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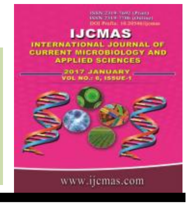

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Integrated Effect of Treated Pressmud and FYM on Mulberry Leaves and Bioassay of Silkworm in Acid Soils of Kalimpong Hills, India

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A field experiment was conducted during 2014-16 at Regional Sericultural Research Station farm and two farmers' field in Kalimpong hills, West Bengal, India with five treatments and four replications to study the integrated effect of treated pressmud and FYM on growth attribute characters, yield and quality of existing BC_259 (*Morus alba* L.) mulberry variety. This experiment was also extended to check its adverse effect on bioassay of SK6×SK7 (*Bombyx mori* L.) silkworm. Based on data analyzed, it was found that, the integrated application of 02 mt treated press mud with 05 mt FYM (T_3) performed better than application of 10 mt FYM alone (T_1). The highest annual leaf yield among above experimental sites was ranged from 11.09 to 14.71 mt ha^{-1} after the application of T_3 treatment. The total leaf yield gain in T_3 treatment was 15.28 to 19.26% higher than control. The nutritional quality like moisture content 76.84%, total chlorophyll 1.67 mg g^{-1}, total soluble protein 25.78 mg g^{-1}, total soluble sugar 34.85 mg g^{-1}, total N 3.44%, total P 0.35% and crude protein 21.53% were also recorded as higher with T_3 than control. Bioassay of silkworm reveals that, the mulberry leaves with T_3 treatment have significant result on single cocoon weight, cocoon yield/ 100 dfls and shell% respectively. The higher cost benefit ratio was also recorded as 1:1.89% with net profit Rs.1.70 Lakhs/ ha/year after the application of T_3 treatment than control.

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).

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. Besides, Kalimpong hills also have its own identity as 'silk route of India'. 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, low nutrients uptake, rainfed cultivation and injudicious use of fertilizers leads 'active acidity' resulting these soils are known as problem soils.

Like agricultural crops, the yield and quality of mulberry leaves are also dependent on soil health, nature of mulberry variety, integrated nutrient management, agronomic practices, environmental condition and protection measures from disease and pest, among them, soil health, environmental condition and nutrient management have greater influence. It is universal fact that, soil is soul of infinite life, which nourishes the whole living things; however, integrated nutrient management (INM) is the wonderful array in the arsenal of farmers and planners to sustain the soil health for desired production and productivity of crops.

It is now being realized that the use of organic manures with other nutrients combination may help to maintain the soil health for sustaining the mulberry sericulture. Farmyard manure (FYM) made with cow dung plays a major key role in this regard, but, the availability and timely application of good quality of FYM is a challenging task, hence, integrated application of FYM with other alternative of organic manures is highly desired for sustaining the soil health and mulberry leaves production. There are several alternative of FYM available to fulfill the requirements, but, either, these alternatives are less available and unaffordable or not much effective to achieve the targeted yield, hence, treated pressmud was chosen for its integrated application with FYM.

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; Zaman *et al.*, 1999a; Zaman *et al.*, 1999b; Ramaswamy, 1999). Rangaraj *et al.*, (2007) reported that, application of pressmud positive effect on the physical, chemical and biological properties of soil whereas according to Khan *et al.*, (2012), it is a good source of essential plants nutrients. Higher yield and quality of various agricultural crops have also reported after application of different doses of pressmud (Al-Mustafa *et al.*, 1995; Oloya and Tagwira, 1996; Haq *et al.*, 2001; Raundal *et al.*, 1999; Sangakkara *et al.*, 2004; Jamil *et al.*, 2008).

The composition of pressmud may vary depending upon the quality of cane and process of cane juice clarification. It has been reported that, sulphitation processed pressmud serves better as a store house of macro and micro nutrients than the carbonation processed pressmud (Virendrakumar and Mishra, 1991; Kapur and Kanwar, 1989), hence, sulphitation processed pressmud was applied either alone or with FYM in different nutrient combination to sustain the yield and quality of mulberry leaves for quality silkworm cocoon production.

Materials and Methods

Experimental site and climate

The experiment was conducted during 2014-16 at Regional Sericultural Research Station

(RSRS) farm and two farmers' field in Mahakaldara village of Kalimpong hills, Darjeeling district, West Bengal. The experimental area 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. 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 temperature curve and obmrothermic diagram is given in Fig.1 and Fig. 2.

Treatment Combination

The experiment was conducted for two years during 2014-16 at RSRS, Kalimpong farm and two farmers field with five nutrients management practices, *viz*, T_1: Control: FYM @ 10 mt ha^{-1}; T_2: Treated pressmud @1 mt ha^{-1} + FYM @ 5 mt ha^{-1}; T_3: Treated pressmud @2 mt ha^{-1} + FYM @ 5 mt ha^{-1}; T_4: Treated pressmud @1 mt ha^{-1} and T_5: Treated pressmud @2 mt ha^{-1}.

The recommended doses of NPK @150:50:50 kg ha^{-1} for existing mulberry variety $BC_2$59 was applied. The soil test based doses (STBD) of dolomite @ 1.5 mt ha^{-1} was uniformly applied in all treatment combination at RSRS farm, whereas, it was 1.16 mt ha^{-1} at both farmers field (Ram *et al*., 2015).

Mulberry variety and Silkworm races

The experiment was conducted in the existing $BC_2$59 (*Morus alba* L.) mulberry variety in both farm and farmers' field. The existing mulberry plantation of RSRS, Kalimpong was about 25 years old; however, it was 5-6 years old in farmers' field 1 and 4-5 years old in farmers' field 2. This variety was developed by back cross technique by earlier researchers and 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, fertilizers and dolomite applied

Integrated application FYM, pressmud, dolomite and mineral fertilizers were applied as per the treatment plan. Cow dung was the only source of FYM, whereas, the processed pressmud through the process of sulphatation was applied as an alternative of FYM. The chemical composition of pressmud is as under: pH – 7.8; organic carbon 35.5%; Nitrogen – 1.8%; Phosphorus – 1.4% and Potash – 1.0% respectively. Likewise, dolomite (CCE@109%) was applied as liming materials, however, 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 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. The statistical analysis was done by using SPSS 16.0 and Microsoft Excel, 2007 software.

Results and Discussion

Morpho-physical properties of soils

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. Sand, silt and clay percent in these areas ranged from 62-75%, 10-18% and 12-23% respectively. Based on the properties, soils of this area have been grouped as fine loamy, mixed, thermic, Typic Hapludepts. Morpho-physical properties of the soils under this pilot study are given in Table 1.

The variation of colour was due to prevalence of well drained conditions, admixture of organic matter (Ram *et al.*, 2015; Swarnam *et al.*, 2004; Rao *et al.*, 2008) whereas the variation in soil texture was caused by slope and terrace (Nayak *et al.*, 2002). The variation in soil structure and consistency was due to variation in clay content of pedons (Rao *et al.*, 2008; Singh and Agrawal, 2003). The high clay content in lower horizons in few soil profiles was due to illuviation or vertical migration of clay (Ram *et al.*, 2010; Rao *et al.*, 2008; Hegde *et al.*, 2008; Taha and Nanda, 2003; Sarkar *et al.*, 2002). The soils of Darjeeling hills under various land use are light textured, strong to moderately acidic in reaction with low exchangeable cations and high organic carbon content (Ray and Mukhopadhyay, 2012; Singh *et al.*, 2011; Maurya *et al.*, 2005; Sahu and Ghosh, 1982). Food Security and Agriculture Department, Government of Sikkim also reported that the soils of Sikkim are light textured with strong to moderate acidity and low to high organic carbon content (www.sikkimagrisnet.org).

Chemical properties of soils

While analyzing the data, it was observed that, the nutrient availability in the soils of Kalimpong is 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 content of the soils was higher. The plot wise nitrogen availability among research farms was medium to slightly high whereas as the availability of phosphorus, potash and sulphur was low to medium. The chemical properties of the soils are given in Table 2.

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 (Ram *et al*., 2013; Nayak *et al*., 2002; Patagundi *et al*., 1996, Bhadrapur and Seshagiri Rao, 1979). Brady and Weil, (1999) defined, soil organic matter as the summation of decomposed plant and animal residues. Albrecht *et al*., (1997) also stated that, the soil pH, cultural practices and application of manures have long term effects on soil organic carbon. The combined application of organic manures and inorganic fertilizers increased the organic carbon content in Darjeeling tea soils over the initial values (Singh *et al*., 2011; Hegde, 1996). Maurya *et al*., (2005) and Banerjee *et al*., (1985) 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.

Effect of pressmud and FYM on growth and yield of mulberry leaves

Analyzed data of RSRS farm and both farmers field revealed that, the growth attribute characters like height of shoot, no. of leaves/shoot and leaf yield of mulberry variety $BC_2 59$ were significantly higher with the integrated application of treated pressmud and FYM (T_3) followed by application of treated pressmud alone (T_5) over the control (T_1). While observing the effect of season (S) × Treatment (T), it was also found that, the higher significant leaf yield was recorded in spring crop than autumn crop. Likewise, the age of plantation was also one of the major factors for higher growth and yield of the mulberry leaves.

RSRS Farm

While analyzing the effect of treated pressmud with FYM and treated pressmud alone on season wise growth attribute characters and leaf yield of mulberry at RSRS farm, it was found that, the maximum leaf yield 6.87 mt ha^{-1} was recorded in autumn crop after the application of treated pressmud with FYM (T_3) followed by 6.58 mt ha^{-1} in same crop season after the application of treated pressmud alone (T_5). Likewise, significantly higher leaf yield was also recorded in the spring crop season with same treatment combination. The maximum leaf yield 7.84 mt ha^{-1} was recorded in spring crop after the application of treated pressmud alongwith FYM (T_3) followed by 7.49 mt ha^{-1} in same crop season after the application of treated pressmud alone (T_5). Integrated effects of treated pressmud and FYM on season wise growth attribute characters and leaf yield of mulberry at RSRS farm are given in Table 3.

The maximum annual leaf yield 14.71 mt ha^{-1} was recorded with treatment combination T_3 followed by 14.07 mt ha^{-1} with T_5 and minimum 11.90 mt ha^{-1} with T_4 respectively. The total leaf yield was 16.0% higher with treatment combination T_3 followed by 10.96% higher with T_5 and 6.15% lower with T_4 over the treatment combination T_1 as control (Table 4).

Farmer's Field 1

Likewise, RSRS farm, effect of pressmud on season and year wise growth attribute characters and leaf yield of mulberry at farmer's field 1 were also significant.

Similarly, Maximum shoot/plant, height of shoot, no. of leaves/shoot, and leaf yield was observed in T_3 treatment combination followed by T_5 and minimum in T_4 treatment combination. While observing the effect of season (S) × Treatment (T) in farmer's field 1, it was also found that, the higher significant leaf yield was recorded in spring than autumn. While analyzing the effect of treated pressmud with FYM and treated pressmud alone on season wise growth attribute characters and leaf yield of mulberry at farmer's field 1, it was found that, the maximum leaf yield 4.98 mt ha^{-1} was recorded in autumn crop followed by 6.11 mt ha^{-1} in spring after the application of T_3 treatment combination; however, the maximum leaf yield was 4.81 mt ha^{-1} in autumn crop followed by 5.90 mt ha^{-1} in spring crop after the application of T_5 treatment. Integrated effects of treated pressmud and FYM on season wise growth attribute characters and leaf yield of mulberry at farmer's field 1 are given in Table 5.

The maximum annual leaf yield 11.09 mt ha^{-1} was recorded with treatment combination T_3 followed by 10.71 mt ha^{-1} with T_5 and minimum 9.05 mt ha^{-1} with T_4 respectively. The total leaf yield was 15.28% higher with treatment combination T_3 followed by 11.33% higher with T_5 and 5.93% lower with T_4 over the treatment combination T_1 as control. Integrated effects of treated pressmud on annual growth attribute characters and leaf yield of mulberry at farmer's field 1 are given in Table 6.

Farmer's Field 2

The integrated application of treated pressmud with FYM (T_3) and without FYM (T_5) have also shown the significant result on growth attribute character and leaf yield farmer's field 2. Likewise, yield gain in both experimental sites indicated above, the maximum leaf yield at farmer's field 2 was 5.19 mt ha^{-1} in autumn crop and 6.39 mt ha^{-1} in spring crop after the application of T_3 treatment combination. The treated pressmud (T_5) also performed better than control. The maximum leaf yield was 5.07 mt ha^{-1} in autumn and 6.04 mt ha^{-1} in spring with T_5 treatment. Effect of treated pressmud on season and year wise growth attribute characters and leaf yield of mulberry at farmers' field 2 are given in Table 7.

The maximum annual leaf yield 11.58 mt ha^{-1} was recorded with treatment combination T_3 followed by 11.11 mt ha^{-1} with T_5 and minimum 9.32 mt ha^{-1} with T_4 respectively. The total leaf yield was 19.26% higher with treatment combination T_3 followed by 14.42% higher with T_5 and 4.02% lower with T_4 over the treatment combination T_1 as control. Integrated effects of treated pressmud on total growth attribute characters and leaf yield of mulberry at farmer's field 2 in Table 8.

Shankar, (1990) reported that the deficiency of essential nutrients in the soil has been found to cause nutritional, anatomical and histological disorders in mulberry, however, Krishna and Bongale, (2001) opined that, unbalanced nutrient management have adverse effect on crop productivity and nutrients availability. 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 organic manures enhanced the bio-chemical and mineral nutrients of mulberry leaves. Similar findings have also been reported by various workers (Ting-Xing *et al.*, 1980; Ray *et al.*, (1973). 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 (Das *et al.,* 1999; Setua *et al.,* 2002, 1999 and Sudhakar *et al.,* 2000).

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, it has been reported that, pressmud can be used as an alternative of FYM. Pressmud or filter cake, a waste by-product from sugar factories, is a soft, spongy, amorphous and dark brown to brownish material which contains sugar, fiber, coagulated colloids, including cane wax, albuminoids, inorganic salts and soil particles. By virtue of the chemical composition and high content of organic carbon, the usefulness of pressmud as a valuable organic manure has been reported by several workers (Rakkiyappan *et al.,* 2005; Ramaswamy, 1999; Virendrakumar and Mishra, 1991). Pressmud has also been reported to be a valuable resource of plant nutrients and may therefore affect physical, chemical and biological properties of a soil (Muhammad and Khattak, 2009; Jamil *et al.,* 2008; Rangaraj *et al.,* 2007; Kumar and Verma, 2002; Nehra and Hooda, 2002; Ramaswamy, 1999).

While discussing about integrated effect of pressmud, it was found that, pressmud alone or with other organic manure and fertilizers have significant result on various crops. Rai *et al.,* (1980) reported that, integrated application of pressmud with mineral fertilizers has significant on yield and quality of sugarcane and rice. Application of pressmud alone or in combination increased the yield and yield and quality of sugarcane (Nagaraju *et al.,* 2000; Ramalinga *et al.,* 1996; Yaduvanshi and Yadav, 1993; Yaduvanshi *et al.,* (1990), seed yield, seed protein and oil contents of sunflower (Tiwari *et al.,* (1998). Yield and quality of various agricultural crops improved after application of different doses of pressmud have also been reported by several workers (Jamil *et al.,* 2008; Sangakkara *et al.,* 2004; Raundal *et al.,* 1999; Oloya and Tagwira, 1996; Al-Mustafa *et al.,* 1995).

Integrated effects of treated pressmud and FYM on nutritional quality of mulberry leaves at RSRS, farm

Analysis of nutritional quality of the mulberry leaves reveals that the treatment T_3 has 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 (Table 9). 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.

The analyzed data reveals that, the higher 76.84% moisture content, 1.67 mg g^{-1} total chlorophyll, 25.78 mg g^{-1} total soluble protein, 34.85 mg g^{-1} total soluble sugar was found in fresh mulberry leaves after the application of treatment combination T_3, whereas, 3.44% total nitrogen, 21.53% crude protein and 0.35% total phosphorus was also found in the dry leaves of same treatment combination. Besides, application of treated pressmud alone with treatment combination T_5 also performed better as compared to control (T_1). Prince *et al*., (2000) reported that the application of coirpith compost have significant effect on growth attributes characters, yield and quality of leaves of the mulberry, however, Chowdhury et.al., (2013) reported that, the integrated application of vermicompost improves the nutritious quality of mulberry leaves than FYM alone. 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. The findings of Ghosh *et al*., (2011) is correlates with our findings with control.

Bioassay of silkworm rearing at RSRS farm

Bioassay of 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 in stars. Integrated effect of treated pressmud with FYM on season wise bioassay of silkworm 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 slightly higher with the treatment combination T_3 followed by T_5 and minimum cocoon yield was recorded with T_4 treatment combination. Unlike, the effect of season on mulberry leaf yield, the cocoon yield was almost similar in both seasons. Maximum 60.8 kg cocoon yield/100 dfls and 18.1% cocoon shell was recorded with treatment combination T_3 in autumn crop followed by 60.00 kg cocoon yield/100 dfls and 18% shell was recorded in spring season in same treatment. Apart from that, the better performance was also noted with the treatment combination T_5 over control. Bioassay of silkworm rearing is given in Table 10.

Silkworm growth and quality cocoon production is 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) and Raje Gowda (1996) 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. Findings of this study are correlates with the several researchers (Sannappa *et al.*, 2005; Raje Gowda, 1996).

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) at RSRS farm (Table 4 and Table 10). 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 Rs. 500/kg or more based on the quality of the seed cocoon, hence, this is also one of the reasons for handsome return. Due to higher leaf yield (14.7 mt/ha/year) with 16.00% leaf yield gain and economic consumption of mulberry leaves (Leaf: Cocoon ratio= 20.3:1) for production of one kg cocoon favours the high economic gain (1:1.89%) with T_3 treatment. Similarly, high economic gain (1:1.88%) was also recorded with the application of two mt treated pressmud (T_5) alone. Based on critical analysis of net benefit ratio, it was found that, the net benefit Rs. 1.70 lakhs/ ha/year was recorded with T_3 against the total input cost Rs. 1.92 lakhs and output cost Rs. 3.62 lakhs/ ha/year.

Table.1 Morpho-physical properties of soils*

Horizon	Depth (m)	Colour (moist)	Sand	Silt	Clay	Texture	Structure	------Consistence--			Boundary	Pores
			(%)					Dry	Moist	Wet		
RSRS, Kalimpong farm												
Ap	0.00-0.12	10 YR 5/4 (d)	74	10	16	Sl	sbk-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A11	0.12-0.45	10 YR 4/4 (m)	72	12	16	Sl	sbk-1-m	dsh	mfr	wss wps	cs	c-vf-f
B11	0.45-0.72	10 YR 6/4 (m)	64	16	20	Scl	sbk-1-m	dh	mfr	ws wp	gs	c-vf-f
B12	0.72-0.96	10 YR 6/4 (m)	62	18	20	Scl	sbk-1-m	dh	mfr	ws wp	-	c-vf-f
Farmer's field 1												
Ap	0.00-0.15	10 YR 6/4 (d)	75	10	15	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.15-0.35	10 YR 5/4 (m)	71	11	18	Sl	sbk-1-f	dsh	mvfr	wss wps	cw	c-vf-f
B11	0.35-0.66	10 YR 5/4 (m)	68	12	20	Scl	sbk-1-f	dsh	mfr	ws wp	gs	c-vf-f
B12	0.66-0.92	10 YR 5/4 (m)	70	10	20	Scl	sbk-1-f	dsh	mfr	ws wp	-	c-vf-f
Farmer's field 2												
Ap	0.00-0.18	10 YR 5/4 (d)	74	14	12	Sl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.18-0.42	10 YR 4/4 (m)	72	10	18	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B11	0.42-0.59	10 YR 4/4 (m)	67	10	23	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B12	0.59-0.85	10 YR 4/4 (m)	68	11	21	Scl	sbk-1-m	dsh	mfr	ws wp	-	c-vf-f

*Based on Soil Survey Manual 1970; Soil Survey Staff, 2006; 1998).

Table.2 Chemical properties of the soils

Soil parameters	RSRS farm	Farmer's field I	Farmer's field II
pH (1:2.5)	5.42	5.40	5.80
EC (dSm^{-1})	0.12	0.10	0.12
Organic C (%)	1.42	1.29	1.89
Available N (kg ha^{-1})	504.3	474.2	502.1
Available P (kg ha^{-1})	18.7	17.4	16.4
Available K (kg ha^{-1})	179.2	291.4	268.8
Available S (kg ha^{-1})	14.9	12.3	11.8

Table.3 Integrated effects of treated pressmud and FYM on season wise growth attribute characters and leaf yield of mulberry at RSRS farm

Autumn 2014-15						Spring 2015-16				
Treatment	No. of shoots-plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)	No. of shoots/ plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)
T_1	9.95	94.59	17.60	175.33	5.90	10.33	97.71	18.10	187.08	6.78
T_2	10.28	98.54	18.23	187.15	6.39	10.73	102.38	19.28	206.15	7.26
T_3	10.35	107.77	20.43	211.34	6.87	11.28	111.73	21.83	245.88	7.84
T_4	10.25	92.97	17.20	176.73	5.53	10.83	97.64	18.20	196.88	6.37
T_5	10.28	101.97	19.28	198.17	6.58	10.58	106.12	20.48	216.60	7.49
SEm (±)	0.11	0.88	0.26	4.29	0.02	0.04	1.13	0.34	2.92	0.01
CD(P=0.05)	NS	3.576	0.999	16.351	0.272	NS	5.692	1.485	17.923	0.196

Table.4 Integrated effects of treated pressmud on annual growth attribute characters and leaf yield of mulberry at RSRS farm

Treatment	Total shoots/ plant/ year	Total length of shoots/ plant/ year (cm)	Total leaves/ two shoots/ year	Total leaves/ plant/ year	Total Leaf yield /year (mt/ha)	Total Leaf Yield gain (%)
T_1	20.28	192.30	35.70	362.41	12.68	0.00
T_2	21.01	200.92	37.51	393.30	13.65	7.75
T_3	21.63	219.50	42.26	457.22	14.71	16.00
T_4	21.08	190.61	35.40	373.61	11.90	(-) 6.15
T_5	20.86	208.09	39.76	414.77	14.07	10.96
SEm (±)	0.09	1.87	0.56	6.84	0.03	1.52
CD (P=0.05)	NS	8.761	2.371	32.656	0.375	3.128

Table.5 Integrated effects of treated pressmud and FYM on season wise growth attribute characters and leaf yield of mulberry at farmer's field 1

Autumn 2014-15						Spring 2015-16				
Treatment	No. of shoots/ plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)	No. of shoots/ plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)
T_1	7.80	85.07	16.88	131.45	4.30	8.25	89.58	17.53	144.60	5.32
T_2	8.15	91.04	18.10	147.22	4.66	8.38	94.33	17.68	148.01	5.61
T_3	8.70	104.16	19.58	170.66	4.98	8.55	109.69	20.33	173.77	6.11
T_4	7.48	81.74	16.61	123.41	4.01	8.53	87.75	16.30	139.10	5.04
T_5	8.00	101.63	18.68	151.75	4.81	8.55	104.75	19.60	167.59	5.90
SEm (±)	0.15	0.66	0.20	2.43	0.03	0.03	0.24	0.07	1.03	0.06
CD (P=0.05)	NS	3.615	0.925	17.273	0.245	NS	2.573	0.671	9.927	0.389

Table.6 Integrated effects of treated pressmud on annual growth attribute characters and leaf yield of mulberry at farmer's field 1

Treatment	Total shoots/ plant/ year	Total leaves/ two shoots/ year	Total leaves/ plant/ year	Total Leaf yield/year (mt/ha)	Total Leaf Yield gain (%)
T_1	16.05	34.41	276.05	9.62	0.00
T_2	16.53	35.78	295.23	10.27	6.76
T_3	17.25	39.91	344.43	11.09	15.28
T_4	16.01	32.91	262.51	9.05	(-) 5.93
T_5	16.55	38.28	319.34	10.71	11.33
SEm (±)	0.12	0.23	1.68	0.07	1.76
CD (P=0.05)	NS	1.332	22.237	0.517	5.503

Table.7 Integrated effects of treated pressmud and FYM on season wise growth attribute characters and leaf yield of mulberry at farmer's field 2

	Autumn 2014-15					**Spring 2015-16**				
Treatment	No. of shoots/ plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)	No. of shoots/ plant	Height of single shoot (cm)	No. of leaves/ shoot	Total leaves/ plant	Leaf yield (mt/ha)
T_1	7.48	85.67	17.34	129.15	4.49	8.90	92.42	17.40	154.80	5.22
T_2	7.88	96.87	18.30	143.91	4.93	8.90	99.44	18.50	164.62	5.70
T_3	8.18	105.85	19.86	165.08	5.19	9.15	110.19	20.93	191.49	6.39
T_4	8.03	82.19	15.07	120.90	4.31	9.13	90.29	16.53	150.76	5.01
T_5	8.28	54.63	19.25	156.62	5.07	9.38	104.76	19.55	183.33	6.04
SEm (±)	0.10	0.86	0.04	1.28	0.03	0.05	0.24	0.04	0.72	0.02
CD (P=0.05)	NS	4.026		17.675	0.205	NS	1.872	0.663	8.291	0.277

Table.8 Integrated effects of treated pressmud on annual growth attribute characters and leaf yield of mulberry at farmer's field 2

Treatment	Total shoots/ plant/ year	Total length of shoots/ plant/ year (cm)	Total leaves/ two shoots/ year	Total leaves/ plant/ year	Total Leaf yield/year (mt/ha)	Total Leaf Yield gain (%)
T_1	16.38	178.09	34.74	283.95	9.71	0.00
T_2	16.78	196.31	36.80	308.53	10.63	9.47
T_3	17.33	216.04	40.79	356.57	11.58	19.26
T_4	17.16	172.48	31.60	271.66	9.32	(-) 4.02
T_5	17.66	159.39	38.80	339.95	11.11	14.42
SEm (±)	0.14	1.09	0.04	1.50	0.03	1.54
CD (P=0.05)	0.583	5.412	1.269	23.257	0.370	4.006

Table.9 Integrated effect of treated pressmud and FYM on nutritional quality of mulberry leaves

Treatment	Moisture (%)	Fresh weight (mg g^{-1})			Dry Weight (%)					
		Total Chlorophyll	Total Soluble Protein	Total Soluble Sugar	Total dry Matter (%)	Total Carbon (%)	Total ash (%)	Total Nitrogen	Crude Protein	Total Phosphorus
T_1	73.85	1.28	20.04	29.19	90.22	45.11	9.78	2.96	18.51	0.27
T_2	75.51	1.46	24.48	33.33	90.14	45.07	9.86	3.13	19.56	0.33
T_3	76.84	1.67	25.78	34.85	88.06	44.03	11.94	3.44	21.53	0.35
T_4	73.07	1.23	18.87	28.79	88.22	44.11	11.78	2.88	18.00	0.24
T_5	75.91	1.60	25.17	32.97	88.05	44.025	11.95	3.34	20.85	0.32
SEm (±)	0.12	0.01	0.11	0.21	0.18	0.09	0.18	0.02	0.12	0.01
CD (P=0.05)	1.494	0.057	0.544	0.657	0.916	0.458	0.916	0.299	1.870	0.022

Table.10 Season wise bioassay of silkworm rearing

	Autumn, 2014							Spring 2015						
Treatment	Weight of ten matured larvae (g	ERR/10000 larvae		Cocoon yield (kg)/ 100 dfls	Weight of single cocoon (g)	Weight of single shell (g)	Shell (%)	Weight of ten matured larvae (g	ERR/10000 larvae		Cocoon yield (kg)/ 100 dfls	Weight of single cocoon (g)	Weight of single shell (g)	Shell (%)
		No.	Weight (kg)						No.	Weight (kg)				
T_1	39.5	8933	14.1	56.4	1.73	0.303	17.5	39.5	8150	14.2	56.8	1.74	0.310	17.9
T_2	39.8	8867	14.4	57.6	1.74	0.309	17.8	40.0	8292	14.6	58.4	1.76	0.311	17.7
T_3	39.9	9033	15.2	60.8	1.75	0.317	18.1	40.2	8492	15.0	60.0	1.77	0.319	18.0
T_4	39.2	9000	13.9	55.6	1.71	0.305	17.8	39.0	8133	13.9	55.6	1.71	0.293	17.1
T_5	39.7	8967	14.9	59.6	1.74	0.313	18.0	40.1	8317	14.4	57.6	1.73	0.310	17.9
SEm (±)	0.07	48.91	0.06	0.26	0.00	0.00	0.06	0.03	21.52	0.04	0.18	0.00	0.00	0.04
CD(P=0.05)	NS	NS	0.33	1.33	0.02	0.00	0.27	0.674	NS	0.449	1.796	0.022	0.006	0.37

Table.11 Cost benefit ratio (Lakh Rs.)

Treat-ment	Mulberry		Silkworm rearing		Total Cost (Rs.)	Total leaf yield (mt /ha/ year)	Total cocoon yield/ 100 dfls	Total cocoon yield (kg/ ha/ year)	Leaf cocoon ratio	Cost of seed cocoon/ kg @ Rs. 500/-	Net Profit (Rs.)	Cost benefit ratio (%)
	Input cost/year (Rs.)	Labour cost/year (Rs.)	Input and depreciation cost/year (Rs.)	Labour cost/year (Rs.)								
T_1	0.25	0.30	0.20	0.98	1.73	12.7	56.5	585.0	21.7	2.93	1.19	1:1.69
T_2	0.24	0.29	0.20	1.05	1.78	13.7	58.0	643.5	21.2	3.22	1.44	1:1.81
T_3	0.29	0.29	0.20	1.13	1.92	14.7	60.5	724.8	20.3	3.62	1.70	1:1.89
T_4	0.17	0.27	0.20	0.91	1.55	11.9	55.7	535.4	22.2	2.68	1.12	1:1.72
T_5	0.22	0.28	0.20	1.09	1.79	14.1	58.6	673.3	20.9	3.37	1.58	1:1.88

*Labour cost: Rs.169.00 $manday^{-1}$; FYM: Rs. 1350.00 mt^{-1}; pressmud: Rs. 5500.00 mt^{-1}; Dolomite: Rs. 3000.00 mt^{-1}; Urea: Rs. 700.00 $quintal^{-1}$; SSP: Rs. 1000.00 $quintal^{-1}$; MOP: 19.00 $quintal^{-1}$; Cost of seed cocoon: Rs. 500.00 kg^{-1}.

Fig.1

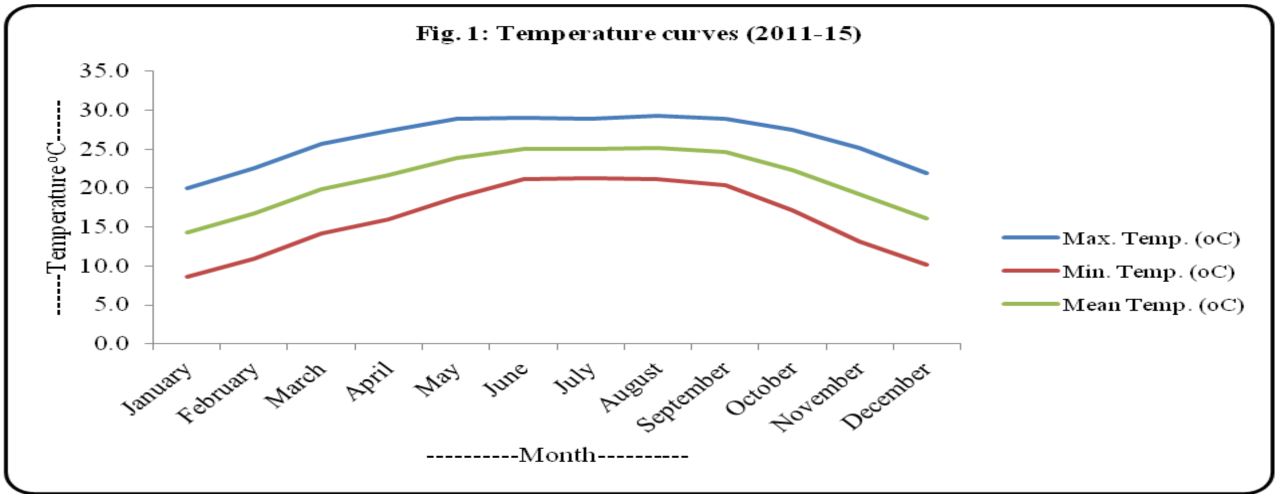
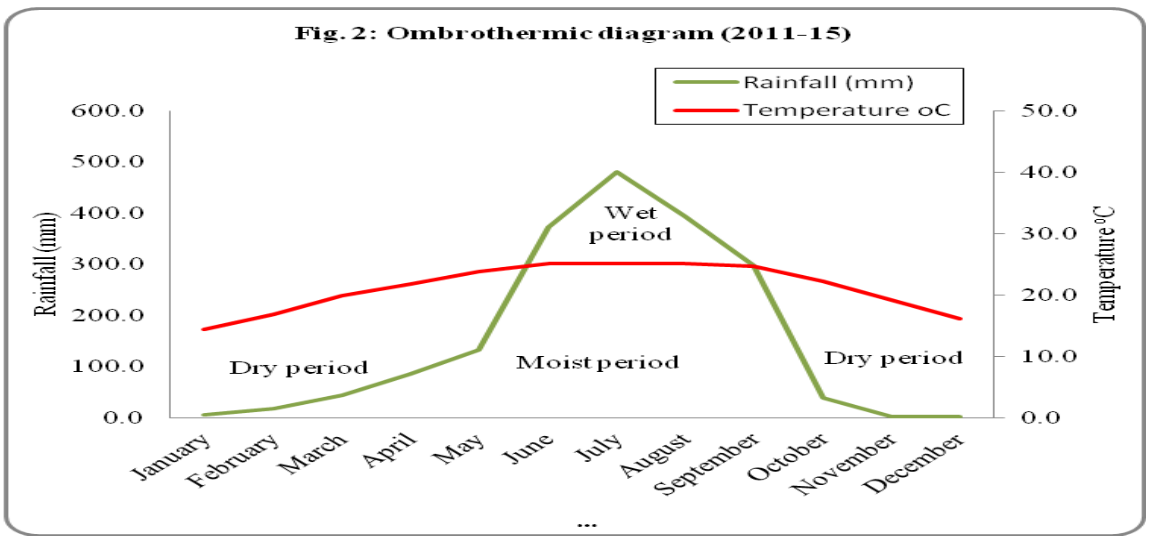


Fig.2



Similar trends of net benefit have also been recorded with the application of two mt treated pressmud alone (T_5). The cost benefit ratio is given in Table 11.

The higher returns by the integrated application of organic manures in mulberry sericulture have also been reported by various workers. Chowdhury *et al.*, (2013) also reported that the integrated application of FYM with vermicompost recorded higher return than the FYM alone. Based on the above facts, it has been concluded that, integrated application of treated pressmud @ 02 mt ha-^{1} + FYM @ 5 mt ha^{-1} (T_3) significantly performed better on season and year wise growth attributes characters like no. of shoot/plant, height of shoot, no. of leaves/shoot, and leaf yield of mulberry variety BC_259 than application of FYM @ 10 mt ha$_{-1}$ alone (T_1). Nutritional quality like moisture, total chlorophyll, total soluble protein, total soluble sugar, total dry matter, total ash, total nitrogen, crude protein and total phosphorus was also improved with same treatment. Bioassay of silkworm reveals that, the mulberry leaves with T_3 treatment do not have any adverse effect on silkworm rearing like effective rate of rearing (ERR), cocoon weight, cocoon yield and shell% respectively. It has been also revealed that, due to higher leaf yield and cocoon production, the net cost benefit ratio was proportionally recorded higher with T_3, hence, integrated application of treated pressmud and FYM with T_3 treatment has been recommended for sericulture farmers for sustaining mulberry sericulture in Kalimpong hills.

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