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RESEARCH ARTICLE

Effect of Micronutrients and Biofertilizers on Growth and Yield of Mulberry (*Morus indica* L.) and Silkworm (*Bombyx mori* L.)

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ABSTRACT

A field experiment was conducted to study the effect of micronutrients and biofertilizers on mulberry in under field condition. Different combination of micronutrients and biofertilizers were used in this study to assess the growth and yield of mulberry and silkworm. Among the treatments, application of 100 % RDF + Soil application of $ZnSO_4$, Fe SO_4, $MnSO_4$ and $MgSO_4$ @ 25 kg ha^{-1} each + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer each @ 1500 ml ha^{-1}) recorded superior growth and yield attributes *viz.,* plant height (198 cm), number of shoots (14 $plant^{-1}$), number of leaves (646 $plant^{-1}$), leaf area (101146 cm^2 $plant^{-1}$) and leaf yield (1218.369 g $plant^{-1}$) with high leaf moisture retention percentage of 93.94. Yield traits of silkworm such as larval weight, effective rate of rearing by number, effective rate of rearing by weight, single cocoon weight, single shell weight and number of cocoon per kilogram were also higher compared to other treatments.

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Silkworm (*Bombyx mori* L.) is a monophagous insect which feed only on mulberry leaves *Morus* spp. Silkworm larval growth and cocoon yield are mainly influenced by nutritional quality of mulberry leaves (Purohit and Pavankumar, 1996). Production of good cocoons crop necessitates production of superior quality mulberry leaves. Hence improvement of mulberry leaf quality and quantity is essential (Chaudhary and Giridhar, 1987). Silk production is dependent on the larval nutrition and nutritive value of mulberry leaves which plays a very effective role in producing good cocoons (Legay, 1958). Quality feed supplementation plays an important role by which cocoon and silk productivity can be increased and quality can be enhanced and maintained. Good quality cocoons can be obtained when silkworms fed on nutritionally superior leaves which results in improved silk production (Seki and Oshikane, 1959). Soil organic matter is the natural source to restock the available micronutrients in soil and since Indian soils are low in organic matter, micronutrients requirement exceeds the natural supply. Micronutrients are involved in several metabolic activity of mulberry plant that are responsible for quality leaf production and stimulate metabolic activity in silkworm which in turn leads to better rearing performance and silk quality. As mulberry is grown for its foliage and harvested 5-6 times a year, nutrient requirement is high and balanced application of nutrients is essential. Currently emphasis is being given to major nutrients with less focus on micronutrients. Even though foliar application of micro nutrients is in practice now, soil application of micronutrient is known to have residual effect. Literature on soil application of micronutrients to mulberry is scanty and hence the study on the effect of micronutrients on growth and yield of mulberry and silkworm was carried out.

MATERIAL AND METHODS

A field experiment was conducted at D. Perumapalayam village of Salem district, Tamil Nadu during 2016-17 in an established mulberry garden with mulberry variety Victory 1 (V1) planted at a spacing of (5+3) x 2 feet in paired row system. The experiment was laid out in Randomised Block Design and replicated thrice with 12 treatments comprising of T_1- Control (100% RDF), T_2-100 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$ @ 25 kg ha^{-1} each, T_3-100 % RDF + Soil application of $ZnSO_4$, Fe SO_4, $MnSO_4$ and $MgSO_4$ @ 25 kg ha^{-1} each + Recommended dose of Biofertilizers (Azos, Phospho and Potash mobilizer), T_4-75 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$ @ 25 kg ha^{-1} + Recommended dose of Biofertilizers (Azos,

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Phospho and Potash Mobilizer), T_5-100 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$@15 kg ha^{-1}, T_6-100 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$@ 15 kg ha^{-1} + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer), T_7-75 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$@ 15 kg ha^{-1} + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer), T_8-100 % RDF + 0.5 % Foliar spray of $ZnSO_4$, Fe SO_4, $MnSO_4$ & $MgSO_4$, T_9-100 % RDF + 0.2 % Foliar Spray of $ZnSO_4$, $FeSO_4$, $MnSO_4$ & $MgSO_4$, T_{10}-100 % RDF + 0.5 % Foliar spray of $ZnSO_4$, Fe SO_4, $MnSO_4$ and $MgSO_4$ + Recommended dose of biofertilizers (Azos, Phospho & Potash mobilizer), T_{11}-100 % RDF + 0.2 % Foliar Spray of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$ + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer) and T_{12}-75 % RDF + 0.2 % Foliar spray of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$ + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer).

The bio-fertilizer inoculants Azos: *Azospirillum lipoferum*, Phospho: *Bacillus megaterium* var. *Phosphaticum* and Potash mobilizer: *Frateuria aurantia* used in this study were mass multiplied on the respective medium and the bacterial inoculants cells were separated and concentrated by tangential flow filtration system (PAUL Life Sciences Inc.) and formulated in a liquid based cell encapsulation medium with declared cell count of 1 x 10^8 CFU ml^{-1} in Bio-fertilizer Production Unit, Department of Agriculture, Salem and given as soil application at recommended dosage of 1500 ml ha^{-1}.

Micronutrients as foliar application were sprayed on 25 days after pruning (DAPR). The observations on growth and yield attributes were recorded on 65 DAPR. Leaf area per plant was measured using a Leaf Area Meter (LICOR, Model LI 3000) and expressed as cm^2 $plant^{-1}$. The moisture retention of leaf samples were calculated using the formula and expressed in percentage.

$$\text{Leaf moisture retention (\%)} = \frac{\text{Fresh wt. of leaf after 10 h} - \text{Dry wt.}}{\text{Fresh wt. of leaf after 10 h}} \times 100$$

Leaves were harvested from 45 days of pruning and fed to the bivoltine silkworm double hybrid (CSR2xCSR26) X(CSR2xCSR27) according to the treatments. Observations on larval weight, effective rate of rearing (ERR), cocoon weight and shell weight and number of cocoons per kg were recorded on 6^{th} day of cocoon formation. Analysis was done and the statistical scrutiny of the experimental data was done by the method of analysis of variance as suggested by Gomez and Gomez (1992).

RESULTS AND DISCUSSION

The present study was aimed to find out combined effect of soil and foliar application of micronutrients along with soil application of biofertilizers on mulberry growth, yield attributes and silkworm cocoon parameters.

Table1. Effect of micronutrients and biofertilizers on growth and yield of mulberry

Treatments	Plant height (cm)	No. of shoots $plant^{-1}$	No. of leaves $plant^{-1}$	Leaf area (cm^{-2})	Fresh leaf yield $plant^{-1}$ (g)	TDMP (g $plant^{-1}$)	Leaf moisture retention After 10 h (%)
T_1	164	9	328	34717	597.77	313.63	90.87
T_2	185	10	396	47269	840.88	434.03	91.77
T_3	198	14	646	101146	1218.36	636.00	93.94
T_4	196	13	571	84312	1183.87	695.77	93.17
T_5	170	10	360	38487	741.43	386.51	91.08
T_6	192	13	550	75939	1194.66	610.54	92.49
T_7	194	13	551	74381	1082.94	604.69	92.78
T_8	175	10	373	40585	732.38	418.48	91.43
T_9	170	10	376	41253	769.97	421.47	91.21
T_{10}	191	12	487	65989	1100.11	583.67	92.18
T_{11}	186	12	455	57857	1020.89	552.12	92.06
T_{12}	184	11	443	53604	977.41	509.49	92.04
Mean	184	11	461	59628	955.06	513.87	92.09
SEd	5.89	0.365	7.61	2449.92	31.92	17.41	1.189
CD(0.05%)	11.08	0.742	15.48	4124.50	64.95	35.42	2.418

Combined application of micronutrients and biofertilizers resulted in better growth and yield of mulberry. Higher plant height (198 cm), number of shoots (14 plant $^{-1}$) number of leaves (646 plant $^{-1}$) and leaf area (101146 cm ^{2} Plant^{-1}) was observed in T_3 followed by T_4 (Table 1). However higher total dry matter production (69.77 g) was observed in T_4 compared to T_3 and other treatments. The increase in plant height, number of leaves per plant, leaf area and total fresh leaf yield per plant in T_3 might be due to balanced nutrition, with biofertilizers and micronutrients role in various physiological processes, favorable nutrient interaction (Shilpashree and Subbarayappa, 2015) and changing the root morphology *via* producing plant growth promoting substances (Bashan *et al*., 2004).

Micronutrients often act as cofactors in enzyme activation and participate in redox reactions, photosynthesis and respiration besides play an essential role in carbohydrate metabolism and sugar translocation (Sinha *et al*., 2006). Better response of mulberry to application of micronutrients and biofertilizers on fresh leaf yield (218.369 g plant^{-1}) was also observed in T_3 as compared to other treatments which might be due to the micronutrients like Zn, Mn, Fe have aided in better uptake of nitrogen and indirectly helped in obtaining better yields. These results are in conformity with findings of Kasiviswanathan and Sitarama Iyengar (1968). Biofertilizers application increases the number of lateral roots and enhances root hair formation to provide more surface area to absorb sufficient nutrients (Mehdipour-Moghaddam *et al.* 2012). This improves the water status of the plant and aids the nutrient profile in the advancement of plant growth and development (Sarig *et al.,* 1992; Ilyas *et al.,* 2012).

Table 2. Effect of micronutrients and biofertilizers on growth and yield of silkworm

Treatments	Weight of matured larvae (g)	ERR by number	ERR by wt (g)	Single cocoon wt (g)	Single shell wt (g)	Shell ratio (%)	No. of cocoons (kg^{-1})
T_1	375.86	9013	15.663	1.65	0.359	21.60	601
T_2	441.08	9445	17.054	1.86	0.410	21.91	534
T_3	535.80	9807	20.319	1.99	0.499	24.93	500
T_4	520.34	9758	19.392	1.95	0.477	24.30	509
T_5	417.20	9065	15.885	1.70	0.373	21.71	581
T_6	501.91	9714	19.003	1.95	0.451	23.06	511
T_7	505.27	9707	18.719	1.94	0.464	23.75	512
T_8	441.03	9411	16.807	1.76	0.386	21.74	564
T_9	434.22	9323	16.825	1.75	0.385	21.78	566
T_{10}	498.41	9673	18.488	1.92	0.437	22.64	518
T_{11}	495.18	9641	18.849	1.90	0.424	22.18	523
T_{12}	482.53	9624	18.266	1.88	0.419	22.11	528
Mean	470.73	9515	17.939	1.86	0.424	22.64	537
SEd	16.17	302.91	0.576	0.059	0.014	0.724	16.893
CD (0.05%)	30.88	616.27	1.172	0.122	0.028	1.474	34.369

Similarly combined application also influenced the moisture retention status of mulberry leaves and this may be due to the influence of nutrients and biofertilizer, which had mediated the moisture availability in the soil rhizosphere, thereby maintaining normal growth, water uptake and other metabolism in plants and also due to water retention capacity of organic manures which steadily supply the moisture and there by moisture content in leaf and fresh leaf weight were increased. Similar findings were reported by Rashmi, (2005), Sunil (2005), Murali *et al.* (2006) and Shashidhar (2009) in S-36 and M-5 mulberry varieties.

Effect of micronutrients application on mulberry was witnessed even in the performance of silkworm. Combined application of micronutrients and biofertilizers resulted in better growth and yield performance of silkworm. Higher larval weight (535.80 g), effective rate of rearing (ERR) by number (9807), effective rate of rearing by weight (20.319 g), single cocoon weight (SCW) 1.99 g, single shell weight (SSW) 0.499 g and number of cocoon per kilogram (500) were obtained in T_3 (Table 2). Increased larval weight in combined application of organic manures and inorganic fertilizers can be attributed to superior leaf quality particularly crude protein and total soluble sugar content in mulberry leaves, which in turn made the larvae healthy which resulted in increased matured larval weight (Rajashekar and Patil, 1999; Ramarethinam and Krishna Chandra., 2007). Higher ERR is also attributed to the increased nitrogen, phosphorus and potassium contents due to the combined application of micronutrient with biofertilizers in the treated leaves. Quality of leaves would be superior, having good palatability, when fed to silkworms, grow healthy enough to give higher ERR with good quality cocoons (Shankar, 1990; Fathima *et al*. 1996); Philomena *et al.,* 2003). Better response could be attributed to better nutritive value of leaves resulting in better silkworm cocoon yield and quality (Vishwanth and Krishnamurthy, 1984; Sinha *et al*., 2006).

CONCLUSION

The present investigation revealed that the combined application of micronutrient and biofertilizers along with recommended dose of major nutrients increases the availability of the essential nutrients in the rhizosphere zone. Particularly, the biofertilizers maintain the availability of these nutrients by fixing from atmosphere, chelating and releasing from the clay minerals so as to avoid conversion to non available form resulted in increase in the growth and yield of mulberry. It is concluded that, treatment T_3 (100 % RDF + Soil application of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and $MgSO_4$ @ 25 kg ha^{-1} each + Recommended dose of biofertilizers (Azos, Phospho and Potash mobilizer) imposed plants performed better in growth parameters *viz*., plant height, number of branches, leaves, leaf area and leaf yield and yield parameters of silkworm such as ERR by number and weight, SCW, SSW, shell ratio (SR) and number of cocoons per kilogram.

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