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# A Comprehensive Review on Mulberry Sericulture in Kalimpong Hills

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**A B S T R A C T**

A field experiment was conducted during 2011–16 in different locations in Kalimpong hills, West Bengal to study the integrated effect different organic manures with FYM on growth attribute characters existing mulberry variety $BC_259$ (*Morus alba* L.). This experiment was also extended to check its effect on performance of SK6×SK7 (*Bombyx mori* L.) silkworm. Based on data compiled, it was found that, individually, the organic manures like potassium humate (KH), pressmud and mixed oil cake with FYM performed significantly higher on yield and nutritional quality of mulberry leaves than FYM alone. Effect of above organic manures was also found significant result on single cocoon weight, cocoon yield 100 $dfls^{-1}$ and shell% respectively. Due to higher leaf yield, the higher cost benefit ratio was higher with mixed oil cake than other organic manures including FYM.

## Introduction

Sericulture is one of the oldest agro based industry in India and probably dates back to the beginning of the Christian era (Purusothaman *et al.*, 2012). Mulberry is the backbone of sericulture industry, because, both economically and traditionally it is a very important plant for the development of this industry. Mulberry leaves are basic food material for silkworm *Bombyx mori* L. (Ravikumar, 1988) and nutritional quality of mulberry leaves supplied as food have great influence on silkworm growth and cocoon yield (ESCAP, 1993). Besides, feeding of good quality mulberry leaves to silkworm larvae results lower mortality of silkworm (FAO, 1990).

Mulberry plants belongs to the family *Moraceae* and are successfully grown under varied climate ranging from warm temperate and subtropical regions of Asia, Africa, Europe and United State of America with the majority of the species native to east and south Asia. Mulberry species successfully grown across the world are *Morus atropurpurea*, *Morus bombycis*, *Morus cathayana*, *Morus indica*, *Morus japonica*, *Morus kagayamae*, *Morus laevigata*, *Morus latifolia*, *Morus liboensis*, *Morus macroura*, *Morus mongolica*, *Morus multicaulis*, *Morus notabilis*, *Morus rotundiloba*, *Morus serrata*, *Morus tillaefolia*, *Morus trilobata and Morus wittiorum* etc. The mulberry species like *Morus alba*, *Morus indica*, *Morus bombycis*, *Morus sinensis* and

*Morus multicaulis etc.* are very important and successfully grown in India, however, the mulberry variety *Morus alba* L. is successfully grown in Kalimpong hills.

## General description of the area

Kalimpong hills, an extension of sub-Himalayan region have great influence on Indian sericulture industry, because, it is a sericulture hub and well known for production of bivoltine silkworm seed cocoon. The Kallimpong hills lies between 26° 31' to 27° 13' N latitude and 87° 59' to 88° 53' E longitude and situated at 3550 feet (1076 m) above mean sea level. Besides, Kalimpong hills also have its own identity as 'silk route of India'. Geographically, this hill is situated on a ridge connecting two hills namely Deolo hill and Durpin hill, where, Deolo is the highest point of this region. Sandstone, quartzite and mica are the major geologic formation in this area which acts as parent materials for the formation of the soil. River Teesta and its tributaries are main water bodies.

The climate is subtropical type (Sub-Himalayan region) with 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 $^{o}$C, while the mean minimum temperature in the coldest months (December to February) in same years was as low as 9.9 $^{o}$C. The mean annual temperature was 21.2 $^{o}$C. The onset period of monsoon was in the second week of June.

The mean annual rainfall was 1870.2 mm, four-fifth of which was received during June to September and remaining one-fifth in October to May. The meteorological data of this region are given in Table 1 whereas; the geographic location, temperature curve and obmrothermic diagram are given in fig.1, fig. 2 and fig. 3 respectively.

## Treatment combination

There was four experiments were conducted in different locations in Kalimpong hills from 2011-16. Recommendations of each experiment were reviewed and compiled for ready reference. The treatment chosen for this review article was $T_1$: FYM @ 10 mt ha$^{-1}$; $T_2$: FYM @ 10 mt ha$^{-1}$ +KH @ 25 kg ha$^{-1}$; $T_3$: FYM @ 20 mt ha$^{-1}$+KH @ 25 kg ha$^{-1}$; $T_4$: Treated pressmud @2 mt ha$^{-1}$ + FYM @ 5 mt ha$^{-1}$; $T_5$: Mixed cake@1.5 mt ha$^{-1}$ + FYM@5 mt ha$^{-1}$ respectively. Except $T_3$, NPK@150:50:50 kg ha$^{-1}$ uniformly applied in all the treatment.

## Mulberry *and Silkworm varieties*

The experiment was conducted in the existing $BC_2$59 (*Morus Alba* L.) mulberry variety. The plantation was about 15-25 years old. The variety was developed by back cross technique by earlier researchers and it is most suitable under the climatic conditions of the Kalimpong hills. The branches of this variety are semi-erect, medium in number, with moderate growth, whereas, the leaves are smooth, unlobed, glossy and thick (Dandin and Giridhar, 2010). Silkworm rearing was conducted only at RSRS farm and bivoltine mulberry silkworm races SK6×SK7 (*Bombyx mori.* L.) was chosen for this purpose.

## Nature of manures and fertilizers applied

Integrated application FYM, KH, pressmud, mixed cake and mineral fertilizers were applied in different treatment plan. Cow dung was the only source of FYM, whereas, KH, a byproduct of lignite coal with 85%–90% water solubility containing around 80% humic acid and 12%–15% potassium was applied. Bhusudha' a processed pressmud through the process of sulphatation was applied as an alternative of FYM. The chemical composition of the Bhusudha is as under: pH –

7.8; organic carbon 35.5%; Nitrogen – 1.8%; Phosphorus – 1.4% and Potash – 1.0% respectively. Likewise, 'Spic Surabhi' was the source of mixed cake. The main ingredient in Spic Surabhi was oil seed cake of Neem, Groundnut, Castor and Sesame with Turmeric powder and Pungamia extracts. These oil cakes were fortified well together in a well-balanced mixed with NPK. The chemical composition of the mixed cake was as under: moisture content 9.2%; pH – 5.5; Electrical Conductivity (dSm-1) – 0.34; organic carbon – 26.5%; Nitrogen –2.45%; Phosphorus – 0.96% ; Potash – 1.0% and C:N ratio – 10:81.1 respectively. Nitrogen was applied through urea (46% N), phosphorus through single superphosphate (18% $P_2O_5$), and potash through muriate of potash (60% $K_2O$).

## Soil *and plant analysis*

Soil samples were collected, dried, sieved and analyzed by adopting the standard procedure (Black, 1985; Jackson, 1979). The processed soil samples were analyzed by following the standard procedures e.g. soil pH (1:2.5 soil: water suspension); easily oxidizable $K_2Cr_2O^7+H_2SO^4$ organic C (Walkley and Black, 1934); alkaline $KMNO_4$ oxidizable N (Subbiah and Asija, 1956); 0.025 N HCl+0.03 N NH4F extractable P (Bray and Kurtz, 1945) and available K (1N NH4OAc exchangeable K) respectively. Likewise, processed mulberry leaves were analyzed by following the standard procedure e.g. leaf moisture (Hot oven drying method), total chlorophyll (Arnon, 1949); total soluble protein (Lowry *et al.*, 1951); and total soluble sugar (Morris, 1948) respectively.

## Morpho-physical properties of the soils

Based on the soil profiles studied, the soils of Kalimpong hills are shallow 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. Morpho-physical characteristics of the soils of Kalimpong hills are given in Table 2.

## Chemical characteristics of soils

The soils samples were collected from 10 different locations and analyzed for pH and major nutrients availability. Based on terrace wise soil samples analyzed, the pH of the soils was recorded as moderately acidic whereas the organic carbon and available N was moderately low to sufficient. Apart from these two nutrients, available P, K and S were also recorded moderately deficient. The nutrient availability throughout the hills was highly variable. The variation in nutrient availability was due to moderately steep to steep sloping and small size of terraced plots. Location wise chemical characteristics mean of Kalimpong hills are given in Table 3.

## *Clay mineralogy of the soils based on X-ray diffraction analysis*

Ram *et al.*, (2018) reported that, the soils of the Kalimpong hills are mostly dominated by the silicate clay minerals like kaolinite, dickite and nacrite, (1:1 lattice type), saponite, vermiculite and smectite (smectite group 2:1 expanding type), mica and muscovite (Mica group 2:1 non-expanding type), chlorite (2:1:1 or 2:2 type) and talc etc. However, mica and kaolinite are the most dominant clay minerals in these soils than others. Similar findings were also reported by various Indian workers (Ghosh, 1964; Ghosh and Datta, 1974). While studying the mineralogy of sand silt and clay fraction of a pedon of soils of Darjeeling Himalayan region, Sahu and Ghosh, (1982) reported that the mica, kaolinite, gibbsite, chlorite and vermiculite was the dominating clay minerals in the Kalimpong hills.

### *Soil Classification*

Based on morpho-physico-chemical properties and meteorological data, soils of Kalimpong hills have been classified as Coarse loamy, mixed, Thermic, Typic Udarthents. It is may be due to soil depth, gravelliness and absence of diagnostic horizons other than ochric epipedon (Soil Survey Staff, 1998). Relief and time are the limiting soil forming factors for soil texture, depth and poor soil health. Likewise, soils of this area under wide flat terraces have ochric epipedon and cambic diagnostic sub-surface horizon and hence, grouped in order Inceptisols. Owing to 'udic' moisture regime, 'thermic' temperature regime, absence of duripan, calcic/petrocalcic horizon within 100 cm from the mineral soil surface and less than 35% clay content, these soils grouped under 'Coarse loamy, Mixed, Thermic, Typic Hapludepts at family level.

### Exchangeable bases and lime requirements (LR) of soils

Ram *et al.,* (2015) reported that, the lower range of exchangeable bases in the soils of Kalimpong hills is responsible for soil acidity. He also reported that, the Exchangeable bases like Ca, ranged from 1.7 to 4.0 cmol $(p^+)$ $kg^{-1}$, Mg ranged from 0.8 to 2.8 cmol $(p^+)$ $kg^{-1}$, Na ranged from 0.7 to 1.8 cmol $(p^+)$ $kg^{-1}$ and K ranged from 0.38 to 0.72 cmol $(p^+)$ $kg^{-1}$ respectively. According to Ram *et al.,* (2015), the cation exchange capacity in this area varied from 9.2 to 15.4 cmol $(p^+)$ $kg^{-1}$, whereas, the exchangeable sodium percent (ESP) and base saturation (BS) ranged from 9.2 to 13.2% and 46.6 to 58.3% respectively. While calculating the doses of LR based on the base saturation method for reclamation of soil, the lime ($CaCO_3$) requirement (LR) in this area varied from 0.55 to 2.34 mt $ha^{-1}$ to raise the base saturation level to 60% from the initial base saturation level. Patiram (1994) also reported the similar findings. Exchangeable bases and lime requirement in soils are given in Table 4.

### *Integrated effects of organic manures and FYM on season wise growth attribute characters and leaf yield of mulberry*

While working on integrated effect of organic manures and FYM on season wise growth attribute characters and leaf yield of mulberry, Ram *et al.,* (2016; 2017a; 2017b; 2018) found that, test based doses of lime, treated pressmud, potassium humate and mixed edible oil cake with reduced recommended doses of FYM found more effective on season wise growth attribute characters, leaf yield and nutritional quality of mulberry than FYM alone. While comparing the effect among the organic manures, it was found that, the higher leaf yield per annum was recorded with the application of mixed cake followed by potassium humate. Performance of pressmud was also equally better. The maximum annual leaf yield 16.49 mt $ha^{-1}$ was recorded with treatment combination $T_5$ followed by 14.97 mt $ha^{-1}$ with $T_2$ and minimum 12.00 mt $ha^{-1}$ with $T_1$ respectively. The total leaf yield was 37.42% higher with treatment combination $T_5$ followed by 24.75% with $T_2$ over $T_1$ as control. Integrated effects of organic manures and FYM on season wise growth attribute characters and leaf yield of mulberry are given in Table 5.

Due to shortage of FYM and lack of its timely application, and to sustain the desired quality mulberry leaves, it is necessary to think for effective and easily available alternative of FYM, hence, different organic manures were chosen and tested as an alternative of FYM.

**Table.1** Meteorological data of Kalimpong (2011-15)

| Month | Max. (°C) | Min. (°C) | Mean (°C) | Rainfall (mm) |
|---|---|---|---|---|
| January | 20.0 | 8.6 | 14.3 | 4.9 |
| February | 22.6 | 11.0 | 16.8 | 16.9 |
| March | 25.7 | 14.1 | 19.9 | 43.2 |
| April | 27.4 | 16.0 | 21.7 | 85.9 |
| May | 28.9 | 18.8 | 23.8 | 132.5 |
| June | 29.0 | 21.1 | 25.1 | 372.8 |
| July | 28.9 | 21.2 | 25.0 | 480.2 |
| August | 29.2 | 21.1 | 25.1 | 393.5 |
| September | 28.9 | 20.4 | 24.7 | 297.8 |
| October | 27.4 | 17.1 | 22.3 | 38.8 |
| November | 25.2 | 13.1 | 19.2 | 2.6 |
| December | 21.9 | 10.2 | 16.0 | 1.1 |

(Source: RSRS, Kalimpong)

**Table.2** Morpho-physical characteristics of the soils

| Horizon | Depth (m) | Colour (moist) | Sand | Silt | Clay | Texture | Structure | ------Consistence------ | | | Boundary | Pores |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | | | | | Dry | Moist | Wet | | |
| **Pedon 1: RSRS, Kalimpong farm** | | | | | | | | | | | | |
| Ap | 0.00-0.15 | 10 YR 5/4 (m) | 73 | 10 | 17 | Sl | sbk-1-f | dsh | mvfr | wss wps | cs | c-vf-f |
| A11 | 0.15-0.42 | 10 YR 4/4 (m) | 70 | 12 | 18 | Sl | sbk-1-m | dsh | mfr | wss wps | cs | c-vf-f |
| B11 | 0.42-0.70 | 10 YR 4/4 (m) | 66 | 14 | 20 | Scl | sbk-1-m | dh | mfr | ws wp | gs | c-vf-f |
| B12 | 0.70-1.10 | 10 YR 4/4 (m) | 64 | 16 | 20 | Scl | sbk-1-m | dh | mfr | ws wp | - | c-vf-f |
| **Pedon 2: RSRSA, Kalimpong farm** | | | | | | | | | | | | |
| Ap | 0.00-0.12 | 10 YR 5/4 (m) | 73 | 11 | 16 | Sl | sbk-1-f | dsh | mfr | wss wps | cs | c-vf-f |
| A11 | 0.12-0.39 | 10 YR 4/4 (m) | 66 | 18 | 16 | Sl | sbk-1-m | dsh | mfr | wss wps | gs | c-vf-f |
| B11 | 0.39-0.86 | 10 YR 4/4 (m) | 66 | 14 | 20 | Scl | sbk-1-m | dsh | mfr | wss wps | - | c-vf-f |
| Bc | 0.86+ | Weathered parent materials of rocks | | | | | | | | | | |
| **Pedon 3: 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 4: Bhalukhop** | | | | | | | | | | | | |
| 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 5: 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 |

(Source: Ram *et al.*, 2015)

**Table.3** *Chemical characteristics of soils*

| Village Name | pH (1:2.5) | EC (dSm) | Organic C (%) | Nitrogen (kg $ha^{-1}$) | Phosphorus (kg $ha^{-1}$) | Potassium (kg $ha^{-1}$) | Sulphur (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| RSRS, Farm | 6.01 | 0.15 | 1.77 | 586.42 | 17.86 | 183.63 | 15.31 |
| RSRSA, Farm | 4.95 | 0.10 | 1.32 | 474.1 | 14.4 | 164.7 | 9.6 |
| Kharka Busty | 6.31 | 0.18 | 1.94 | 643.5 | 23.5 | 210.0 | 10.4 |
| Bhalukhop | 6.53 | 0.11 | 1.92 | 675.1 | 21.3 | 252.0 | 13.6 |
| Makaldhara | 5.88 | 0.09 | 1.53 | 562.6 | 16.9 | 333.2 | 10.7 |
| Khani | 5.90 | 0.10 | 0.80 | 432.8 | 15.0 | 280.0 | 12.0 |
| Gitdabling | 5.70 | 0.10 | 1.50 | 617.8 | 17.9 | 294.0 | 12.7 |
| Saurani | 5.90 | 0.20 | 1.80 | 590.9 | 23.1 | 372.4 | 14.9 |
| Dolapchand | 5.90 | 0.20 | 1.30 | 532.5 | 21.3 | 319.2 | 12.6 |
| Sangsay | 5.80 | 0.16 | 1.60 | 668.6 | 17.2 | 215.6 | 15.4 |

(Source: Ram *et al.*, 2015)

**Table.4** Exchangeable bases and lime requirement in soils

| Village Name | Exchangeable bases mean [cmol (p+) $kg^{-1}$] | | | | | | ESP (%) | BS (%) | LR (mt $ha^{-1}$) @ 60% BS |
|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | CEC | | | |
| RSRS, Farm | 3.6 | 2.1 | 1.3 | 0.50 | 7.50 | 13.6 | 9.4 | 54.8 | 1.50 |
| RSRSA Farm | 1.7 | 0.9 | 0.7 | 0.40 | 3.74 | 8.02 | 9.2 | 46.6 | 2.34 |
| Kharka Busty | 4.0 | 2.8 | 1.8 | 0.38 | 8.98 | 15.4 | 11.6 | 58.3 | 0.60 |
| Bhalukhop | 3.1 | 2.5 | 1.8 | 0.51 | 7.91 | 13.6 | 13.2 | 58.2 | 0.55 |
| Makaldhara | 2.6 | 0.8 | 1.3 | 0.65 | 5.35 | 10.0 | 13.0 | 53.5 | 1.40 |
| Khani | 2.5 | 1.0 | 0.9 | 0.48 | 4.88 | 9.20 | 9.30 | 53.1 | 1.35 |
| Gitdabling | 3.4 | 1.5 | 1.3 | 0.52 | 6.72 | 12.2 | 10.1 | 55.1 | 1.30 |
| Saurani | 2.1 | 1.7 | 1.2 | 0.72 | 5.72 | 10.6 | 11.3 | 54.0 | 1.45 |
| Dolapchand | 2.5 | 1.9 | 1.3 | 0.57 | 6.27 | 11.4 | 11.0 | 55.0 | 1.25 |
| Sangsay | 3.3 | 2.0 | 1.4 | 0.41 | 7.11 | 12.9 | 11.0 | 55.1 | 1.40 |

(Source: Ram *et al.*, 2015)

**Table.5** *Integrated effects of organic manures and FYM on season wise growth attribute characters and leaf yield of mulberry*

| Treatment | Total shoots $plant^{-1}$ $year^{-1}$ | Total length of shoots $plant^{-1}$ $year^{-1}$ (cm) | Total leaves two $shoots^{-1}$ $year^{-1}$ | Total leaves $plant^{-1}$ $year^{-1}$ | Total Leaf yield $year^{-1}$ (mt $ha^{-1}$) | Total Leaf Yield gain (%) |
|---|---|---|---|---|---|---|
| $T_{1\ FYM}$ | 21.00 | 196.45 | 17.8 | 373.99 | 12.00 | 0.00 |
| $T_{2\ KH}$ | 21.05 | 222.23 | 21.38 | 450.50 | 14.97 | 24.75 |
| $T_{3\ KHO}$ | 21.50 | 213.76 | 20.28 | 436.49 | 14.17 | 18.08 |
| $T_4$ PM | 21.63 | 219.50 | 21.13 | 457.22 | 14.71 | 22.58 |
| $T_{5\ MC}$ | 23.87 | 118.3 | 22.93 | 547.07 | 16.49 | 37.42 |
| CD ($p$=0.05) | 0.95 | 3.97 | 0.84 | 21.67 | 0.63 | 5.82 |

**(Source: Ram *et al.*, 2017a; 2017b; 2018)**

**Table.6 Effect of organic manures and FYM on nutritious quality of mulberry leaves**

| Treatment | Moisture (%) | Fresh weight (mg g$^{-1}$) | | | Dry Weight (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total Chlorophyll | Total Soluble Protein | Total Soluble Sugar | Total carbon (%) | Total ash (%) | Total Nitrogen | Crude Protein | Total Phosphorus |
| $T_{1\ FYM}$ | 74.79 | 1.29 | 19.88 | 30.09 | 43.29 | 13.43 | 3.11 | 19.43 | 0.26 |
| $T_{2\ KH}$ | 76.78 | 1.77 | 24.78 | 36.23 | 43.77 | 12.46 | 3.58 | 22.40 | 0.35 |
| $T_{3\ KHO}$ | 76.84 | 1.67 | 25.78 | 34.85 | 44.03 | 11.94 | 3.44 | 21.53 | 0.35 |
| $T_{4\ PM}$ | 75.67 | 1.63 | 23.30 | 34.34 | 43.68 | 12.65 | 3.33 | 20.78 | 0.33 |
| $T_{5\ MC}$ | 75.66 | 1.63 | 25.64 | 34.37 | - | - | 3.41 | 21.30 | 0.32 |

**(Source: Ram *et al.*, 2017a; 2017b; 2018)**

**Table.7** Effect of organic manures and FYM on season wise performance of silkworm rearing

| Treatment | Weight (g) | Yield 10000 larvae$^{-1}$ | | Yield (kg) | Weight (g) | | Shell (%) |
|---|---|---|---|---|---|---|---|
| | Ten matured larvae | ERR (Number) | ERR (Weight) | 100 dfls | Single Cocoon | Single Shell | |
| $T_{1FYM}$ | 39.52 | 8688 | 14.99 | 59.95 | 1.73 | 0.297 | 17.36 |
| $T_{2KH}$ | 40.03 | 8892 | 15.62 | 62.47 | 1.76 | 0.319 | 18.19 |
| T3$_{KHO}$ | 39.76 | 8688 | 15.09 | 60.36 | 1.78 | 0.307 | 17.76 |
| $T_{4PM}$ | 40.05 | 8762 | 15.1 | 60.4 | 1.76 | 0.318 | 18.05 |
| $T_{5MC}$ | 40.10 | 8916 | 15.4 | 61.3 | 1.72 | 0.310 | 18.00 |

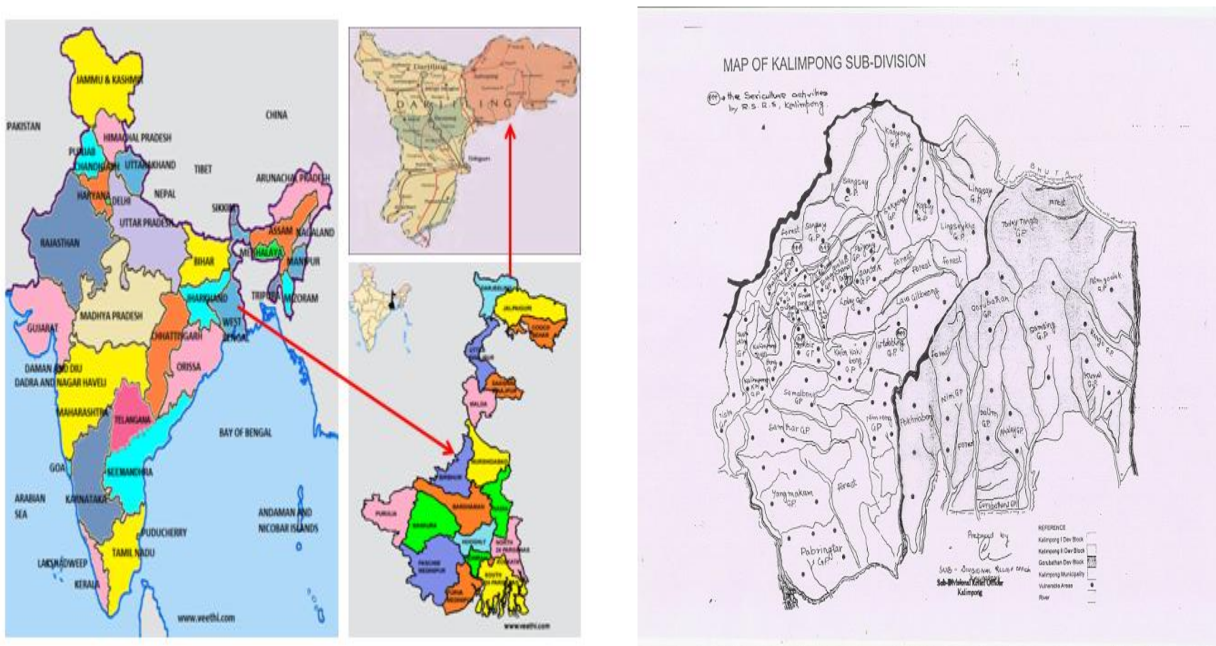
**(Source: Ram *et al.*, 2017a; 2017b; 2018)**

**Table.8** Cost benefit ratio

| Treat-ment | Mulberry | | Silkworm rearing | | Total Cost (₹ .) | Total leaf yield (mt ha$^{-1}$ year$^{-1}$) | Total cocoon yield 100 dfls$^{-1}$ | Total cocoon yield (kg ha$^{-1}$ year$^{-1}$) | Leaf cocoon ratio | Cost of sale of cocoon (₹ . 500 kg$^{-1}$) | Net Profit (₹ .) | Cost benefit ratio (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Input cost year$^{-1}$ (₹ .) | Labour cost year$^{-1}$ (₹ .) | Input and depreciation cost year$^{-1}$ (₹ .) | Labour cost year$^{-1}$ (₹ .) | | | | | | | | |
| $T_{1FYM}$ | 0.25 | 0.30 | 0.20 | 0.89 | 1.64 | 12.00 | 59.95 | 564.4 | 21.27 | 2.82 | 1.18 | 1:1.71 |
| $T_{2KH}$ | 0.27 | 0.30 | 0.20 | 1.07 | 1.85 | 14.97 | 62.47 | 707.8 | 21.15 | 3.54 | 1.69 | 1:1.92 |
| $T_{3KH}$ | 0.34 | 0.32 | 0.20 | 1.04 | 1.91 | 14.17 | 60.36 | 665.7 | 21.29 | 3.33 | 1.42 | 1:1.74 |
| $T_{4PM}$ | 0.29 | 0.29 | 0.20 | 1.13 | 1.92 | 14.70 | 60.40 | 724.8 | 20.30 | 3.62 | 1.70 | 1:1.89 |
| $T_{5MC}$ | 0.35 | 0.32 | 0.20 | 1.21 | 2.07 | 16.49 | 61.30 | 764.2 | 21.58 | 4.20 | 2.13 | 1:2.03 |

**(Source: Ram *et al.*, 2017a; 2017b; 2018)**

**Fig.1** Geographic map of Kalimpong sub-division



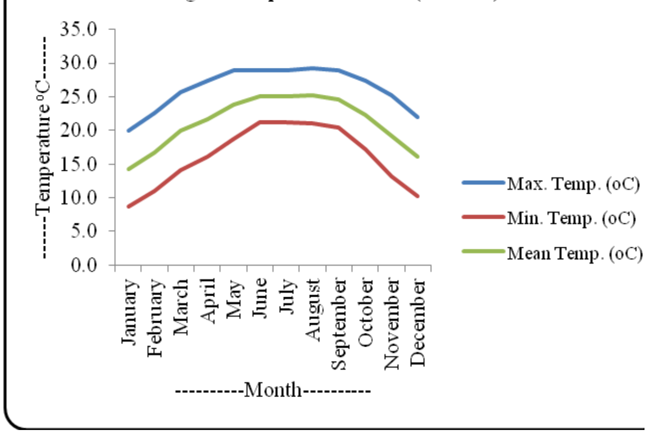




**Fig. 2: Temperature curves (2011-15)**

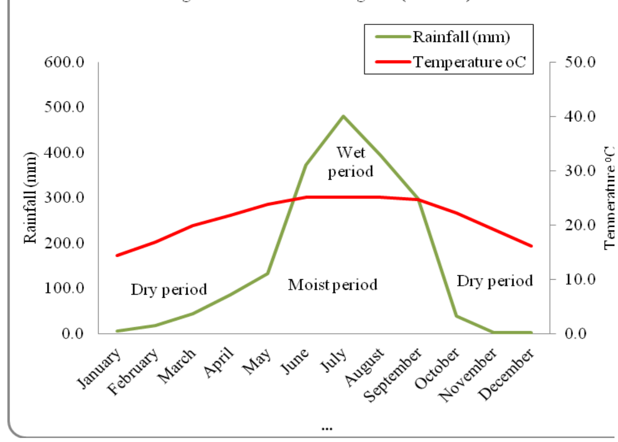



**Fig. 3: Ombrothermic diagram (2011-15)**

The significant effect of KH to enhance the growth attributing characters, yield and quality of various crops have also been reported by various workers across the globe (Ahmed *et al.,* 2013 and Arancon *et al.,* 2002). Findings of the Prakash *et al.,* (2013) were also correlates in different crops including mulberry.

Pressmud, a waste byproduct of sugar factories, is a soft, spongy, amorphous and dark brown to brownish material which contains sugar, fiber, coagulated colloids, including cane wax, albuminoids and inorganic salts etc. (Ghulam *et al.*, 2012). The usefulness of pressmud as a valuable organic manure has been reported by several workers (Khan *et al.*, 2012; Ramaswamy, 1999).

The beneficial effect of organic manures on growth attributes, leaf yield and quality due to proper decomposition, mineralization, solubilizing effects and availability of sufficient nutrients in mulberry have reported by various workers (Setua *et al.,* 2002 and Sudhakar *et al.,* 2000).

### Integrated effects of organic manures and FYM on nutritional quality of mulberry leaves

Analysis of nutritional quality of the mulberry leaves reveals that the all the organic manures have significant result on moisture (%), total chlorophyll, total soluble protein, total soluble sugar, total dry matter (%), total carbon (%), total ash (%), total nitrogen, crude protein and total phosphorus. The highest nutrient content in the leaf was found the $T_3$ treatment followed by $T_5$ and least in $T_4$ over the control. The moisture (%) and total chlorophyll content in $T_3$ treatment was slightly higher than other treatments, which directly favours the chawki silkworm rearing. Similarly, the total nitrogen, phosphorus and protein content in mulberry leaves are backbone of its nutritious quality and also a milestone of successful late age silkworm rearing.

Data compiled revealed that, the organic manures performed better with FYM on nutritious quality of mulberry leaves than FYM alone. Effect of organic manures and FYM on nutritious quality of mulberry leaves

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. Hence, several workers have conducted the research in this regard. Umesha and Sannappa, (2014) reported that, INM of FYM with other treatment combination enhanced the bio-chemical and mineral nutrients of mulberry leaves. Ghosh *et al.,* (2011) reported that, total soluble protein of $BC_2$59 mulberry genotype was ranged 20.86 to 21.29% in Darjeeling district with farmers recommended practices.

### Effect of organic manures and FYM on season wise performance of silkworm rearing

Silkworm rearing has direct correlation with nutritious mulberry leaves, because, it is the only basic food materials of silkworm *Bombys mori* L. Silkworm at chawki stage requires tender nutritious leaves with higher moisture content whereas, in contrary, they require matured nutritious leave in bulk at their fourth and fifth instars. Integrated effect of organic manures with FYM on season wise performance of silkworm rearing revealed that, except effective rate of rearing (ERR No.) of matured larvae, the performance of other rearing parameters like single cocoon weight, single shell weight, shell percent and cocoon yield/100 dfls were found significant in both season. While analyzing the data, it was found that, the cocoon yield and shell percent was higher with all the organic manure combinations over control. Maximum cocoon yield and shell percent was recorded with treatment combination $T_2$ followed by $T_5$ than control. Except control ($T_1$), the overall better performance was also noted with the treatment combination. Effect of organic manures and FYM on season wise performance of silkworm rearing is given in Table 7.

Silkworm growth and quality cocoon production dependent on nutritious mulberry leaves, however, yield and quality of mulberry leaves dependent on nutrient management and agronomic practices. According to Sannappa *et al.,* (2005) application of organic fertilizers to mulberry had a significant influence on cocoon yield, shell ratio, silk productivity and single cocoon filament length. Singhal *et al.,* (1999) opined that quality of mulberry leaf fed to silkworms is the most important factor that influences successful cocoon production by mulberry silkworm.

## Cost benefit ratio

The economic gain or cost benefit ratio is the difference of total input and output cost of a produce. In the case of mulberry, sale of seed cocoon is the cost of output and this output is directly related with the leaf: cocoon ratio, total mulberry leaf yield and total cocoon production. In this case, the economic gain or cost benefit ratio was analyzed based on the total mulberry leaf (mt/ha/year) and silkworm cocoon yield (kg/ha/year) (Table 5 and Table 7). Though, this zone has been declared as bivoltine seed zone by Department of Textiles (Sericulture), Govt. of West Bengal. The concerned authority directly purchased the good seed cocoons from the sericulture farmers at the rate of ₹ . 500/kg, hence, this is also one of the reasons for handsome return. Due to higher leaf yield and cocoon production, cost benefit ratio increased from 1.74 to 2.03 percent with all the organic manures combination. Details of cost benefit ratio are given in Table 8.

It has been concluded that, the integrated effect different organic manures like potassium humate (KH), pressmud and mixed oil cake with FYM performed significantly higher on yield and nutritional quality of mulberry leaves than FYM alone. Effect of above organic manures was also found significant result on single cocoon weight, cocoon yield 100 $dfls^{-1}$ and shell% respectively. Due to higher leaf yield, the higher cost benefit ratio was higher with mixed oil cake than other organic manures including FYM.

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