

Conceptualization of research work and designing of experiments (BS, HMM); Execution of field/lab experiments and data collection (HMM, BS); Analysis of data and interpretation (BS, HMM); Preparation of Manuscript (HMM, BS).

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