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Research Article

EFFECT OF SOIL HEALTH, NUTRIENT MANAGEMENT AND SOIL TEST BASED DOSES OF LIME ON MULBERRY LEAF YIELD (*Morus alba* L.) IN ACID SOILS OF KALIMPONG HILLS

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Abstract- A field experiment was conducted at 10 farmers field in 05 villages namely Kharka Busty, Balukhap Makaldara, Makaldara, Khani and Dolapchand in Kalimpong Block-I, Darjeeling district, West Bengal, India with four treatments and four replications to study the effect of soil health, nutrient management and STBD of lime on mulberry leaf yield (*Morus alba L.*). The soils are moderately deep to very deep in depth; dark yellowish brown (10 YR 4/4) to brown (10 YR 5/4 and 6/4) in colour; sandy loam to sandy clay loam texture; single grain to fine, medium, subangular blocky structure and clear to gradual smooth and gradual wavy horizon boundary. The pH of the soil was quite low with medium to high organic carbon and available nitrogen. The availability of NPK and S was low to medium. While analyzing the leaf yield data, it was found that, the maximum leaf yield was ranged from 5.41 to 7.03 mt ha^{-1} after the application of RD of nutrients and STBD of dolomite (T_4) and minimum leaf yield range was 4.22 to 5.64 mt ha^{-1} with farmers existing practices (T_1) in spring season. The cumulative leaf yield of T_4 treatment was 20.87% higher over control. Likewise, in autumn season, maximum leaf yield was ranged from 4.49 to 5.91 mt ha^{-1} with T_4 and minimum leaf yield ranged from 4.00 to 4.48 mt ha^{-1} T_1 respectively. The cumulative leaf yield of T_4 treatment was 19.18% higher than control. While analyzing the total leaf yield per annum, the maximum leaf yield among the farmers field was ranged from 9.96 to 12.94 mt ha^{-1} in T_4 treatment followed by 9.68 to 12.35 mt ha^{-1} in T_3, and minimum 8.33 to 10.12 mt ha^{-1} in T_1 respectively. The total leaf of T_4 was 20.08% higher over control.

Keywords- Mulberry, Soil health, Nutrient Management, Acid soils, Lime

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Introduction

Mulberry sericulture is one of the oldest industries in India and probably dates back to the beginning of the Christian era [1]. Mulberry leaves are back bone of this industry, because, it is one of the important key factors for production and productivity of quality cocoon. Mulberry leaves are only the food for survival of mulberry silkworm (*Bombyx mori* L), hence, the quality mulberry leaves are directly correlates with healthy larval cycle and quality cocoon production. Productions of good quality of mulberry leaves depend on soil health, nature of mulberry varieties, integrated nutrient management, agronomic practices and environmental condition etc., among them, soil health, environmental condition and nutrient management have greater influence.

Like agriculture and allied sectors, sericulture is also an agro based industry to nurture the rural economy. There are several factors such as climatic condition, soil health, environmental factors and nutrient management etc. are a big challenge to ensure the productivity and profitability in sericulture. Out of these factors, soil health and nutrient management are most important and it cannot be ignored, because, the yield and quality of mulberry leaves are directly or indirectly affected by "how the soil is handled". Soil characteristics are key factor in this regard and it can be defined as the quality or capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation [2].

Kalimpong hills, an extension of sub-Himalayan region are sericulture hub and well known for production of bivoltine silkworm cocoon. Soils of this region have potential with high organic carbon content and available nitrogen, but, shallow to moderately deep soil depth, light textured soil, steep sloping, severe erosion, terrace farming, low temperature, heavy rainfall, leaching of bases, slow decomposition of soil organic matter, low nutrients uptake, rainfed cultivation and injudicious use of fertilizers leads 'active acidity' resulting these soils are known as problem soils.

Management of active soils acidity is highly desired for production and productivity of quality mulberry leaves, because, due to lack of proper corrective measures, active acidity leads aluminum, iron, manganese, zinc, copper and cobalt toxicity; adverse effect on microbial activity and decomposition of organic matter, increased deficiency of nitrogen, phosphorus, potash, sulphur, calcium, magnesium, boron and molybdenum which affects the physiological growth and yield of mulberry leaves. Management of acid soils through the application of different liming materials is a widely recognized practice to enhance crops productivity [3-5]. Among them, dolomite is one of the most popular, effective and easily available liming materials, hence, soils test based doses (STBD) of dolomite were applied with recommended doses (RD) of manures and fertilizers in four treatment plan to achieve the targeted yield and quality of mulberry leaves.

Materials and Methods

Experimental site and climate

The experiment was conducted at 10 farmers field in 05 villages namely Kharka Busty, Balukhap Makaldara, Makaldara, Khani and Dolapchand in Kalimpong Block-I, Darjeeling district, West Bengal, India lies between the latitude 26° 31' to 27° 13' N and longitude 87° 59' to 88° 53' E at 1076 m altitude above the mean sea level. It has semi-arid, subtropical (Sub-Himalayan region) hot dry summers and cold winters. The mean maximum temperature during the hottest months (March to June) in the year 2011-15 was about 27.7 °C, while the mean minimum temperature in the coldest months (December to February) in same years was as low as 9.9 °C. The mean annual temperature (maximum + minimum) was 21.2 °C. The mean annual rainfall was 1870.2 mm, four-fifth of which was received during June to September and remaining one-fifth during October to May.

Treatment Combination

The experiment was conducted for two years during 2014-16 at ten farmers' field from five villages stated above with four nutrients management practices, *viz*, T_1: Farmers existing practices (control); T_2: Farmers existing practices + STBD of lime; T_3: RD of FYM and Fertilizers; T_4: RD of FYM and Fertilizers + STBD of lime.

STBD of lime formula: To detect and deliver the STBD of lime, the following equation was used to calculate the STBD of $CaCO_3$ [6].

$$\text{STBD of } CaCO_3 \text{ (tons ha}^{-1}\text{ 10cm}^{-1}\text{)} = CEC \times (V_d - V_i) \times 0.5/100,$$

Where,

V_d = Desire of final base saturation of the soil;

V_i = Initial base saturation of the soil.

Nature of manures, fertilizers and dolomite applied

Integrated application of FYM, dolomite and mineral fertilizers were applied as per the treatment plan. Cow dung was the only source of FYM, whereas, the dolomite (CCE@109%) was applied as liming materials. Nitrogen was applied through urea (46% N), phosphorus through single superphosphate (18% P_2O_5) and potash through muriate of potash (60% K_2O). The treatments were distributed in a randomized complete block design (RCBD) with four replications in different terrace of fixed plot size.

Soil analysis

Soil samples were collected, dried, sieved and analyzed by adopting the standard procedure given in the various books [7-8]. Similarly, study of morphological characteristics and its interpretation was done as per the procedures of Soil Survey Manual and Soil Survey Staff [9-11].

Mulberry Varieties

The mulberry varieties like $BC_2$59, Kosen, KPG local, KPG-2 and Tr-10 etc. of *Morus alba* L. are successfully grown in the Kalimpong hills. Out of these, $BC_2$59 and Kosen varieties are most popular in this region. For this purpose, existing $BC_2$59 mulberry varieties was chosen at farmer's field No. 1, 8, 9 and 10 whereas, Kosen variety was chosen at farmers field No. 4. Likewise, the mixed plantation of KPG local and $BC_2$59 was chosen at farmer's field No. 2 3 and 7, whereas, KPG-2, was chosen at farmer's field No. 5 and 6 respectively.

Result and Discussion

Morpho-physical properties of soils

The soils of farmers' field from above villages of Kalimpong hills are developed over hill side slope due to translocation and deposition of weathered parent materials caused by severe soil erosions, heavy rainfall, steep to very steep slope and irregular small size terrace. Due to above reasons, soil depth throughout the experimental area also have irregular trends which ranged from shallow to very deep. Based on the soil profiles studied, the soils of the experimental area are moderately deep to very deep in depth; dark yellowish brown (10 YR 4/4) to brown (10 YR 5/4 and 6/4) in colour; sandy loam to sandy clay loam texture; single grain to fine, medium, subangular blocky structure; dry semi hard, moist very friable to friable, wet slightly sticky to sticky and wet slightly plastic consistency; very fine to fine, few to many pores and clear to gradual smooth to wavy horizon boundary. Sand, silt and clay percent in these areas ranged from 68-77%, 9-17% and 12-23% and classified as sandy loam to sandy clay loam. Morpho-physical properties of the soils of Kalimpong hills are given in [Table-1].

Table-1 *Morpho-physical properties of the soils*

Horizon	Depth (m)	Colour (moist)	Sand	Silt	Clay	Texture	Structure	------Consistence------			Boundary	Pores
			(%)					Dry	Moist	Wet		
Pedon 1: Kharka Busty												
Ap	0.00-0.20	10 YR 4/3 (m)	76	11	13	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.20-0.43	10 YR 6/4 (m)	77	9	14	Sl	gr-1-f				-	c-vf-f
Ac	0.43+	Weathered parent materials of rocks										
Pedon 2: Bhalukhop Makaldhara												
Ap	0.00-0.15	10 YR 6/4 (m)	73	10	17	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.15-0.37	10 YR 5/4 (m)	71	11	18	Sl	sbk-1-f	dsh	mvfr	wss wps	cw	c-vf-f
B11	0.37-0.65	10 YR 5/4 (m)	68	12	20	Scl	sbk-1-f	dsh	mfr	ws wp	gs	c-vf-f
B12	0.65-1.10	10 YR 5/4 (m)	70	10	20	Scl	sbk-1-f	dsh	mfr	ws wp	-	c-vf-f
Pedon 3: Makaldhara												
Ap	0.00-0.18	10 YR 4/4 (m)	69	11	20	Scl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.18-0.47	10 YR 4/4 (m)	68	10	22	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B11	0.47-0.69	10 YR 4/4 (m)	68	9	23	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B12	0.69-1.05	10 YR 4/4 (m)	70	9	21	Scl	sbk-1-m	dsh	mfr	ws wp	-	c-vf-f
Pedon 4: Khani												
Ap	0.00-0.12	10 YR 4/6 (m)	68	17	15	Sl	gr-1-f	dvs	mvfr	wss wps	cs	c-vf-f
A12	0.12-0.33	10 YR 4/5 (m)	71	15	14	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
B12	0.33-0.55	10 YR 4/5 (m)	70	15	15	Sl	sbk-1-m	dsh	mvfr	wss wps	-	c-vf-f
Ac	0.55+	Weathered parent materials of rocks										
Pedon 5: Khani												
Ap	0.00-0.12	10 YR 5/4 (m)	76	11	13	Sl	sbk-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.12-0.35	10 YR 4/4 (m)	77	11	12	Sl	sbk-1-m	dsh	mvfr	wss wps	cs	c-vf-f
B11	0.35-0.70	10 YR 4/4 (m)	75	9	16	Sl	sbk-1-m	dh	mfr	ws wp	gs	c-vf-f
B12	0.70-1.10	10 YR 4/4 (m)	74	11	15	Sl	sbk-1-m	dh	mfr	ws wp	-	c-vf-f

While studying the morpho-physical properties of the soils of experimental site, it was found that, there was no much morpho-physical variation other than soil depth. The variation of colour was due to prevalence of well drained conditions, admixture of organic matter [12-14], whereas the variation in soil depth was due to nature of terrace, rocky phase, sloppy land developed on hill side and soil erosion etc. The light texture was due to sandstone, quartzite and other light textured secondary rocks acted as parent material for the formation of this soil. Poor soil structure and low consistency was due to light soil texture [12, 14,15].

Chemical properties of soils

While analyzing the data, it was found that, the chemical properties of the soils of experimental area are highly variable. The terrace wise variation of nutrient availability within the same research plot was also recorded. Based on the mean data, it was found that, the pH of the soil under this study was quite low and grouped under 'moderate active acidity'. Unlike pH, the organic carbon and available nitrogen content of the soils was medium to high. The availability of phosphorus, potash and sulphur was low to medium; however, the STBD of lime was variable. The chemical properties of the soils are given in [Table-2].

Table-2 *Chemical properties of soils*

Village Name	pH (1:2.5)	EC (dSm^{-1})	Organic C (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulphur (kg ha^{-1})	*LR (mt ha^{-1})
Kharka Busty	6.08-6.67	0.07-0.34	1.29-2.49	587.1-700.0	20.2-26.0	123.2-257.6	6.7-13.4	
Bhalukhop Makaldhara	6.23-6.73	0.06-0.16	1.74-2.19	617.2-730.1	17.9-26.0	123.2-302.4	6.7-21.3	0.60
Makaldhara	5.40-6.34	0.05-0.13	0.90-1.29	474.2-579.5	15.7-19.0	369.6-425.6	6.7-12.3	0.55
Khani	5.90-6.00	0.10-0.12	0.21-0.39	316.1-376.3	12.3-15.7	179.2-224.0	14.6-16.8	1.40
Dolapchand	5.53-5.93	0.07-0.09	1.50-1.89	579.5-677.4	17.9-20.2	224.0-347.2	6.7-14.6	1.35

*Lime requirement (LR) mean @ 60% base saturation.

The low soil pH might be due light texture, steep sloping, severe erosion, terrace farming, nature of parent material, heavy rainfall and leaching of bases, whereas, high organic carbon and nitrogen content was due to low temperature, forest leaf litter, application of FYM and other alternative organic manures. The low availability of phosphorus and sulphur was affected by soil pH whereas lower potash availability was due to Kaolin (1:1 type) group of minerals.

Various workers from the different part of the country have reported that the leaching of bases, intensive weathering and sloping landforms was major factors in the variation of soil pH [12, 16-18]. Brady and Weil [19] defined the soil organic matter as the summation of decomposed plant and animal residues. Albrecht *et al*. [20] stated that, the soil pH, agronomic practices and application of organic manures enriched the soil organic carbon in soil, whereas, other workers have also reported that the organic matter enriched in the Tea garden soil by the combined application of organic manures in Darjeeling hills [21-22].

Maurya *et al*. [23] and Banerjee *et al*. [24] have also reported that the fertility status of soils of Darjeeling and Kalimpong hills are highly variable. Both the researchers opined that the soils of this area are highly acidic with high organic carbon and available nitrogen, and low to medium phosphorus and potash respectively. Liming is an effective and dominant practice to raise soil pH and reduce acidity related constraints to improve crop yields, however, the quantity of lime required depends on the soil type, quality of liming material, costs and crop species or cultivars [5]. Patiram [25] also reported that the furrow application of small doses of limestone every year achieved optimum productivity than a relatively higher dose once in three to four years.

Effect of soil health, nutrient management and STBD of lime on leaf yield of different mulberry varieties

Based on the data analyzed, it was found that, the integrated effect of FYM, fertilizers and STBD of lime were increased the mulberry leaf yield significantly among all farmers' field throughout the year. It was also observed that, the total leaf yield among the farmers field was not uniform and it was varied from one farmer's field to another farmer's field. The variation in leaf yield among the farmers' field was highly affected by soil depth; pH, nutrient use efficiency, neutralizing capacity of dolomite and mulberry varieties etc. While analyzing the effect of mulberry varieties on its leaf yield, it was found that, the $BC_2$59 and Kosen performed better than other varieties, but, the effect of nutrient management and STBD of lime was significant to achieve higher leaf yield.

Effect of soil health, nutrient management and STBD of lime on Mulberry leaf yield

While analyzing the leaf yield data in spring season, it was found that, the maximum leaf yield was recorded in T_4 treatment followed by T_3 and minimum in T_1. The maximum leaf yield 5.41 to 7.03 mt ha^{-1} was recorded after the application of RD of nutrients and STBD of dolomite (T_4) and minimum 4.22 to 5.64 mt ha^{-1} was recorded with farmers existing practices (T_1). The cumulative leaf yield of T_4 treatment was 20.87% higher followed by 15.34% higher with T_3 over control. The effect of nutrient management and STBD of lime on mulberry leaf yield in spring season is given in [Table-3].

Table-3 *Effect of soil health, nutrient management and STBD of lime on mulberry leaf yield in spring season*

Treatment	Farmers field wise mulberry leaf yield mt ha^{-1}										Mean (mt/ha)	Leaf Yield gain (%)
	Kharka Busty		Bhalukhop		Mahakaldara		Khani		Dolapchand			
	1	2	3	4	5	6	7	8	9	10		
T_1	4.98	4.75	5.02	4.63	5.64	4.22	4.68	5.09	4.56	4.75	4.83	0.00
T_2	4.99	5.10	5.26	5.00	5.72	4.61	5.04	5.31	5.07	5.07	5.12	5.90
T_3	5.38	5.33	6.25	5.56	6.73	5.03	5.38	5.52	5.34	5.24	5.57	15.34
T_4	5.41	5.89	6.47	5.66	7.03	5.47	5.61	5.76	5.59	5.52	5.84	20.87
SEm(±)	0.035	0.029	0.013	0.034	0.028	0.046	0.040	0.043	0.154	0.028	0.045	-
CD (P= 0.05%)	0.163	0.140	0.193	0.214	0.305	0.269	0.214	0.141	0.024	0.222	0.188	-
CV (%)	0.017	0.014	0.035	0.017	0.014	0.023	0.020	0.021	0.024	0.014	0.020	-

The leaf yield in autumn season was slightly lower than spring season. Maximum leaf yield 4.49 to 5.91 mt ha^{-1} was recorded after the application of RD of nutrients and STBD of dolomite (T_4) and minimum 4.00 to 4.48 mt ha^{-1} was recorded with farmers existing practices (T_1). The cumulative leaf yield of T_4 treatment was 19.18% higher followed by 13.92% higher with T_3 over control. The effect of nutrient management and STBD of lime on mulberry leaf yield in autumn season is given in [Table-4].

While analyzing the total leaf yield per annum, the maximum leaf yield mean of all the farmers' field ranged from 9.96 to 12.94 mt ha^{-1} in T_4 treatment followed by 9.68 to 12.35 mt ha^{-1} in T_3, and minimum 8.33 to 10.012 mt ha^{-1} in T_1 respectively. The total leaf of T_4 was 20.08% higher over control. Effect of soils health, nutrient management and STBD of lime on total mulberry leaf yield per year in [Table-5].

Table-4 *Effect of soil health, nutrient management and STBD of lime on mulberry leaf yield in spring season*

Treatment	Farmers field wise mulberry leaf yield mt ha^{-1}										Mean	Leaf Yield gain (%)
	Kharka Busty		Bhalukhop		Mahakaldara		Khani		Dolapchand			
	1	2	3	4	5	6	7	8	9	10		
T_1	4.25	4.19	4.42	4.04	4.48	4.11	4.08	4.32	4.00	4.10	4.20	0
T_2	4.47	4.46	4.57	4.25	4.35	4.23	4.33	4.55	4.32	4.34	4.39	4.48
T_3	4.64	4.65	5.24	4.87	5.62	4.39	4.69	4.81	4.49	4.45	4.78	13.92
T_4	4.87	5.21	5.53	5.03	5.91	4.49	4.96	4.90	4.57	4.57	5.00	19.18
SEm(±)	0.020	0.013	0.029	0.023	0.051	0.075	0.038	0.034	0.055	0.055	0.039	-
CD (P= 0.05%)	0.131	0.107	0.244	0.210	0.150	0.110	0.199	0.164	0.181	0.124	0.162	-
CV (%)	0.010	0.006	0.014	0.012	0.026	0.037	0.019	0.017	0.032	0.027	0.020	-

Table-5 *Effect of soils health, nutrient management and STBD of lime on total mulberry leaf yield per year*

Treatment	Farmers field wise mulberry leaf yield mt ha^{-1}										Mean	Leaf Yield gain (%)
	Kharka Busty		Bhalukhop		Mahakaldara		Khani		Dolapchand			
	1	2	3	4	5	6	7	8	9	10		
T_1	9.23	8.94	9.44	8.67	10.12	8.33	8.76	9.41	8.56	8.86	9.03	0.00
T_2	9.46	9.56	9.83	9.25	10.07	8.84	9.37	9.86	9.39	9.42	9.50	5.24
T_3	10.02	9.98	11.48	10.43	12.35	9.42	10.07	10.32	9.83	9.68	10.36	14.68
T_4	10.29	11.10	12.00	10.69	12.94	9.96	10.57	10.66	10.15	10.09	10.84	20.08
SEm(±)	0.035	0.039	0.045	0.053	0.069	0.108	0.078	0.069	0.087	0.081	0.066	-
CD (P= 0.05%)	0.209	0.223	0.272	0.421	0.373	0.328	0.280	0.280	0.249	0.277	0.291	-
CV (%)	0.017	0.020	0.023	0.035	0.035	0.054	0.035	0.035	0.043	0.040	0.034	-

The production and productivity of quality mulberry leave depends on 'how soil is managed', however, the modern concept of soil health management is to apply the plant nutrients in an integrated manner to achieve the targeted yield with maintaining soil health at benchmark level. In this regard, application of organic manures is well known to maintain the fertility status of soil to achieve the desired yield. Several workers have conducted the research in this regard. Umesha and Sannappa [26] reported that, INM of FYM with other organic manures enhanced the bio-chemical and mineral nutrients of mulberry leaves. Similar findings have also been reported by various workers [27-28].

In case of acid soils, amelioration of this type of soil is highly desired for production and productivity of quality mulberry leaves. Management of acid soils through the application of different liming materials to enhance crops productivity was reported by Mesic [3]. Application of liming materials improves the soil health and crop productivity have also been reported by various workers [[29-34].

Conclusion

It has been concluded that, the mulberry leaf yield among all the farmers' field stated above was significantly higher over the control after the application of STBD of lime with RD of manures and fertilizers. It was also concluded that, the total leaf yield among the farmers field varied from one farmer's field to another and the variation in leaf yield among the farmers' field was highly affected by soil depth; pH and mulberry varieties.

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Author Contributions

R.L. Ram (Principal Investigator); S. Chatterjee (Co-Investigator); C. Maji (Co-ordinator); P.K. Sharma (Additional support); Priyanka Rani (Additional support).

Abbreviations

STBD= Soil test based doses of lime; RD= Recommended doses; FYM= Farm yard manures; Sl= Sandy loam; Scl= Sandy clay loam; gr= granular; sbk= Sub angular blocky; dsh= dry semi hard; dh= dry hard; mfr= moist friable; mvfr= moist very friable; ws wp= wet sticky and wet plastic; wss wps= wet slightly sticky and wet slightly plastic; cs= clear smooth; gs= gradual smooth; cw= clear wavy; c-vf-f= common, very fine to fine.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of Interest: None declared

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