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Research Article

Influence of Macro- and Micro-Fertilizers on Silkworm Economic Parameters

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Abstract

An intensive research was carried out during 2018-2022 at the Regional Sericultural Research Station, Salem, Tamil Nadu. The research focused on assessing the significance of micronutrients and their effects on the growth, moisture content, yield parameters and nutrient composition of mulberry leaves. The combined results indicated that treatments T_2 and T_3 exhibited higher larval weight, shell weight, rendita and denier, with values of 42.90 g, 0.42 g, 6.14 kg and 2.33 d, respectively. Treatment T_5 also showed promising results, with larval weight of 42 g, shell weight of 0.38 g, rendita of 6.2 kg and denier of 2.65 d. In terms of single cocoon weight, treatment T_3 had the highest value of 1.88 g, closely followed by T_2 with 1.86 g. Regarding shell ratio and silk filament length, T_2 exhibited higher values (22.58% and 1103 m) compared to T_3 (22.55% and 1099 m). Among the five crops studied, the fourth crop demonstrated the best results when treated with T_2 and T_3. These treatments resulted in higher larval weight (51.37 g and 51.6 g), cocoon weight (2.2 g and 2.3 g), shell weight (0.56 g and 0.55 g), shell ratio (25% and 24.67%), pupal weight (1.65 g and 1.71 g), silk filament length (1416 m and 1412 m), rendita (6 kg) and denier (2.46 d and 2.79 d) respectively.

Keywords: Inorganic fertilizers, Panchagavya, Poshan, Silkworm, V_1 mulberry variety

Introduction

Sericulture is a vital industry for millions of families worldwide, especially small and medium-scale farmers, offering low investment and high profits. India ranks second globally in raw silk production, with 33,770 MT in 2020-21. Mulberry silk contributes 23,896 MT; while Eri, Tasar and Muga silks contribute 6,946 MT, 2,689 MT and 239 MT, respectively (Anonymous 2021). In India, Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu and Kashmir, accounting for 95.87% of India's total mulberry silk production (Giridhar *et al.*, 2011).

High-quality cocoons in silkworms (*Bombyx mori* L.) depend on superior mulberry leaf feed. *Morus* sp. leaves are the main source of nutrition for *Bombyx mori* during cocoon production. Timely supply of quality mulberry leaves is crucial for raw silk production. In field crop, diseases (24%), insects (18%), weeds (7%) and others (51%) can affect mulberry leaf quality and quantity. Postpone of mulberry pruning and silkworm rearing by two weeks helps mitigate the effects of climate change, while revised crop schedules enhance yield and cocoon production for sustainable farming (Suresh *et al.*, 2022).

The nutrient composition of mulberry leaves has a effect on the larval growth, digestion, assimilation and silk quality in silkworms (Ramesha *et al.*, 2010; Jyothi *et al.*, 2014; Lalfelpuii *et al.*, 2014). The routine life cycle of *Bombyx mori*, originating from the same genetic stock, can vary significantly based on the nutritional quality of mulberry leaves (Rahmathulla, 2012). Rearing performance in terms weight of larval, cocoon weight, shell and silk percentage are important factors for achieving high productivity and quality (Gaviria *et al.*, 2006; Gangawar, 2010; Seidavi, 2011). The presence of higher concentrations of calcium (Ca), magnesium (Mg) and iron (Fe) in mulberry leaves stimulates the metabolic activity of silkworms, resulting in shorter larval

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duration and an increased pupation rate (Horie *et al.*, 1985). Combining 100% recommended fertilizer dose (RDF) with liquid Bio-NPK and Zn solubilizing bacteria maximized yield and nutrient concentrations, showing superior performance compared to individual applications (Singh *et al.*, 2022).

The mineral content of mulberry leaves plays a crucial role in the growth, development and silk quality of silkworms. Proper mineral nutrition is vital for high-quality silk production, as imbalances can negatively affect both the quantity and quality of the silk (Shree *et al.*, 2005; Mahadeva and Shree, 2005; Mahadeva, 2016). Supplementation of mulberry leaves with nickel (Ni) and zinc (Zn) chloride has been found to increase larval and cocoon weights. However, micronutrients should be applied carefully based on soil tests, ideally once every three years. They can be combined with mixed fertilizers or incorporated into granular fertilizers. Continuous application of organic manure can help address long-term micronutrient deficiencies (Wani *et al.*, 2016).

Bombyx mori L. larvae fed with nano-micronutrients mulberry treated enhance larval weight, growth duration, food-to-silk conversion efficiency (ERR) and silk productivity. Foliar application of nano-micronutrients has a more significant impact (Choudhury *et al.*, 2019). For optimal growth and silk protein synthesis, silkworm larvae need a dietary protein and amino acid content of 20-25% (Horie *et al.*, 1985). Foliar spray of micronutrients does not significantly impact larval growth and cocoon traits, except for magnesium, which has been found to increase cocoon yield (401 kg ha^{-1}) and cocoon weight (1.5 g) (Viswanath and Krishnamurthy, 1982). Applying boron (4 kg ha^{-1}) and iron (5 kg ha^{-1}) in mulberry gardens boosts silkworm cocoon yield, whereas zinc (10 kg ha^{-1}) decreases it. The growth, yield and quality of the Kanva-2 mulberry variety are enhanced with various doses of magnesium, manganese, iron, zinc and boron (Lokanath *et al.*, 1986). Applying 200 kg of nitrogen as urea increases leaf yield by 23.83% compared to higher nitrogen doses. Silkworms fed mulberry leaves treated with micronutrients such as iron, manganese, copper, boron and molybdenum show improved silk quality and zinc application promotes both mulberry and silkworm growth (Bose and Bindroo, 2009). Research conducted by Wani *et al.* (2017) aimed to increase quality and quantity of silk and silkworm eggs by administering additional nutrients through spray or dust onto silkworm larvae and demonstrated the significant impact of foliar application of micronutrients on cocoon production. This method influences the physiological functions of silkworm breeds and enhances seed cocoon parameters, particularly with the utilization of zinc and boron.

Treating mulberry leaves with nano zinc oxide (20 ppm) through foliar spray and feeding them to silkworm larvae has shown favorable results. These include reduced molting and 5th instar duration, enhanced larval weight, improved silk conversion efficiency, increased cocoon and shell weight, longer filament and finer denier (Aslam and Ashfaq, 2004; Etebari *et al.*, 2004; Nithya *et al.*, 2018). During silk production, the posterior silk gland secretes fibrous protein, while sericin acts as an adhesive to bind fibroin and form silk cocoons in silkworms (Sabina *et al.*, 2013). Therefore, the present study aims to determine the necessary amount of micro fertilizers for a mulberry garden and to assess their impact on the economic parameters of silkworm production.

Materials and Methods

From 2018 to 2022, a research took place at the Regional Sericultural Research Station, Salem, Tamil Nadu. The objective was to explore the role of micronutrients and their effect on silkworm and cocoon production. The experiment utilized the V_1 mulberry variety with a garden layout featuring 3’×3’ spacing. Ten distinct treatments were supply to mulberry field by plotting layout in a randomized block design with three replications. 300 larvae of the silkworm crossbreed (CB) per replication and they were fed three times a day. Silkworm bioassay carried out by followed standard protocol described by Krishnaswami (1979a, 1979b).

Treatment Details

T_1: 100% RDF (350:140:140 kg NPK $ha^{-1}year^{-1}$).

T_2: 100% RDF + 30 kg $ha^{-1}year^{-1}$ micronutrients - soil application.

T_3: 100% RDF + 25 kg $ha^{-1}year^{-1}$ micronutrients - soil application.

T_4: 100% RDF + 20 kg $ha^{-1}year^{-1}$ micronutrients - soil application.

T_5: 100% RDF + 0.5% micronutrients (Zn, Fe, Mn) + 0.2% Borax - foliar application.

T_6: 100% RDF + 0.25% micronutrients (Zn, Fe, Mn) + 0.1% Borax - foliar application.

T_7: 100% RDF + 0.7% Poshan - foliar application.

T_8: 100% RDF + 3% panchagavya - soil application.

T_9: 100% RDF + 5% panchagavya - soil application.

T_{10}: Absolute control.

Micro- and macro-nutrients applied in mulberry garden in the form of $ZnSO_4$, $FeSO_4$, $MnSO_4$, Borax and poshan purchased from CSR&TI, Mysore.

Results and Discussion

Pooled Data of 5-Crops

10-Larval Weight (g)

In the field experiment, T_2 (100% RDF + 30 kg $ha^{-1}year^{-1}$ micronutrients - soil application) and T_3 (RDF + Fe, Zn, Mn, B - 25 kg $ha^{-1}year^{-1}$ - soil application) showed the highest larval weights on the 6th day fifth instar. T_2 had a weight of 42.90 g, followed by T_4 (100% RDF + 20 kg $ha^{-1}year^{-1}$ micronutrients - soil application) with 42 g (Figure 1). Among the crops, the fourth crop’s T_3 and T_2 treatments had the highest larval weights, measuring 51.6 g and 51.37 g, respectively (Table 1). Choudhury *et al.* (2019) and Wani *et al.* (2017) also documented comparable results.

Figure 1: Silkworm larvae

Figure 2: Silkworm cocoon

Table 1: Effect of micronutrient application on 5th instar grown larval weight (g)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	36	36.33	36.33	42.6	43.07	38.87
T_2	37	37.33	38.02	50.77	51.37	42.90
T_3	37.33	37	38	50.53	51.6	42.89
T_4	37	37	36.51	49.2	50.43	42.03
T_5	35.67	38.22	37	43.67	48.2	40.55
T_6	35.67	37.55	36	43.83	46.93	40.00
T_7	37	35.33	35.47	42.12	48.07	39.60
T_8	35.67	36	36	41	41.2	37.97
T_9	35.33	36.67	37	39.7	40.93	37.93
T_{10}	35.87	28.33	15.74	15.7	15.37	22.20
F-value	35.38	51.25	77.93	74.14	88.36	135.52
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Single Cocoon Weight (g)

Among the ten nutrient levels tested (pooled data), T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1}year^{-1} through soil application) followed by T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients through soil application) showed significantly higher values in terms of cocoon weight, measuring 1.88 g and 1.86 g, respectively (Figure 2). Among the five crops studied, the fourth crop's T_3 and T_2 treatments exhibited relatively higher cocoon weights, measuring 2.3 g and 2.2 g, respectively (Table 2). Bose and Bindroo (2009), Shilpashree *et al.* (2015), Geetha *et al.* (2017), Wani *et al.* (2017), Choudhury *et al.* (2019) and Nazar *et al.* (2019) found similar results.

Single Shell Weight (g)

Among the ten nutrient levels tested, T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1}year^{-1} through soil application) and T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients through soil application) showed significantly higher values in terms of single shell weight, measuring 0.42 g and 0.38 g, respectively. Among the five crops studied, the fourth crop's T_2 and T_3 treatments exhibited relatively higher single shell weights, measuring 0.56 g and 0.55 g, respectively (Table 3). Murali *et al.* (2006), Shilpashree *et al.* (2015), Geetha *et al.* (2017) and Choudhury *et al.* (2019) found similar results.

Table 2: Effect of micronutrient application on single cocoon weight (g)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	1.65	1.81	1.68	1.68	1.73	1.71
T_2	1.68	1.67	1.87	1.9	2.2	1.86
T_3	1.67	1.7	1.85	1.9	2.3	1.88
T_4	1.67	1.63	1.73	1.63	1.63	1.66
T_5	1.63	1.67	1.81	1.74	1.82	1.76
T_6	1.73	1.7	1.58	1.67	1.59	1.65
T_7	1.67	1.67	1.71	1.74	1.6	1.68
T_8	1.53	1.67	1.71	1.67	1.63	1.64
T_9	1.47	1.513	1.56	1.43	1.54	1.5
T_{10}	1.53	0.6	0.31	0.23	0.33	0.64
F-value	24.55	21.70	51.09	49.32	40.74	145.01
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Pupal Weight (g)

T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1} year^{-1}) and T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients) had the highest pupal weights (1.46 g and 1.44 g, respectively) among the ten nutrient levels tested. In the fourth crop, T_2 and T_3 had the highest pupal weights (1.65 g and 1.71 g, respectively) (Table 4). Bose and Bindroo (2009), Geetha *et al.* (2017) and Wani *et al.* (2017) found similar results.

Shell Ratio (%)

Among the ten nutrient levels tested (pooled data), T_2

Table 3: Effect of micronutrient application on shell weight (g)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	0.34	0.37	0.34	0.38	0.38	0.36
T_2	0.34	0.35	0.42	0.46	0.55	0.42
T_3	0.34	0.35	0.41	0.46	0.56	0.42
T_4	0.35	0.37	0.36	0.36	0.36	0.36
T_5	0.33	0.35	0.38	0.41	0.43	0.38
T_6	0.35	0.34	0.32	0.36	0.36	0.35
T_7	0.33	0.34	0.35	0.35	0.35	0.34
T_8	0.35	0.34	0.35	0.36	0.35	0.35
T_9	0.31	0.31	0.32	0.33	0.35	0.32
T_{10}	0.31	0.09	0.04	0.03	0.03	0.10
F-value	25.98	38.48	36.97	54.28	44.90	90.80
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Table 4: Effect of micronutrient application on pupal weight (g)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	1.31	1.44	1.34	1.3	1.35	1.35
T_2	1.34	1.32	1.47	1.45	1.65	1.44
T_3	1.33	1.38	1.44	1.44	1.71	1.46
T_4	1.32	1.26	1.37	1.27	1.27	1.32
T_5	1.30	1.32	1.43	1.33	1.39	1.38
T_6	1.38	1.36	1.26	1.31	1.23	1.30
T_7	1.34	1.33	1.36	1.39	1.25	1.34
T_8	1.18	1.33	1.36	1.31	1.28	1.29
T_9	1.16	1.203	1.24	1.1	1.19	1.18
T_{10}	1.22	0.51	0.27	0.2	0.3	0.54
F-value	22.81	12.81	28.50	46.77	39.34	121.14
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

(100% RDF + 30 kg ha^{-1}year^{-1} micronutrients through soil application) followed by T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1}year^{-1} through soil application) showed significantly higher values in terms of shell ratio, measuring 22.58% and 22.55%, respectively. Among the five crops studied, the T_2 and T_3 treatments in the fourth crop exhibited a relatively higher shell ratio of 25% (Table 5). Murali *et al.* (2006), Bose and Bindroo (2009), Shilpashree *et al.* (2015), Geetha *et al.* (2017) and Nazar *et al.* (2019 also documented comparable results.

Filament Length (m)

Out of the ten nutrient levels tested (combining data), T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients *via* soil application) and T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1} year^{-1} *via* soil application) displayed notably higher values in terms of silk filament length, measuring 1,103 m and 1,099 m, respectively. Among the five crops examined, the fourth

Table 5: Effect of micronutrient application on shell ratio (%)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	20.61	20.44	20.24	22.62	21.97	21.17
T_2	20.24	20.96	22.45	24.21	25.00	22.58
T_3	20.36	20.23	22.16	24.21	24.67	22.55
T_4	20.96	22.70	20.81	22.09	22.09	20.48
T_5	20.25	20.96	20.99	23.56	23.63	21.60
T_6	20.23	20.00	20.25	21.56	22.64	20.97
T_7	19.76	20.36	20.47	20.11	21.88	20.48
T_8	22.88	20.36	20.47	21.56	21.47	21.34
T_9	21.09	20.49	20.51	23.08	22.73	21.51
T_{10}	20.26	15.00	12.90	13.04	9.09	15.63
F-value	15.50	3.58	10.38	75.46	10.44	19.78
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

crop treated with T_2 and T_3 showed relatively longer silk filament lengths of 1,416 m and 1,412 m respectively (Table 6). Researchers Shilpashree *et al.* (2015) and Nazar *et al.* (2019) also found comparable data.

Table 6: Effect of micronutrient application on filament length (m)

Treat-ment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	832	824	822	1212	1230	986
T_2	815	830	1028	1405	1416	1103
T_3	825	812	1022	1405	1412	1099
T_4	844	826	922	1188	1189	979
T_5	815	830	959	1330	1343	1054
T_6	814	808	868	1186	1242	984
T_7	529	812	898	1172	1202	974
T_8	869	812	892	1175	1196	996
T_9	846	818	907	1224	1246	999
T_{10}	817	525	585	432	597	582
F-value	17.64	10.23	18.09	28.03	24.83	49.19
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Renditta (kg)

In the study, T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients through soil application) and T_3 (RDF + Fe, Zn, Mn, B - 25 kg ha^{-1}year^{-1} through soil application) showed significantly lower renditta values, measuring 6.14 kg and 6.20 kg, respectively. In the fourth crop, treatments T_2, T_3 and T_5 had relatively lower renditta values of 6 kg each (Table 7). Murali *et al.* (2006), Shilpashree *et al.* (2015) and Nazar *et al.* (2019) also documented comparable results.

Denier (%)

In the study, T_2 (100% RDF + 30 kg ha^{-1}year^{-1} micronutrients

Table 7: Effect of micronutrient application on renditta (kg)

Treatment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	8.2	8	9	8.4	8	8.32
T_2	7	6	6	5.7	6	6.14
T_3	7.8	6	5.6	5.7	6	6.14
T_4	7.4	6	7	7	7	6.88
T_5	7	6	6	6	6	6.2
T_6	10	10	9	8.5	8	9.1
T_7	10	8	8.3	8.5	8.5	8.66
T_8	6.5	9	8.3	8	8.5	8.06
T_9	7.43	8	7.3	7	7	7.346
T_{10}	9.5	10	12.5	14	13	11.8
F-value	6.86	14.10	60.48	72.53	144.21	78.16
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

through soil application) and T_3 (RDF + Fe, Zn, Mn, B - 25 kg $ha^{-1}year^{-1}$ through soil application) recorded significantly lower values in denier, measuring 2.33 d and 2.65 d, respectively. Among the five crops studied, the fourth crop's T_2, T_3 and T_5 treatments exhibited relatively lower denier values of 2.33 d and 2.65 d (Table 8). Thangamani and Vivekanandan (1984), Etebari *et al.* (2004), and Aslam and Ashfaq (2004) also documented comparable results.

Table 8: Effect of micronutrient application on denier (d)

Treatment	Crop-1	Crop-2	Crop-3	Crop-4	Crop-5	Pooled
T_1	3.33	3.28	3.64	3.51	3.74	3.5
T_2	2.88	2.64	2.70	2.48	2.56	2.65
T_3	2.64	2.50	2.48	2.56	2.56	2.55
T_4	2.64	2.41	2.41	2.57	2.62	2.53
T_5	3.12	3.12	3.34	3.51	3.48	3.313
T_6	3.08	2.97	2.84	2.84	2.67	2.883
T_7	2.94	3.33	3.28	3.28	3.33	3.233
T_8	3.13	3.21	3.18	3.27	3.46	3.25
T_9	3.54	3.26	3.33	3.42	3.55	3.42
T_{10}	3.84	3.74	3.66	3.72	3.72	3.733
F- value	59.50	144.72	126.74	105.16	137.98	1001.27
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Conclusion

The study's results suggested that T_2 and T_3 yielded positive outcomes in silkworm economic parameters for both crop-4 and pooled data. Notably, there were no significant distinctions observed among the treatments except for T_{10} (control).

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