Impact of Vermicompost on Soil Fertility and Crop Productivity of Mulberry

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Abstract. Vermi-compost amendments in soil had a positive impact on soil physio-chemical properties, leaf yield & quality as well as suppresses of foliar diseases in mulberry plant. A two years' field experiment was conducted in the experiment field at Bangladesh Sericulture Research and Training Institute (BSTRI), Rajshahi, Bangladesh to examine the effect of vermi-compost on soil properties, growth, leaf yield and quality as well as severity of foliar diseases of mulberry plant. This study consisted of 4 treatments: T_0 = control, T_1 = basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, T_2 = only 5 MT vermicompost/ha/year and T_3 = 5 MT vermi-compost/ha/year + basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year. Results showed that the combined application of 5 MT vermicompost/ha/year + BSRTI recommend basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year exposed better growth, leaf yield and quality of mulberry plant followed by T_2, T_1 and T_0 treatments respectively. Between the two cropping years the maximum leaf yield was 50.40 MT/ha/year in 2nd year crop which was 73.25% greater than the maximum leaf yield of control. The leaf quality viz: moisture (%), soluble carbohydrate (%), total chlorophyll (mg/g), crude protein (%), mineral (%) and total sugar (%) were also 8.59, 34.27, 31.75, 23.32, 31.45 and 38.29 percentage respectively greater in 2nd year for the same fertilizer management over the control treatment. Furthermore, the soil physio-chemical properties viz: OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn except soil pH content were increased in 2nd year than the 1st year soil with maximum suppress of foliar diseases viz: leaf spot, powdery mildew, tukra and leaf rust in 2nd year for the treatment of T_3. This study concluded that utilization of vermi-compost improves soil fertility, leaf productivity, leaf quality of mulberry plant and reduce the foliar diseases with the respect to cropping year.

Key words: pruning, decomposition, powdery mildew, leaf spot, leaf rust, tukra.

Introduction

Vermi-compost is a finely divided peat-like material with high porosity, aeration, drainage, water-holding capacity and microbial activity which are stabilized by the interactions between earthworm and microorganisms in a non-thermophilic process (Edwards and Burrows, 1988: 211-220). They have greatly increased surface areas, providing more microsites for microbial decomposing organisms, strong adsorption and retention of nutrients (Shi-wei et al., 1991: 539-542). Vermi-composts is the microbial composting of organic wastes through earthworm activity to form organic fertilizer which contain higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Edwards et al., 1996; Ranganathan, 2006; Parthasarathi et al., 2007: 87-97). It contains most of the nutrients in plant-available forms such as nitrates, phosphorus, exchangeable calcium and soluble potassium (Orozco, 1996: 162-166). Due to its different production processes vermi-compost might exhibit different physical and chemical features which might influence plant growth and morphology in diverse ways. It may be increased nutrient uptake status by mulberry plant.

Mulberry (*Morus* spp.) is a perennial, heterozygous and high biomass producing hardy deciduous plant, continues to grow throughout the year for leaves production as a sole food for monophagous insect silkworm, *Bombyx mori* L. Aggarwal et al. (2004: 477-479). The continuous production of mulberry for a long time results in gradual reduction in leaf yield and quality (Rashmi et al., 2009: 165-169). Nearly 70 % of the silk proteins are produced by the silkworm is directly derived from the protein of mulberry leaves (Rangaswami et al., 1976). So, silkworms should be fed with good quality mulberry leaves in abundant quantity for the successful cocoon production (Vijaya et al., 2009: 1006-1012). Hence, quality of mulberry leaf is one of the basic prerequisite of sericulture and plays a pivotal role for successful silkworm cocoon crop (Guttierrez et al., 1997: 604-608). Mulberry plant requires the macro and micro nutrients viz: N, P, K, Ca, Mg, S, Fe, B, Ma, Zn, Cu, Mo and some other microelements from the soil for its growth and development Anonymous (1975). The leaf quality and quantity as well as the nutritional status of mulberry leaf are directly influenced by the application of manures and fertilizers to soil (Murarkar et al., 1998: 85-87). Due to the excessive use of chemical fertilizer and other agrochemicals creates depletion in soil fertility, pollution in surface water, soil nutrient and increase the soil acidity with nitrification and causes diseases in mulberry plant. The role of vermi-compost in improving the soil structure and there by the bumper yields of conventional crops and mulberry plant has been amply documented by Murarkar et al. (1998: 85-87). Besides many studies have been demonstrated the effectiveness of vermi-compost in providing protection against various plant diseases (Chaoui, 2002: 711-716).

Impact of vermi-compost on mulberry plant growth, leaf yield, quality and suppression of foliar disease is hardly available. In this aspect, the present study was undertaken to estimate the effect of vermi-compost on soil properties, leaf yield, quality and suppress of foliar diseases in mulberry plant. It may be hypothesized that vermi-compost will be enhanced the leaf yield, quality as well as suppress of foliar diseases in mulberry plant.

Material and methods

Experimental location: The experiment was conducted at the experimental field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh (24° 22' 29" North and 88° 37' 3.84" East). On the basis of Agro Ecological Zone (AEZ), BSRTI, Rajshahi falls under the Active Ganges Floodplain-10 and High Ganges River Floodplain-11.

Experimental condition: Generally, in Bangladesh silkworm is reared four commercially rearing seasons for each year. Depending upon the silkworm rearing season for this experiment the mulberry garden was pruned four times in a year each after three months interval. The vermi-compost was applied 2 days after pruning but the basal dose of NPK were applied 20 DAPr (Days after Pruning) when the sprouting of mulberry plant was started and other cultural practices like irrigation, digging cum weeding, insect-pest management practices etc. were done as per requirement. The mulberry variety BM-11 and the plantation system high bush (plant to plant and row to row distance was 3ft and plant height 1.5 ft) was used for this study.

Experimental design and treatments: This experiment was laid out in a randomized complete block (RCBD) design with three replications and the respective fertilizer treatments were randomly applied in the assign experimental plots. The following treatments were applied in the experimental plots:

T_0: Control (No input was applied)

T_1: Only the BSRTI recommended basal dose of N_{300} P_{150} K_{100} kg/ha/year (BRBD)

T_2: Only 5 MT vermi-compost per hectare per year

T_3: BRBD + 5 MT vermi-compost per hectare per year

Recorded growth parameters: Growth attributes namely, node per meter, length of longest shoot per plant, total branch number per plant, total branch height per plant (cm), total shoot weight per plant (g), 10 leaf area per plant (cm^2), 10 leaf weight per plant (gm) and total leaf yield/ha/year (MT) were recorded crop wise. Data were collected at 90 DAPr for each cropping seasons. i.e. four times data was collected in a year and the annual yield was computed by pooling the four seasons data.

Soil condition: The soils of the experimental plots of BSRTI were mainly clay loam in nature, having normally alkaline characteristics with pH ranging from 7.2 to 7.6. As a consequence of this alkalinity, the soil is poor in potassium and available phosphorus. Both carbon and nitrogen levels are low in uncultivated as well as in the cultivated plots. Nitrogen level is not in balanced with carbon. This is more prominent in the farm areas where mulberry is cultivated for years. Toxic metals are present in traces but they are well below the harmful levels (BSR, 1991). The basic physical and chemical properties of initial soil are shown in (Table 1).

Table 1. Initial soil properties of the experimental soil

Soil pH	Organic Carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (%)	Mg (%)	Na (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)
8.2	0.29	129.00	11.10	204.00	1.69	3.71	0.05	10.90	0.53	8.80

Analysis of soil: Soil texture analysis was conducted by using an abbreviated version of the international pipette method. Clay content was determined by a pipette method after pretreatment with H2O2 to remove organic matter (Gee and Bauder, 1986). The soil pH was determined in deionizer water using a soil: water ratio of 1:5 by using the glass electrode method (Haber et al., 1909). Organic carbon of the soil samples was determined by wet oxidation method (Walkley and Black, 1934). Soil organic matter content was determined by multiplying the percent value of organic carbon with the conventional Van-Bemmelen's factor of 1.724 (Piper, 1950: 368). The nitrogen content of the soil sample was determined by distilling soil with alkaline potassium permanganate solution (Subhaiah and Asija, 1956). The distillate was collected in 20 ml of 2% boric acid solution with methylred and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder et al., 2012: 289-294). Soil available S (ppm) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen, 1996). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas et al., 2012: 261-265). The available P of the soil was determined by spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005: 13-40). Sodium, calcium and magnesium content were determined following the method of Tandon (1993) and copper were estimated by atomic absorption spectrophotometer (AAS) Tandon, 1993). Manganese was estimated by Spectrometrically (Jackson, 1973; Chopra et al., 1991: 34-56). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979: 1411-1420).

Analysis of leaf quality: The mulberry leaf samples at different heights of the plant (top, middle and bottom) were collected in paper bags at 70 DAPr and composite leaf samples were made. Then, the prepared leaf samples were shade dried for three days and again dried in hot air oven at 70°C for one hour and were ground into powder for chemo-assay. The moisture (%) was determined following Vijayan et al. (1996: 95–98), soluble carbohydrate (%) following Dubois et al. (1956) method, total chlorophyll content was estimated by the procedure of Hiscox and Israelstam (1979: 1332-1332) using spectrophotometer and computed using the standard formulae of Arnon (1949: 1-15), crude protein (%) following Kjeldahl's method (Wong, 1923: 427), total mineral (%) following AOAC, (1980: 13044), Total sugar (%) following Miller (1972: 426-428) and Loomis et al. (1937) procedure (Mahewarappa et al., 1999: 318-323).

Analysis of disease incidence: The occurrence of disease incidence for two consecutive years in each replication 10 mulberry plants were taken into observation to study the incidence of foliar diseases viz: powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) leaf rust (*Peridiopsora mori*) and tukra (*Meconellicoccus hirsutus*) diseases respectively and data were collected at 60 days after pruning. Disease incidence (%) was assessed as number of total mulberry leaves per plant was infected by leaf spot, tukra, leaf rust and powdery mildew diseases with any visible symptom of respective disease. The percentage of disease incidence (PDI) was calculated using the formula of Rai and Mamatha (2005) which was following:

$$\text{Percent Disease Incidence (PDI)} = \frac{Number of total\ leaves\ on\ each\ plant}{Number of diseased\ leaves\ on\ each\ plant} \times 100$$

Statistical Analysis:

The growth and yield contributing data were analyzed by using the Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK) and one-way ANOVA was performed to detect differences for each parameter among the treatments. Sigma Plot 12.5 versions was used for representing the results as a figure form. The leaf quality and diseases data were statistically analyzed and mean values were evaluated by DMRT test through using the Statistic-10 software. In case of soil the mean values of post-harvest soil properties were recorded for this study.

Results

Effect of cropping years and fertilizer treatments on post-harvest soil properties.

The organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), copper (Cu) and zinc (Zn) content except soil pH were tended to be increased in soil treated with 5mt vermi-compost/ha/yr + BSRTI recommended basal dose of NPK (T_4) followed by the other treatments (Table 4). Among the six types of fertilizer treatments and between the two cropping years the maximum average OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn were found 6.76%, 212.33 kg/ha, 18.87 kg/ha, 314 kg/ha, 3.05%, 0.88%, 0.18, 95.27, 17.56%, and 41.30 respectively in 2nd year soil treated by the T_3 (BSRTI recommended basal dose of NPK + 5MT vermicompost/ha/yr) treatment. However, the minimum average OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn were 0.29%, 129 kg/ha, 11.10 kg/ha, 204 kg/ha, 1.69%, 3.71%, 0.05, 10.90, 0.53 and 8.80 respectively in 1st year soil for the control treatment. The maximum average soil pH was 8.20 in 2nd year soil for control treatment whereas the minimum soil pH was 7.55 in 2nd year soil for the treatment of T_3. Soil physio-chemical properties were similar between cropping seasons except soil pH and OC (Table 2).

Table 2. Post-harvest soil properties under different treatments and two cropping years

Treat	pH	Organic Carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (%)	Mg (%)	Na (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)

	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_0	8.20a	8.10b	0.29f	0.30f	129.00f	130.33f	11.10e	11.20e	204.00e	205.67e	1.69g	1.70fg	0.53e	0.55de	0.05g	0.07fg	10.90d	11.03d	3.71f	3.74f	8.80e	8.93e
T_1	7.86c	7.84c	0.20g	0.22g	189.00e	191.33de	13.40cd	13.50cd	256.00c	257.67c	2.31d	2.33d	0.55de	0.56d	0.07fg	0.08def	11.20d	11.20d	5.00d	5.08d	10.40d	10.57d
T_2	7.72d	7.71de	6.69b	6.76a	211.00a	212.33a	18.80a	18.87a	311.33a	314.00a	3.03a	3.05a	0.65b	0.67b	0.16a	0.18a	95.20a	95.27a	13.90b	13.95b	41.10a	41.30a
T_3	7.63ef	7.55f	3.23c	3.25c	199.67b	201.67b	15.27b	15.43b	267.00b	269.00b	2.69b	2.70b	0.87a	0.88a	0.11bc	0.13b	84.77b	84.83b	17.53a	17.56a	33.70b	33.80b

Here, T_0 = Control, T_1 = BSRTI recommended basal dose of NPK (BRBD), T_2 = 5 MT Vermicompost/ha/yea, T_3 = BRBD + 5 mt Vermicompost/ha/year

Effect of cropping years and fertilizer treatments on growth and yield of mulberry plant

Node per meter per plant: The average number of nodes per meter was highly significant irrespective to fertilizer treatment, cropping year and the interactive effect of treatment × cropping year. Between the two cropping years the maximum node per meter was 23.97 for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr) in the 2nd year and the minimum node per meter was 18.36 also in the 2nd year for T_0 (control) treatment (Table 3; Fig. 1).

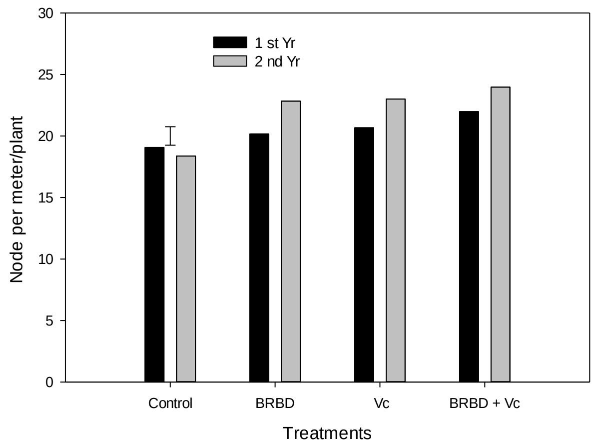

Fig. 1. Node per meter in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total branch number per plant: The average total branch number per plant was highly significant for the fertilizer treatments but it was not significantly differed by the cropping year (Table 3; Fig. 2). However, between the two cropping years the maximum total branch number per plant was 18.12 in 2nd year for T_3 (BRBD + 5 MT vermicomst/ha/yr) treatment and the minimum total branch number was 10.50 in 1st year for control treatment.

Table 3. Level of significance for the main and interaction effect on fertilizer treatments and cropping years

Source of variation	Node per meter per plant	Total branch number per plant	Total branch height per plant (cm)	Total shoot weight per plant (gm)	Length of longest shoot (cm)	Total leaf number per plant	10Leaf area (cm) per plant	10 Leaf weight (g) per plant	Total leaf weight per plant (g)	Total leaf yield/ ha/yr (mt)
Treatments	***	***	*	***	***	***	***	***	***	***
Cropping years	***	n. s.	n. s	n. s	**	*	n. s.	n. s	**	*
Treatments × Cropping years	***	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	*	n. s

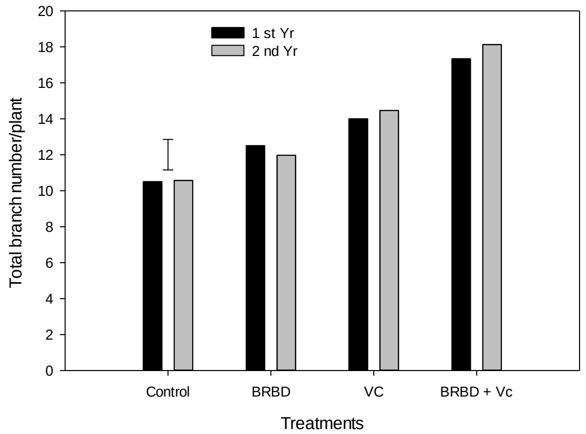

Fig. 2. Total branch number per plant as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total branch height per plant (cm: The average total branch height was significantly (*$P \leq 0.05$)* differed within the fertilizer treatments but did not significantly varied between the cropping years. Similarly, the fertilizer treatments and cropping season interaction was not significant (Table 3; Fig. 3). Among the six fertilizer treatments the maximum total branch height was 1521.67cm in 2nd year for the treatment of T_3 and the minimum total branch height was 931 cm in 1st year for the control treatment.

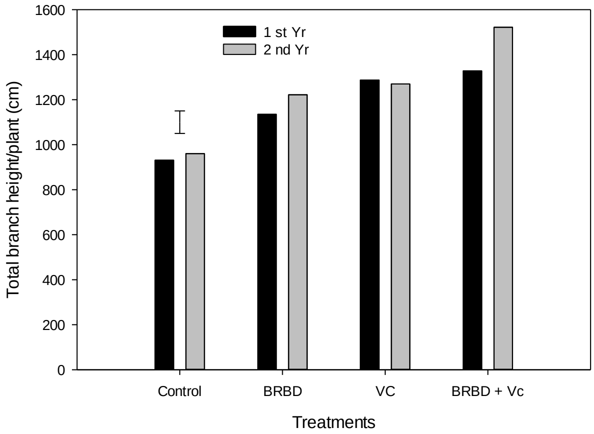

Fig. 3. Total branch height per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total shoot weight per plant (g): The average total shoot weight was highly significant ($P \leq 0.001$) for the fertilizer treatments. Between the two cropping years, the maximum total shoot weight was 376.20g in 2^{nd} year for the treatment of T_3 (BRBD + 5 MT vermi-omst/ha/yr). The minimum total shoot weight was 222.97 g in 1^{st} year for the T_0 (control) treatment. But their interactive effect was not significant (Table 3; Fig. 4).

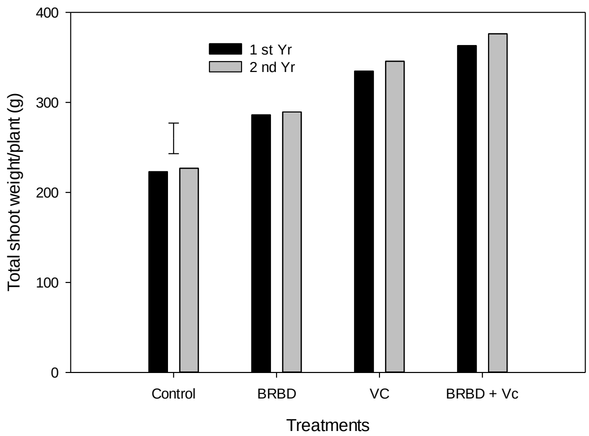

Fig. 4. Total shoot weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/yea. Vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Length of longest shoot (cm:) The average length of longest shoot was highly significant both for the fertilizer treatment ($P \leq 0.001$) and the cropping year ($P \leq 0.01$) but their interactive effect was not significantly differed (Table 3; Fig. 5). Between the two cropping years and the four types of fertilizer treatments the maximum length of longest shoot was 131.46 cm in 2^{nd} year for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr), whereas the minimum length of longest shoot was 108.77 cm in 1^{st} year for the control treatment.

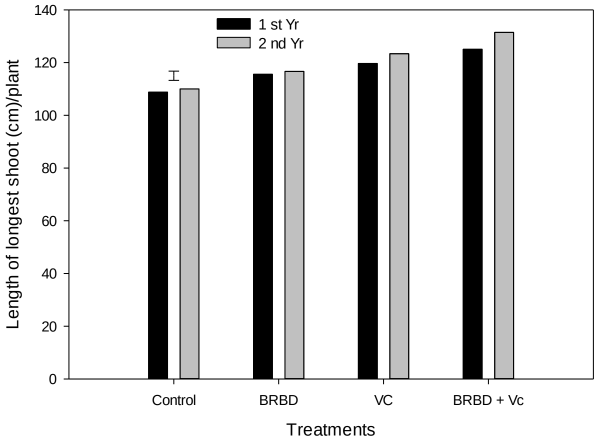

Fig. 5. Length of the longest shoot per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total leaf number per plant: The average total leaf number per plant was increased remarkably due to the fertilizer treatments and the cropping years (Table 3; Fig. 6). The maximum total leaf number was 324.88 in 2^{nd} year for the treatment of T_3 (BRBD + 5 MT vermicomst/ha/yr) whereas the minimum total leaf number was 228.94 in 1^{st} year for T_0 treatment.

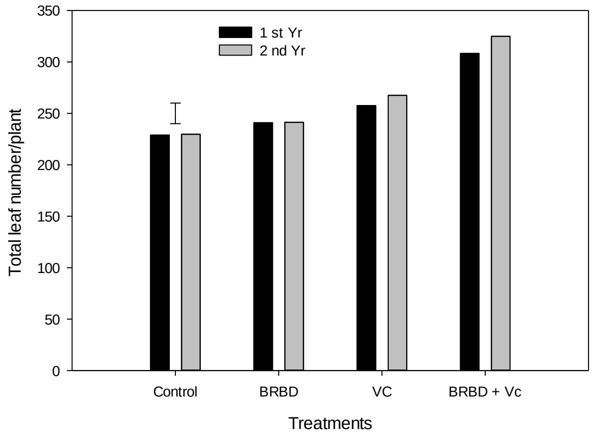

Fig. 6. Total leaf number per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/yea. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

10 Leaf area (cm^2) per plant: The 10 leaf area of mulberry plant was highly significant (*P ≤ 0.001*) for the fertilizer treatments (Table 3; Fig. 7). Among the four types of fertilizer treatments the maximum 10 leaf area was 607.76 cm^2 for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr) in 2^{nd} year. However, the 10 leaf area did not change remarkably for the cropping year and fertilizer treatments × cropping years. The minimum 10 leaf area was 367.77 cm^2 in 1^{st} year crop for the control treatment.

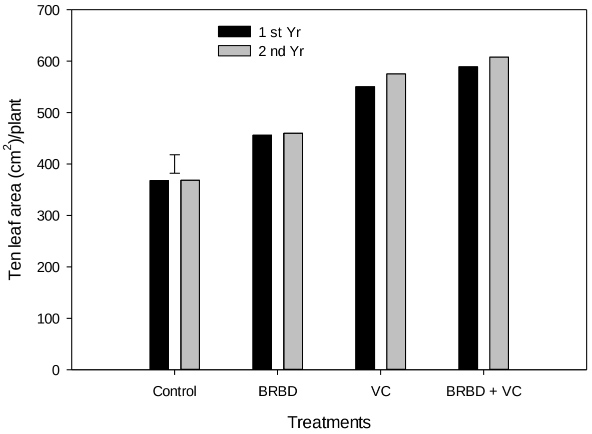

Fig. 7. 10 leaf area per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 MT Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Ten leaf weight per plant (g): The average ten leaf weight was highly significant (*P ≤ 0.001*) only for the fertilizer treatments (Table 3; Fig. 8). Among the four types of fertilizer treatments and between the two cropping years, the maximum average 10 leaf weight was 32.88 g for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr) in 2nd year. The minimum10 leaf weight was 26.27 g in 2nd year for the control treatment.

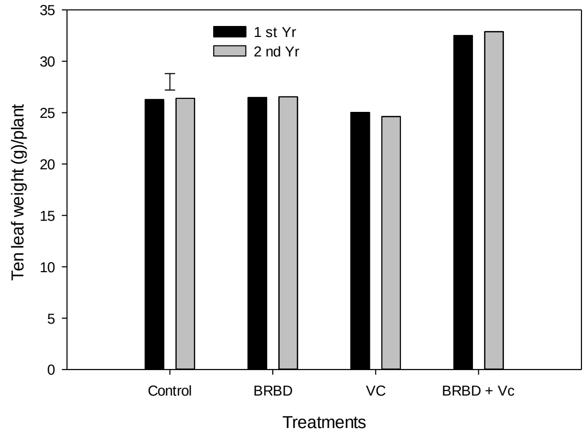

Fig. 8. Ten leaf weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total leaf weight per plant (g:) The average total leaf weight was highly significant (P ≤ *0.001*) for the fertilizer treatment, cropping year and the interactive effect of fertilizer treatments × cropping years (Table 3; Fig. 9). Among the four types of fertilizer treatments and between the two cropping years, the maximum total leaf weight was 1068 g in 2nd year for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr). The minimum total leaf weight was 601.46 g in 1st year for the control treatment.

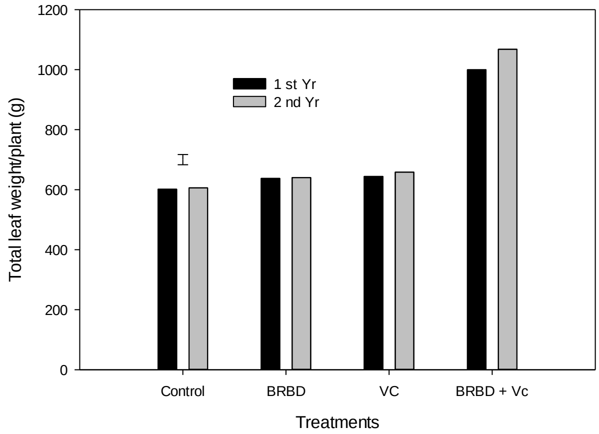

Fig. 9. Total leaf weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Total leaf yield/ha/yr (MT): The average total leaf yield/ha/year was highly significant ($P \leq 0.001$) for the fertilizer treatment and the cropping year, but their interactive effect was not significantly differed (Table 3; Fig. 10). Between the two cropping years and among the four types of fertilizer application the maximum total leaf yield/ha/yr was 50.40 MT in 2^{nd} year for the treatment of T_3 (BRBD + 5 MT vermi-comst/ha/yr). The minimum total leaf yield/ha/yr was 28.87 MT in 1^{st} year for the control treatmen.

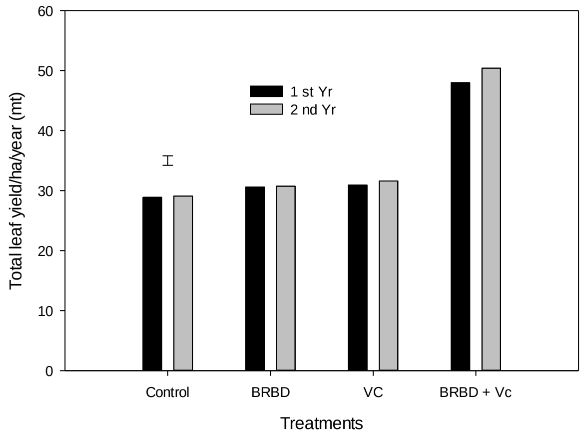

Fig. 10**.** Total leaf yield per hectare per year as influenced by the fertilizer treatments. Where, T_0 = Control, T_1 = BRBD of NPK, T_2 = Only 5 MT vermi-compost/ha/year, T_3 = BRBD + 5 mt Vermicompost/ha/year. Vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years' interactions

Effect of cropping years and fertilizer treatments on leaf quality of mulberry plant

The leaf quality of mulberry plant viz: moisture (%), soluble carbohydrate (%), total chlorophyll (mg/g), crude protein (%), mineral (%) and total sugar (%) were significantly increased for the treatment of T_3 (BRBD of NPK + 5mt vermi-comst/ha/yr) (Table 4). Between the two cropping years, only the soluble carbohydrate was significantly differed. Among the six fertilizer treatments and between the two cropping years, the average maximum moisture was 76.13% in 2nd year mulberry leaf for the T_3 (BRBD + 5mt vermicomst/ha/yr) treatment.

Table 4. Effect of vermicompost on mulberry leaf quality

Treatments	Moisture (%)		Soluble Carbohydrate (%)		Total Chlorophyll mg/g		Crude protein (%)		Mineral (%)		Total Sugar (%)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_0	69.30 i	70.11 h	7.36 h	7.44 h	2.46 h	2.52 gh	15.39 f	15.48 f	9.97 e	10.46 cde	4.36 h	4.44 h
T_1	70.89 g	70.93 g	7.95 g	8.07 fg	2.62 fg	2.68 f	16.38 e	16.47 e	10.30 de	10.54 bcde	4.99 g	5.08 fg
T_2	74.16 bc	74.50 b	9.07 c	9.15 c	3.11 bc	3.16 b	17.60 b	17.70 b	13.05 abcd	13.39 abc	5.84 c	5.93 bc
T_3	75.80 a	76.13 a	9.66 b	9.99 a	3.22 ab	3.32 a	18.95 a	19.09 a	13.56 ab	13.75 a	6.07 ab	6.14 a
Here, T_0 = Control, T_1 = BSRTI recommended basal dose of NPK (BRBD), T_2 = 5 MT Vermicompost/ha/yea, T_3 = BRBD + 5 mt Vermicompost/ha/year												

Similarly, the average maximum soluble carbohydrate was 9.99% in 2nd year for the treatment of T_3. The average maximum total chlorophyll was found 3.32 mg/g in 2nd year for the same treatment. The crude protein % was statistically greater due to the application of T_3 treatment where the maximum average crude protein was 19.09% in the leaf of 2nd year. The maximum average mineral percentage was tended to be increased in T_3 treatment as compared to other treatments. Between the two cropping years the average maximum total sugar was 6.14% in the 2nd year's mulberry leaf for the treatment of T_3.

Effect of cropping years and fertilizer treatments on incidence of foliar diseases in mulberry plant

The incidence of mulberry foliar diseases viz: leaf spot, powdery mildew and leaf rust tended to be declined due to fertilizer applications except tukra for the two consecutive years (Table 5). Among the six types of fertilizer treatments and two cropping years the minimum average incidence percentage of leaf spot, powdery mildew, leaf rust and tukra were 0.35, 1.48, 1.66 and 0.28 respectively in 2nd year for the treatment of T_3 (BSRTI recommended basal dose of NPK + 5 mt vermicompost/ha/yr).

In case of tukra disease there was no significant effect observed both for the fertilizer treatment and the cropping years. The maximum average incidence percentage of leaf spot, powdery mildew, leaf rust and tukra were 7.52, 5.07, 13.56 and 1.79 respectively in 1st year for the control treatment (Table 5).

Table 5. Incidence of foliar diseases under different fertilizer treatments and two cropping years

Treatments	Leaf Spot		Powdery mildew		Leaf rust		Tukra	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_0	7.52a	3.33de	5.07a	3.70ab	13.56a	6.02d	2.67a	2.47a
T_1	6.80ab	1.95ef	4.21ab	3.55ab	13.05ab	5.02d	1.79ab	1.75b

T_2	5.39bc	0.72f	3.59ab	2.62bc	10.30c	2.41ef	1.11ab	1.02b
T_3	4.62cd	0.35f	2.87bc	1.48c	9.97c	1.66f	1.07ab	0.97b
Here, T_0 = Control, T_1 = BSRTI recommended basal dose of NPK (BRBD), T_2 = 5 MT Vermicompost/ha/yea, T_3 = BRBD + 5 mt Vermicompost/ha/year								

Discussion

Vermicompost enhanced soil physiochemical properties

Vermi-compost has a great impact on the improvement of soil properties (Subbiah and Asija, 1995: 259-260). Findings showed that the application of 5 MT/ha/yr verimi-compost with full dose of NPK (T_3) increased the availability of OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn contents in soil among the treatments. However, the soil pH reduced due to the application of verimi-compost in soil. Among the four types of fertilizer treatments the minimum soil pH was 7.55 for application of 5 mt vermi-compost/ha/yr (T_2) whereas the maximum average soil pH was 8.20 for control (T_0) treatment. Our findings are similar with the previous findings of Manivannan et al. (2009: 275-281), who found that the application of vermi-compost @ 5 tonnes ha^{-1} in clay loam soil reduced the soil pH about (1 to 1.02 units). They also found that other soil physio-chemical properties like organic carbon, Mg,), Na (2.4 and 3.8 times), Mn (8.2 and 10.6 times), Zn (50 and 52 times), Cu (14 and 22 times), N (1.6 and 1.7 times), P (1.5 and 1.7 times) and K (1.5 and 1.4 times) increased due to vermi-compost amendment. They speculated that the acidifying effect of organic acids produced during the decomposition of organic amendments and or the increased permeability and leaching of salts the soil pH was slightly reduced, besides the other nutrients were increased in soil due to the higher amount of OC content in vermi-compost and reduces the losses of nutrients through leaching from the soil by changing the soil physicochemical properties. However, our speculation was the applied vermi-compost + BSRTI recommended basal dose of NPK content maximum amount of organic carbon and high levels of total and available nitrogen, phosphorus and potassium as a results which improved the soil microbial activities, water-holding capacity, soil decomposition rate, enhanced the availability of NPK in terms the soil physiochemical properties viz: OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn of our experimental soil was increased in T_3 treatment than the other treatments. This concept is lined with the previous finding of Maheswarappa (1999), Parthasarathi et al. (1999: 107-113), Sreenivas et al. (2000: 108-113) and Venkatesh et al. (1998: 117-121). They reported that vermicompost increased organic carbon, microbial populations, dehydrogenase activity of soil, significantly increased the amounts of soil nitrogen, P and K availability.

Vermi-compost boosts up the growth and leaf yield of mulberry plant

Growth and leaf yield of mulberry plant showed an increasing trend in different fertilizer treatments. The leaf productivity of mulberry plant was recorded in the tone of 50.40 MT/ha/yr after application of 5 MT vermi-compost/ha/yr with BSRTI recommended full dose of 300 kg N, 150 kg P and 100 kg K/ha/yr (T_3) in four split doses. Vermi-compost amendments @ 5 mt/ha/yr with BSRTI recommended basal dose of 300 kg N, 150 kg P and 100 kg K/ha/yr (T_3 significantly increased the average growth and leaf yield contributing characters of mulberry plant viz: nodes per meter, total branch number per plant, total branch height, total shoot weight, length of longest shoot, total leaf number per plant, 10 leaf area, 10 leaf weight, total leaf weight per plant and total leaf yield/ha/year than the other treatments. Among the treatments, the maximum leaf yield was recorded 50.40 MT/ha/yr in T_3 treatment which was 73.25% and 64.01% respectively greater than the maximum leaf yield of control (T_0) and only the BSRTI recommended basal dose of NPK (T_1) treatments respectively. Our findings are similar with the previous findings of Murarkar et al. (1998: 85-87). They found that the application of vermi-compost @ 6000 kg/ha with full dose of NPK (300:120:120) significantly increased the number of branches, height of the plant, number of leaves per plant and the leaf yield per plant of mulberry as comparted to control treatment. Similarly, Gururaj (2005) observed that the mulberry garden treated with vermicompost @ 7.5 MT/ha/yr with 300:120:120 kg NPK/ha/year the leaf production was significantly greater i.e. 5.29 MT/ha/yr in irrigated M-5 mulberry variety and 7.23 MT/ha/yr V-1 mulberry variety in comparison to yield of 4.43 MT/ha/yr and 6.04 MT/ha respectively without vermicompost application. Thus, the application of vermi-compost with BRBD of NPK the soil properties viz: the soil pH, the soil microbial activities, the soil cation exchange capacity were improved as well as it might be enhanced the plant growth regulators such as N, P, K and micronutrients status of soil in available forms, as a results the plant uptake the essential nutrients in maximum and balanced proportion. So the growth and development of mulberry plant was better in T_3 treated mulberry plot, in terms the leaf yield. Regardless of that that the vermi-compost has high levels of total and available N, P, K, micronutrients, microbial activities and growth regulators which changed the biological properties as well as changes the enzymes activity within soil.

Vermicompost improved the mulberry leaf quality

Vermicompost has a significant impact on improving the leaf quality of mulberry. Our experimental findings showed that the leaf quality of mulberry plant viz: moisture (%), soluble Carbohydrate (%), total Chlorophyll (mg/g), crude protein (%), mineral (%) and total sugar (%) were notably increased due to the application of 5 MT vermicompost with BSRTI recommended basal dose of NPK (T_3) among the treatments. The similar trend was observed previously by Umesha and Sannappa (2014: 348-355), who found that the leaf quality of mulberry viz: leaf moisture (%), chlorophyll, protein and total sugar content in mulberry leaf were significantly increased due to the application of vermicompost in the soil. They opined that due to the enhancement of organic matter and water holding capacity in the soil the absorption of water by the plant was increased as well as the leaf moisture% was increased. However, our observation might be due to the improvement of the water holding capacity of the soil, the moisture uptake by the plant as well as the mulberry leaf was greater through combined application of T_3 treatment. The total chlorophyll content was increased due to the maximum and available nitrogen uptake by the mulberry plant and leaf through the combined application of 5 MT vermicompost with BSRTI recommended basal dose of NPK (T_3). Because nitrogen is an essential element of photosynthesis which is lined with the opined of Singhal et al. (2000: 27-55) and Rao et al. (2011: 290-293). They reported that nitrogen plays a greater role in improving the chlorophyll synthesis, as it is an essential constituent of photosynthesis and the combined application of chemical fertilizer with Seri-compost increased the total chlorophyll content in mulberry. Due to the better and balanced growth of mulberry plant through the application of 5 MT vermi-compost/ha/yr and BSRTI recommended basal dose of NPK (T_3) combinedly enhanced the production of plant growth substances and enzyme activities of mulberry plant resulting improved the mineralization attributes as well as increased the total sugar content which is lined with the previous findings of Rashmi et al. (2009: 165-169). They found the higher total sugar in mulberry leaf which was treated by the combined dose of chemical fertilizer and vermicompost. Similarly, Ranadive et al. (2011: 131 -135) found that the soluble protein and carbohydrate content in mulberry were higher due to combined application of vermicompost + NPK fertilizer which may be more amounts of organic nutrients essential for microbes and plant growth contain by the applied vermicompost. Our speculation was the combined application of 5 MT vermicompost with BSRTI recommended basal dose of NPK (T_3) content maximum amount of macro and micro nutrients in available forms that enhanced the balanced uptake and growth of mulberry plant as a result the protein and carbohydrate content were higher in T_3 treated mulberry plot which is more or less lined with the previous findings (Dubios at al., 1956: 250-256; Hartanto, 2017: 693-698).

Effect of vermicompost on severity of foliar diseases in mulberry plant

Vermicomposting reduced the intensity of foliar diseases of mulberry plant. The incidence percentage of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra were observed for two consecutive years. Two years pooled data revealed different intensity of foliar diseases severity among the treatments (Table 5). The powdery mildew, leaf spot, leaf rust and tukra e diseases severity was low in the treatment of 5 MT vermi-compost/ha/yr plus BSRTI recommended basal dose of NPK followed by the only 5 MT vermi-compost/ha/yr (T_2), BRBD (T_1) and Control (T_0) treated plot respectively. However, in case of tukra disease the similar result was found both for the treatment of T_3 and T_2 where the lowest incidence percentage was 0.28. The similar finding was observed by the Maji et al. (2013: 54-58). They found that the lowest incidence of powdery mildew, leaf spot and leaf rust foliar diseases in mulberry plant were 4.07, 5.39 and 4.51 respectively due to application of 15 MT/ha/yr vermi-compost with NPK (168:90:56), whereas the maximum incidence were 10.06, 15.22 and 10.96 respectively for the control treatment. They opened that the vermi-compost + NPK may be increased the levels of soil microbial activity leading to increased competition and antagonism in the rhizosphere which may contributed factors for reduction of diseases severity. Our assumption the low powdery mildew, leaf spot and leaf rust severity under vermi-compost + NPK may be due to enhanced activities of antagonistic microbes increased the competition against pathogens for resources that cause fungistatsis release of fungitoxic compounds during the organic matter decomposition or induction of systemic resistance in the host plants, in addition the production of various growth substances or hormones by azotobacter, azospirillum and partial application of NPK which enables plants to develop resistance power in the plant against the pathogens. For tukra mealy bug *Maconellicoccus hirsutus* (Green) of mulberry plant the more or less similar result was found by the Samuthiravelu et al. (2012: 228-232). They found that the incidence of tukra mealy bug *Maconellicoccus hirsutus* were minimum for the application of 15% vermiwash (liquid form of vermi-compost) than the Panchakavya and Control treatments respectively. They opined that the vermicompost or vermiwash could be attributed to the changed the biochemistry of plant which would made the plant system defensive against pest infestation. In our study, the lower infestation of tukra disease was found may be our applied vermicompost release the essential plant nutrients gradually throughout the growth period that induced development of resistance which subsequently helped in escaping the infestation of mulberry mealy bug as well as reduced the infestation of tukra disease.

Effect of cropping year on soil, leaf productivity and foliar diseases of mulberry plant

Application of vermicompost in soil varied soil physio-chemical properties in some extent with respect to cropping year. Findings showed that most of the soil physiochemical properties viz: N, P, K, Ca, Mg, Na, Mn, Cu and Zn were slightly increased due to vermicompost amendment. In contrast, the OC was significantly reduced in 2nd year than the 1st year for the application of 5mt vermi-compost/ha/yr + BSRTI recommended basal dose of NPK. In 2nd year, the OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn were increased 1.05%, 0.63%, 0.37%, 0.86%, 0.66%, 0.17%, 12.5%, 0.07%, 1.15% and 0.49% respectively than the 1st year for the same fertilizer treatment. The similar trend was observed by Musaida et al. (2013: 215-220). They found that increasing the vermi compost application duration, the P content was increased by more than 80 ppm; K content was increased by more than 14 ppm and Cu content in were increased 8.0 ppm in soil. Because, P does not exist in elementary form and most of the P was insoluble in the vermi-compost and unavailable to the soils and plants but increase of K due to the good nutrient absorbing properties of clay-loam soil and the micro-organisms in the vermi-compost reloaded the soil with more K ions which hence the K increased in soil. Similarly, increased the soil Cu content due to increase the organic matter which resulted in improved soil aeration and microbial activity in soil. Due to the applied of vermi-compost both the 1st year and 2nd year the total applied quantity of vermi-compost was increased as well as the activities of living micro-organisms was abundant in 2nd year soil in terms of the Zn and Mn content increased because vermi-compost is rich organic material. In addition, it may be as vermi-compost promotes steady and slow release of nutrients in the soil and the combined application of NPK with vermi-compost as a basal dose for each year the overall soil nutrients quality viz: OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn was improved in 2nd year than the 1st year soil.

The growth, leaf yield and leaf quality of mulberry plant was responded differently to the cropping years due to application of vermi-compost in soil. Between the two cropping years the growth and yield parameters of mulberry plant viz: nodes per meter, total branch number per plant, total branch height, total shoot weight, length of longest shoot, total leaf number per plant, 10 leaf area, 10 leaf weight, total leaf weight per plant and total leaf yield/ha/year were 9.05%, 4.56%, 14.60%, 3.64%, 19.79%, 5.39%, 3.20%, 1.20%, 6.83% and 5.04% respectively increased in 2nd year than the 1st year for the application of 5 MT vermi-compost + BSRTI recommended basal dose of NPK. Similarly, the leaf quality parameters viz: moisture, soluble Carbohydrate, total Chlorophyll, crude protein, mineral and total sugar were also 0.43%, 3.42%, 3.10%, 0.74%, 1.40% and 1.15% respectively increased in 2nd year mulberry leaf than the 1st year mulberry leaf for the same fertilizer management. It may be due to the reasons that vermi-compost application duration enhances the decomposition of organic matter, microbial diversity and populations of micro-organisms, soil structure, soil water holding capacity, fertility, release of nutrients in soil as well as the soluble plant macro and micronutrients availability might be improved in 2nd year soil than the 1st year soil. Thus the essential plant nutrients and growth regulators uptake by the 2nd year mulberry plant was optimum quantity and balanced proportion resulting the growth and development of mulberry plant was better in 2nd year crops than the 1st year in terms the growth and leaf yield as well as the leaf quality viz: moisture (%), soluble Carbohydrate (%), total Chlorophyll (mg/g), crude protein (%), mineral (%) and total sugar % were significantly increased in 2nd year crop than the 1st year crop.

Vermi-compost application reduced the incidence of foliar diseases in mulberry plant in two different cropping years. Foliar diseases viz: leaf spot, powdery mildew, leaf rust and tukra were observed in two different cropping years. The experimental results showed that increasing the vermi-compost application duration the severity of mulberry foliar diseases viz: leaf spot, powdery mildew, leaf rust and tukra were reduced from 1st year to 2nd year crop. Between the two cropping years the infestation of leaf spot and leaf rust diseases were significantly differed with the respect of cropping years but the infestation of powdery mildew and tukra diseases were not significantly differed within the cropping years. However, the maximum incidence percentage of leaf spot, powdery mildew, leaf rust and tukra diseases were 7.52, 5.07, 13.56 and 2.67 respectively in 1st year for control treatment, whereas the minimum incidence percentage were 0.35, 1.48, 1.66 and 0.97 in 2nd year crop which was 92.42%, 48.43%, 83.35% and 74.77%

respectively lowest in 2nd year than the 1st year crop for the treatment of T_3 (5 MT vermi-compost + BSRTI recommended basal dose of NPK). The reduction of foliar diseases in mulberry plant with the respect of vermi-compost application duration might be due to the slow decomposition and slow release of nutrients improved the soil quality as well as production of maximum various growth substances or hormones by the applied vermi-compost and nitrogen in 2nd year soil than 1st year soil which enabled the mulberry plant to developed resistance power in the plant against the pathogens which is lined with the previous findings of Sharma et al. (1994: 31-35). They found that the organic amendments (azotobacter and azospirillum) with partial application of nitrogen produce various growth substances or hormones which develop the resistance power against the certain pathogen.

Conclusions

This study revealed that the vermi-compost amendments in soil either with or without BSRTI recommended basal dose of NPK can improve the soil physio-chemical properties, leaf yield and quality as well as reduces the infestation of foliar diseases in mulberry plant. The soil properties, mulberry leaf yield & quality and the incidence of foliar diseases viz: leaf spot, powdery mildew, tukra and leaf rust were drastically reduced in second year from first year due to application of 5 MT vermi-compost in soil either with or without BSRTI recommended basal dose of NPK. However, the maximum mulberry leaf yield was found in combined application of 5 MT vermi-compost/ha/yr with BSRTI recommended basal dose of 300 kg,150 kg and 100 kg NPK respectively in second year crop with maximum soil properties and leaf quality. Similarly, the lowest incidence of leaf spot, powdery mildew, tukra and leaf rust disease were found in second year than first year for the same fertilizer management. This study concluded that vermi-compost regulates growth, yield and quality of mulberry leaf. Further soil fertility and foliar diseases suppress occurred due to vermi-compost amendments.

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