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Advanced fertilizer management enhances productivity and suppresses foliar disease of mulberry plant'

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ADVANCED FERTILIZER MANAGEMENT ENHANCES PRODUCTIVITY AND SUPPRESSES FOLIAR DISEASE OF MULBERRY PLANT

SUBMITTED BY

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Dedicated
To

My beloved father Md. Abu Jafar and mother
Most. Monowara Begum

Statement of Authorship

"Except where reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

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CERTIFICATE

Certified that this thesis, entitled '**Advanced fertilizer management enhances productivity and suppresses foliar disease of mulberry plant**' is a record of research work done independently by **Faruque Ahmed** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to him.

Professor Dr. Md. Toufiq Iqbal
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ABSTRACT

Quality and quaintity of mulberry plant production is well known to be extremely demanding to fertilizer and disease management. The advanced fertilizer management is the pre-requisities for sustainable mulberry plant production and improvement of mulberry leaf

various diseases like, powdery mildew, leaf spot, leaf rust, bacterial blight, root rot, root knot, tukra etc. due to fertilizer management. Among them common foilar diseases viz: powdery mildew, leaf spot and tukra were studied for this study irrespective to advanced fertilizer management practices. Among the all fertilizers management practices, the performanace of seri-waste compost was good in terms of leaf yield, leaf qualities and suppression of foliar diseases. However, among the organic and liquid fertilizers management on top of BSRTI recommended basal plus seri-waste compost performanace was best followed on top of B+CW, B+VC, B+FM, B+MB, B+RB and B+LF fertilizers management. The maximum leaf yield was 52.23 MT/ha/year for the B+SW fertilizer management which was 87.07% higher than the average leaf yield of only the basal treated plant. The leaf qualities of mulberry plant was also better on top of B+SW fertilizer management followed by on top of application of B+CW, B+VC, B+FM, B+MB, B+RB and B+LF fertilizers management. The leaf qualities percentage viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar were 9.11, 32.52, 40.03, 38.08 and 26.05 respectively greater for on top of B+SW treated

mulberry plant over the single application of BSRTI recommended basal dose of NPK (B). Furthermore, on top of basal plus seri-waste compost was also reduction the incidences of powdery mildew, leaf spot and tukra diseases were 80.64, 89.44 and 87.58 percent respectively greater than the single dose of BSRTI recommended basal dose of NPK (Traditional fertilizer management). Similarly, among the organic fertilizer management next to B+SW fertilizer management the performance on top of basal plus cow-dung compost was 2nd higest interms of growth, leaf yield, leaf quality as well as suppression of foliar diseases. However, on top of basal plus 3 times foliar srpray of 2ml LF/L water after 15 days intervale gave the leaf yield was 36.77 MT/ha/year which was 31.70% greater than the average leaf yield of basal with maximum leaf quality and maximum reduction of foliar diseases incidences followed by the recommended basal dose of NPK. Furtheremore, among the inorganic fertilizer management the elevated 400 kg N/ha/year with four split doses along with BSRTI recommended basal dose of 150 kg P and 100 kg K showed the better performance followed by the elevated doses of 200 kg P and 150 kg K/ha/year respectively. Similarly, the leaf yield was 47.20 MT/ha/year with higher moisture, crude protien, total sugar, mineral and soluble carbohydrate percentage for the graded doses of 400 kg nitrogen/ha/year. However, among the inorganic fertilizer management the elevated dose of potassium presented the better results in terms of reduction of foliar diseases incidences. The elevated 150 kg K/ha/year with recommended 300 kg N and 150 kg P/ha/year with four split doses reduction the powdery mildew, leaf spot and tukra diseases incidences were 38.73, 30.28 and 19.98% respectively greater over the recommended basal dose of NPK. Likewise, between the 0-5 and 6-10 year’s ages of mulberry plant the 6-10 years ages of plant gave the maximum leaf yield with better leaf quality as well as maximum reduction of foliar diseases followed by the 0-5 year’s ages of mulberry plant. Furthermore, this study showed that among the three foliar diseases and three cropping seasons namely, late autumn, rainy and summer seasons the incidence of powdery mildew disease in late autumn season was comparatively high. Likewise, the BM-11, BM-8, and Black varieties to powdery mildew, BM-4, BM-11 to leaf spot and BM-8, BM-10, BM-11 and S-30 were comparatively resistant to tukra disease. However, this study concluded that among the all fertilizers management irrespective to mulberry plant growth, mulberry leaf yield and quality as well as maximum suppression of common foliar diseases, the performance of BSRTI recommended convational basal dose of NPK plus 10MT Seri-waste compost/ha/year was the best management practice for sustainable mulberry cultivation in Bangladesh.

Chapter 5

Integrated impact of inorganic fertilizer management on productivity and incidence of foliar diseases of mulberry plant

Chapter 5

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5.1. INTRODUCTION

Mulberry is the host plant of silkworm (*Bombyx mori L.*) that mainly cultivated for its foliage for rearing of silkworm to produce cocoon and silk yarn. Nutrition plays an import ant role in improving the growth and development of the silkworm (*Bombyx mori L.*) like other organisms. Legay (1958) reported that silk production depends on the larval nutrition and nutritive value of mulberry leaves which plays a very effective role in producing good quality cocoons.

Seki *et. al.,* (1959) observed better growth and development of silkworm larvae as well as good quality cocoons when fed on nutritionally enriched leaves. Silkworm obtains its entire nutritional requirement from mulberry leaves because this insect is mono-phagous and can complete the life cycle on mulberry leaves exclusively. Ito (1978) found that in mulberry leaf generally vitamins present in satisfactory level but silkworm needs in minimum quantity and the content of vitamins in mulberry leaves depend on environmental conditions, usages of fertilizers, mulberry varieties and other field practices. So it is very much needed to improve the nutritional status of mulberry leave.

Generally in Bangladesh, fertilizers are applied in soil. But in many cases foliar spray of nutrients is preferred and gives quicker and better results than the soil application (Jamal *et. al*., 2006). Generally mulberry plant takes a number of elements, viz., N, P,K, Ca, Mg, S, Fe, B, Na, Zn, Cu, Mo, and some other micro-elements from the soil (Anon, 1975). Plant requires specific amount of certain nutrients in specific form at appropriate time, for their growth and development (Sajid *et. al*., 2008).

Nutrients such as calcium (essential part of plant cell-wall structure, provides for normal transport and retention of other elements as well as strength in the plant), magnesium (plays vital role in photosynthesis and activate many plant enzymes which are needed for growth), iron (actively participate in transformation of carbohydrates and regulators consumption of sugars) are most important nutrients for mulberry. Micronutrients always play a major role in mulberry cultivation. Therefore, foliar spray of micronutrients is known to influence the growth, quality and yield of mulberry crop (Chikkaswamy *et. al.,* 2006).

The previous study showed that mulberry plant production was highest in single liquid fertilizer treated plot followed by the single application of urea, basal and control treatments respectively. But the earlier findings reported that only the single application of foliar nutrient is not adequate for the satisfactory crop production because foliar nutrients act as a supplementary nutrients supplier. Several studies found that the combined application of foliar urea along with NPK fertilizers significantly increased the leaf yield and leaf quality of mulberry plant (Gooding *et. al.,* Readman *et. al.,* 1997 and Quader *et. al.,* 1989). But the study on combined effect of NPK fertilizers along with foliar nutrients management on mulberry plant production was hardly available in Bangladesh.

That's why, this study was undertaken to estimate the efficacy of foliar nutrients along with BSRTI recommended basal doses of NPK on growth, leaf yield, quality and suppresses of common foliar diseases in mulberry plant. It was hypothesized that combined application of basal + liquid fertilizer will be responded better among the others combined chemical fertilizer management practices in terms of mulberry plant production.

5.2. MATERIALS AND METHODS

5.2.1. Experimental site

This experiment was conducted in the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh which is at $24^{\circ}22'29''$ N and $88^{\circ}37'84''$ E.

5.2.2. Soil physical and chemical properties of experimental site

The soils of the experimental plots of BSRTI were loam in Texture, having moderately alkaline in nature with pH ranging from 8.2 to 8.6. Because, according to the USDA soil taxonomy loamy soil contains 7 to 27% clay, 28 to 50 % silt and less than 52 % sand. As a consequence of this moderate alkalinity, the soil is poor in potassium and available in phosphorus. Both carbon and nitrogen levels are low in uncultivated as well as in the cultivated plot. Several mulberry experimental field values showed that nitrogen level is not in balance with carbon (BSR, 1991). This is more prominent in the farm area where mulberry is cultivated for years. Toxic metals are present in traces but they are below the harmful levels (BSR, 1991). The basic soil physical and chemical properties are shown in Table 5.1.

Table 5.1. Initial physical and chemical properties of the experimental soil

Soil pH in H_2O	Nitrogen (%)	Phosphorus (ppm)	Potassium (Cmol/Kg)	Sulphur (ppm)	Zinc (ppm)	Organic matter (%)
8.5	0.06	11.3	0.33	8.8	0.94	1.01

5.2.3. Experimental plant

The mulberry (*Morus spp*) plant, variety BM-11 (BM = Bangladesh Mulberry) was used as a test plant. Mulberry plant is small to medium sized shrubs or trees with a thick tan-gray ridged trunk which is perennial, deep rooted and hardy in nature. For its perennial, deep rooted and hardy habit, mulberry is grown in wide range of soil and agro-climatic condition in Bangladesh.

5.2.4. Experimental condition

The plantation system was high bush. In general, we can get mulberry leaf for four times in a year each after three months interval. Depending on the producing of mulberry leaf four commercial silkworm rearing seasons are followed in Bangladesh. On the basis of silkworm rearing season for this experiment the mulberry garden was pruned four times in a year namely month of January, April, July and October.

5.2.5. Experimental design and treatments

The experiment was laid out in a randomized complete block design with three replications. Each fertilizer treatments were randomly applied in the experimental plots. Each plot size was 5 m long and 4 m wide. The number of plants per plot was 20. The following fertilizer treatments were used for this experiment:

I. Control: No fertilizer was applied.
II. Basal dose: The recommended basal dose of Bangladesh Sericulture Research and Training Institute (BSRTI) is 300 kg N, 150 kg P and 100 kg K/ hectare/ year respectively with four split doses each after three months interval 15-20 days after pruning (DAPr).
III. Basal + Urea: 3 g urea/ L water was applied for 3 times in a season each after 15 days interval as foliar spray with BSRTI recommended basal dose of NPK.
IV. Basal + LF: 2 ml liquid fertilizer/L water for 3 times in a cropping season each after 15 days interval was applied as foliar spray with BSRTI recommended basal doze of NPK. Liquid fertilizer (LF) is one type of foliar nutrient which contents 13 number of essential plant nutrients (N, P, K, S, Ca, Mg, Cu, Fe, Zn, B, Mn, Mo and Cl) and other beneficially elements. It is locally produced in Rajshahi, Bangladesh.

Mass percent (%) composition of urea, Triple Super Phosphate, Muriate of Potash and liquid fertilizer (LF) which were used as basal treatment are given Table (5.2).

Table 5.2. Mass percent (%) composition of liquid fertilizer (LF) used in this experiment

Fertilizers Name	Chemical formula	Content elements with symbol	Mass Percent (%)
Urea	$CO(NH_2)_2$	Carbon(C)	20.00
		Hydrogen(H)	6.66
		Nitrogen(N)	46.66
		Oxygen (O)	26.66
Triple Super Phosphate	$Ca(H_2PO_4)_2$	Calcium(Ca)	15.89
		Hydrogen(H)	2.39
		Oxygen(O)	57.13
		Phosphorus(P)	24.58
Muriate of Potash	KCl	Potassium(K)	50.00
		Chloride(Cl)	46.00
Liquid fertilizer (LF)	None	*Total Nitrogen (N)	10.51
		Phosphorus (P)	5.58
		Potassium (K)	6.33
		Sulphur (S)	0.10
		Zinc (Zn)	0.16
		Copper (Cu)	0.04
		Iron (Fe)	0.0006
		Manganese (Mn)	0.006
		Boron (B)	0.25
		Calcium (Ca)	0.07
		Magnesium (Mg)	0.007

*Result obtained from the chemical analysis of Liquid fertilizer was done in the Soil Resource Development Institute, Regional Research Station, Dhaka.

5.2.6. Fertilizer application and other intercultural operation

In every case, basal fertilizer was applied at 20 days after pruning (DAPr) when the spurting was started. But urea and liquid fertilizer (LF) were sprayed as a foliar dose for 3 times in a season viz: 1st spray was at 30 DAPr, 2nd and 3rd sprays were 45 and

60 DAPr, respectively. Other cultural practices like irrigation, weeding, insect-pest management practices etc. were done as per requirement.

5.2.7. Selected growth and yield parameters of mulberry plant

The selected growth and yield parameters of mulberry plant were total branches number per plant, total branches height per plant, 10 leaves area, 10 leaves weight per plant, nodes per meter, total shoots weight per plant, total leaves weight per plant and total leaf yield per hectare per year. The total green leaf yield per hectare per year was estimated by the following formula:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2\text{ plant} \times \text{number of crop season per year} \times 10000\text{ m}^2}{1000\text{ g} \times 1000\text{ kg}}$$

5.2.8. Data collection

Data were collected on growth, leaf yield, leaf quality and diseases incidence percentage for respective cropping seasons. The growth and yield data was collected at 90 days after pruning (DAPr) for each cropping seasons. i.e. Four times data was collected for each year. The same experiment was repeated for 2nd year.

5.2.9. Measurement of soil physical and chemical properties

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).

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). 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). 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). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

5.2.10. 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), soluble carbohydrate percentage following Dubois *et. al.,* (1956) method, crude protein percentage following Kjeldahl's method (Wong, 1923), total mineral percentage following AOAC (1980), total sugar percentage following Miller (1972) and Loomis *et. al.,* (1937) procedure.

5.2.11. Disease incidence

The diseases incidence percentage of mulberry plant were recorded for two consecutive years each after 70 days of pruning, by randomly taking 10 plants for each replication. Foliar diseases viz: powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra caused by mealy bug pest (*Meconellicoccus hirsutus)* were recorded during this period. Studies on percent incidence (PI) in respect of powdery mildew, leaf spot and tukra diseases were recorded and the data during both the years were pooled and analyzed. The percent incidence was calculated by applying the following formula given by the Rai and Mamatha (2005).

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

5.2.12. Statistical analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1thed^{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 Duncan Multiple Range Test (DMRT) through using the Statistic-10 software. In case of soil the mean values of post-harvest soil properties were recorded for this study.

5.3. RESULTS

5.3.1. Integrated effect of basal plus liquid fertilizer on growth and yield of mulberry plant

The total branches number per plant was significantly ($P \leq 0.05$) differed by the fertilizer treatments. The more marked significant increasing trend was found for the treatment of B+LF. However, the total branches numbers per plant were 10.93, 12.06, 12.31 and 13.96 for the control, basal, B+U and B+LF treatments respectively (Figure 5.1; Table 5.3).

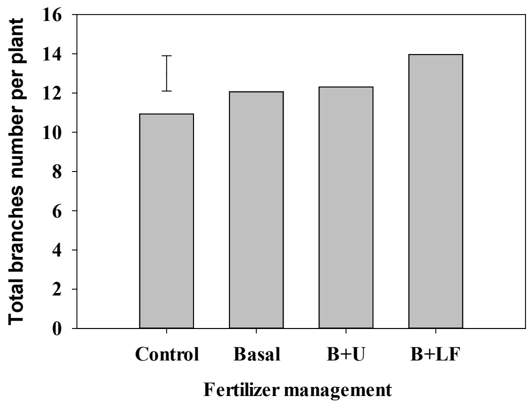

Figure 5.1: Effect of fertilizer management on total branches number per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (P = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The total branches height per plant of mulberry was highly significant ($P \leq 0.001$) among the fertilizer treatments. The most remarkable rising trend was recorded for the B+LF treatment. The recorded total branches height were 781.14, 1019.24, 1189.57 and 1209.93 cm for the treatments of control, basal, B+U and B+LF, respectively (Figure 5. 2; Table 5.3).

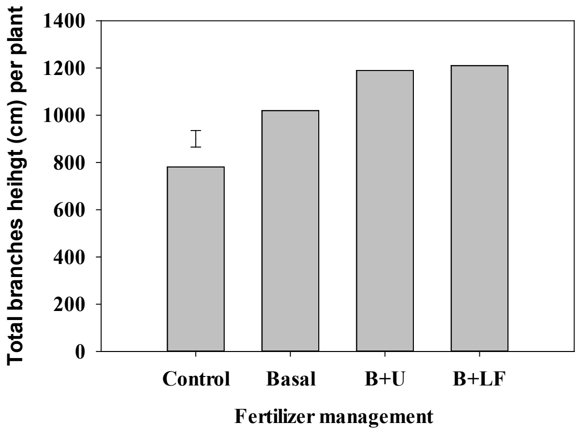

Figure 5.2: Effect of fertilizer management on total branches height per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (P = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The fertilizer treatments significantly ($P \leq 0.01$) increased the nodes per meter of mulberry plant. The more marked increasing trend was recorded for the B+LF treatment. However, the noted nodes per meter were 17.78, 20.26, 21.37 and 22.10 for the treatments of control, basal, B+U and B+LF, respectively (Figure 5.3; Table 5.3).

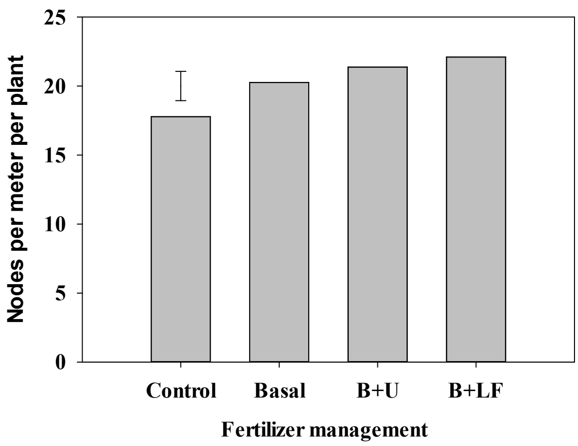

Figure 5.3: Effect of fertilizer management on nodes per meter per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (P = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

Table 5.3. Significance levels from the analysis of variance for the main effects of growth and yield parameters among various fertilizers management

Source of variation	Total branches number per plant	Total branches height per plant (cm)	Nodes/ meter per plant	10 leaves area (cm^2)	10 leaves weight (g)	Total shoots weight/plant (g)	Total leaves weight/plant (g)	Total leaf yield/ha/year (MT)
Fertilizer types	*	***	**	***	***	***	***	***

Note. Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

The highly significant ($P \leq 0.001$) variation was observed among the fertilizer treatments irrespective to 10 leaves area of mulberry plant. The B+LF treatment showed the more significant rising tendency among the treatments. The recorded 10 leaves areas were 427.40, 529.11, 540.34 and 546.50 cm^2 for the treatments of control, basal, B+U and B+LF respectively (Figure 5.4; Table 5.3).

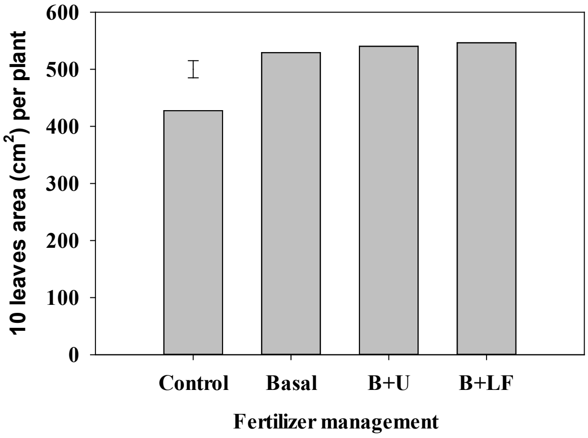

Figure 5.4: Effect of fertilizer management on 10 leaves area per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD ($P = 0.05$) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The 10 leaves weight of mulberry plant was highly significant ($P \leq 0.001$) by the treatments. The more increasing trend was found for the B+LF treatment. However, the recorded 10 leaves weight were 19.93, 24.55, 25.13 and 33.07 g due to the application of control, basal, B+U and B+LF treatments, respectively (Figure 5.5; Table 5.3).

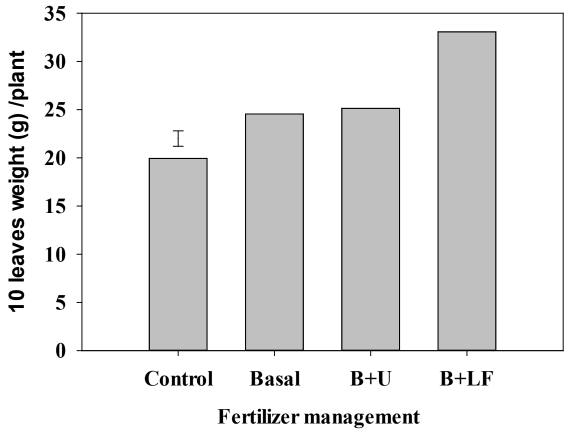

Figure 5.5: Effect of fertilizer management on 10 leaves weight per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (P = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The fertilizer treatments showed the highly significant ($P \leq 0.001$) trends irrespective to total shoots weight of mulberry plant. Among the fertilizer treatments B+LF represented the more rising trend. The total shoots weight were 34.79, 482.69, 527.23 and 545.47 g due to the control, basal, B+U and B+LF treatments, respectively (Figure 5.6; Table 5.3).

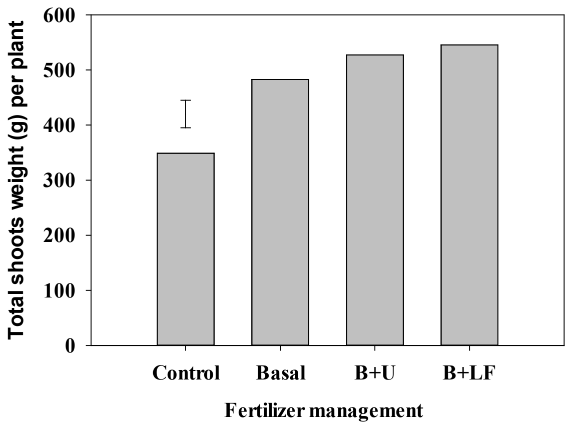

Figure 5.6: Effect of fertilizer management on total shoots weight per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (P = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The fertilizer treatments were significantly ($P \leq 0.001$) increased the total leaves weight per plant of mulberry. The more remarkable increasing rate was observed for the B+LF treatment. However, the recorded total leaves weight per plant were 493.25, 584.21, 714.79 and 766.05 g for the treatments of control, basal, B+U and B+LF, respectively (Figure 5.7; Table 5.3).

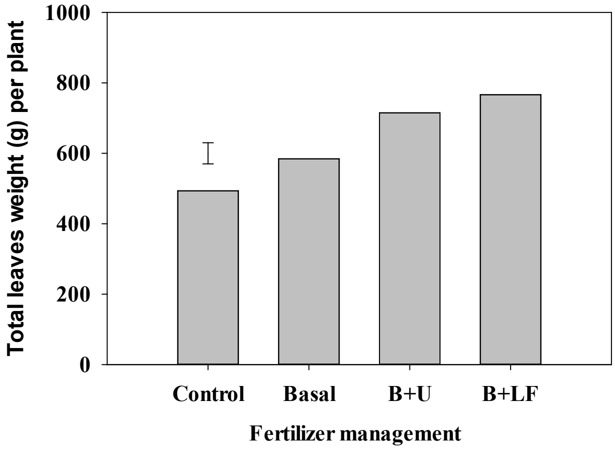

Figure 5.7: Effect of fertilizer management on total leaves weight per plant of Mulberry (*Morus spp)*. Vertical bar represent LSD (*P* = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

The highly significant ($P \leq 0.001$) difference was found among the fertilizer treatments irrespective to total leaf yield per hectare per year of mulberry plant. The more marked increasing trend was found for the B+LF treatment. However, the maximum leaf yield was 36.77 MT/ha/year for the B+LF treatment followed by the B+U (34.31 MT/ha/yr), B (28.04 MT/ha/yr) and control (23.68 MT/ha/yr) treatments respectively (Figure 5.8; Table 5.3).

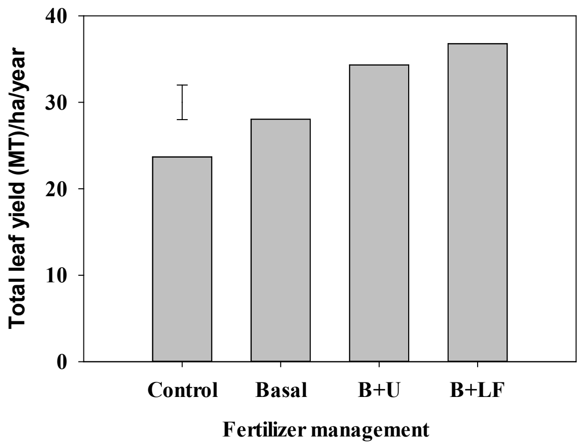

Figure 5.8: Effect of fertilizer management on total leaf yield per hectare per year of Mulberry (*Morus spp)*. Vertical bar represent LSD (*P* = 0.05) for various fertilizer management. Where, Control = Nothing was applied, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+U = Basal+3 g urea/L water 3 times foliar spray after 15 days interval and B+LF = 2 ml LF /L water 3 times foliar spray after 15 days interval.

5.3.2. Combined effect of basal and liquid fertilizer on leaf quality of mulberry plant

The similar trend was observed among the fertilizer treatments for the leaf quality of mulberry plant. Among the four types of fertilizer treatments the combined application of 3 times foliar spray of 2 ml liquid fertilizer/l water (LF) with BSRTI recommended basal dose of NPK (B+LF) comparatively improved the average leaf quality viz; moisture, crude protein, mineral, total sugar and soluble carbohydrate percentage of mulberry leaf followed by the B+U, B and control treatments respectively. However, the maximum moisture, crude protein, mineral, total sugar and soluble carbohydrate of mulberry leaf were 71.44, 17.15, 10.39, 5.13 and 8.23% for B+LF treatment followed by the other treatments. Conversely, the minimum moisture, crude protein, mineral, total sugar and soluble carbohydrate were 69.69, 15.30, 7.88, 3.62 and 7.29% respectively for the treatment of control (Table 5.4).

Table 5.4. Bio-chemical constitutions of mulberry leaf for various fertilizers management

Treatments	Moisture (%)	Crude Protein (%)	Mineral (%)	Total Sugar (%)	Soluble Carbohydrate (%)
C	69.69a	15.30a	7.88b	3.62a	7.29a
B	70.24a	15.46a	9.96a	4.98a	7.72a
B+U	70.61a	16.69a	10.11a	5.01a	8.10a
B+LF	71.44a	17.15a	10.39a	5.13a	8.23a

Where, C = Control, B = BSRTI recommended basal doses of NPK, B+U = B + 3 g urea/L water 3 times foliar spray after 15 days interval, B+LF = B+ 2ml liquid fertilizer /L water 3 times foliar spray after 15 days interval. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

5.3.3. Impact of basal and liquid fertilizer on foliar diseases of mulberry plant

The incidences of mulberry foliar diseases were statistically differed among the fertilizer treatments. Among the four types of fertilizer treatments the lowest incidence percentage of powdery mildew disease was 9.17 for the B+LF treatment which was significantly ($P \geq 0.05$) lower compared to the control treatment. The minimum incidence of leaf spot disease was 8.00% for the same (B+LF) treatment which was significantly ($P \geq 0.05$) lower compared to the other treatments. In case, of tukra disease the similar trend was observed among the B+LF and B+U treatment. However, the minimum occurrence percentage was 7.19 for the B+LF treatment. This incidence percentage was statistically differed with the basal and control treatments respectively. However, the maximum incidence of powdery mildew, leaf spot and tukra diseases were 11.37, 11.31 and 9.94 % respectively for the control treatment (Table 5.5).

Table 5.5. Effect of various fertilizers management on occurrence (%) of mulberry plant diseases

Treatments	Powdery mildew	Leaf spot	Tukra
C	11.37a	11.31a	9.94a
B	10.67ab	10.11a	8.19ab
B+U	10.27ab	9.93a	7.73b
B+LF	9.17b	8.00b	7.19b

Where, C = Control, B = BSRTI recommended basal doses of NPK, U = 3 g urea/L water 3 times foliar spray after 15 days interval, LF = Liquid fertilizer 2ml/L water 3 times foliar spray after 15 days interval. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

5.4. DISCUSSION

5.4.1. Impact on integrated inorganic fertilizer management for mulberry plant production

The combined application of BSRTI recommended basal dose of NPK + LF had a wider impact on mulberry plant production. My findings showed that the mulberry yield contributing characters viz: total branches number, nodes per meter, total branches height, 10 leaves area, 10 leaves weight, total shoots weight and total leaves weight per plant as well as total leaf yield per hectare year were significantly ($P \geq 0.05$) increased due to several integrated inorganic fertilizer application.

The more increasing trend was found for the treatment of B+LF followed by the B+U, basal and control treatments respectively. The yield contributing parameters viz: 10 leaves area, 10 leaves weight, total branches height, total leaves weight and total shoots weight per plant were 27.87, 65.93, 54.89, 55.31 and 56.39 percent respectively, increased due to the application of B + LF treatment over the control. Even the leaf yields were 7.17, 31.13 and 55.28 percent respectively greater for the same (B+LF) fertilizer treatment (B+LF) followed by the (B+U), B and control treatments respectively.

The similar types of finding in mulberry crop were unavailable. But, Katiyar *et. al.,* (1995) found that the application of foliar nutrients directly influenced the growth and development as well as also enhanced the productivity of mulberry plant. They thought due to the presence of essential amino acids, macro-micronutrients and antioxidants in foliar nutrients which was highly effective or capable for the growth and development of mulberry plant. Similarly, Dhiraj *et. al.,* (2012) reported that the foliar spray of commonly used foliar nutrients increased the growth (shoot height, number of shoots, leaves per plant) as well as enhanced the leaf yield of mulberry plant. Likewise, Setua *et. al.,* (2005) also found that the integrated nutrient management increased the mulberry leaf yield.

The speculation was the soil applied nutrients might be lead to some losses due to the leaching, volatilization or runoff water. But, the foliar applied liquid fertilizer (LF) with the basal dose of NPK, could be supplied all most all the plant nutrients (macro and micro) as per requirements. Furthermore, the leaching or de-nitrification losses of nutrients was minimize, the other nutrients uptake from the soil was greatly by the plant root as well as nutrients absorption by the mulberry leaf rapidly and efficiently through foliar application. For the above mentioned positive impacts the balanced physiological reaction, growth and development should be maintained by the foliar application of liquid fertilizer (LF) along with additional soil application of recommended basal dose of NPK (B+LF). Because this combination contents the maximum number of essential plant nutrients as a balanced proportion and nutrient deficiencies can be rectified by timely foliar application of the deficient nutrients through B+LF treatment.

In addition, this nutrient deficiency also would have avoided for canopy closure reduces the soil losses, maximum, rapidly and efficiently utilized by the mulberry plant as the application method was foliar spray. In terms, almost all the yield contributing characteristics of mulberry plant were positively marked through the B+LF treatment. Regardless of that the leaf yield was increased by the B+LF treatment compared to the other treatments. The above speculation was lined with the previous finding of Malakouti (2008). He reported that the foliar spray of micronutrients has positive effect on the growth parameters of plant. This could be due to maintain balanced plant physiology as mentioned in several research studies on their reaction and disturbances caused by their deficiency which was positively related with my speculation.

Likewise, Wani, *et. al.,* (2017) reported that the foliar application of liquid fertilizer at 0.25% in two sprays per crop was significantly increased the mulberry productivity. Their opinion was the foliar spray of liquid fertilizer might be containing all necessary nutrients in balanced proportion and in easily available form for healthy growth of mulberry plant. Resulting, the foliar spray of liquid fertilizer increased the mulberry productivity. Similarly, Witte *et. al.,* (2002) reported that nutrients such as calcium (essential part of plant cell-wall structure, provides for normal transport and retention of other elements as well as strength in the plant), magnesium (plays vital role in photosynthesis and activate many plant enzymes which are needed for growth), iron (actively participate in transformation of carbohydrates and regulators consumption of sugars) are most important nutrients for mulberry plant.

5.4.2. Impact of integrated inorganic fertilizer management on leaf quality of mulberry plant

The combined application of basal plus liquid fertilizer (B+LF) had a positive impact on improving the leaf quality of mulberry plant. Though there was no significant difference was found in leaf quality parameter for fertilizer managements but the overall leaf quality of mulberry plant viz: moisture, crude protein, mineral, total sugar and soluble carbohydrate percentage were increased due to the foliar application of liquid fertilizer with BSRTI recommended basal dose of NPK (B+LF) compared to the other treatments. Such type of finding in mulberry plant was not available in literature. However, Narahari *et. al.,* (2001) found that the commercially available foliar formulation used on mulberry under irrigated condition increased the leaf quality viz: total chlorophyll, sugar and protein contents of mulberry leaf which was more or less similar with this experimental finding.

Similarly, Dhiraj *et. al.,* (2012) reported that the foliar spray of commonly used foliar nutrients increased the (Leaf moisture, chlorophyll, soluble sugar, total soluble protein, sugar, amino acid etc) as well as enhanced the leaf quality of mulberry. In this study the combined application of 2 ml LF/L water with BSRTI recommended basal dose of NPK (B+LF) showed the better responses of leaf quality could be due to the maximum and balanced proportion of macro and micro nutrients were supplied through combined application of liquid fertilizer and the basal dose of NPK. Besides the foliar application of LF reduced the atmospheric losses and quickly boosts up the plant with healthy growth and establishment of mulberry plant due to easily available form. Resulting that could be promoted the uptake of nutrients, stimulate photosynthesis, other physiological process, protein synthesis, enzyme activities, leaf moisture percentage, total carbohydrate and other plant nutrients contents by the mulberry plant as well as improved the leaf quality. The above assumption was similar with the previous report of Jyothi *et. al.,* (2002). They reported that the foliar application of foliar nutrients promote the uptake of nutrients, stimulate photosynthesis, protein and enzyme activities of plant. Because, the foliar nutrients contain most of major macro and micro nutrients in balanced and available form for the plant.

5.4.3. Impact of integrated inorganic fertilizer management on foliar diseases of mulberry plant

The combined application of BSRTI recommended basal dose of NPK + LF significantly ($P \geq 0.05$) reduced the occurrences of foliar diseases of mulberry plant. In case of powdery mildew disease the incidence was 19.35% and 14.06% reduced in B+LF treatment compared to the control and basal treatments, respectively. Similarly, the incidence of leaf spot disease was 29.27% and 20.87% lower in B+LF treatment over the control and basal treatments, respectively. The same fertilizer (B+LF) management also reduced the incidence of tukra disease were 27.67% and 12.22% followed by the control and basal treatments, respectively. The above findings were similar with the previous finding of Maji *et. al.,* (2006). They found that the foliar application of foliar nutrient drastically reduced the powdery mildew disease caused by the *Phyllactinia corylea*. They also reported that foliar spray of foliar nutrient is safe and eco-friendly for management of mulberry foliar diseases. In the same way, Chikkaswamy (2006) reported that the foliar application of foliar nutrients successfully reduced the leaf spot disease of mulberry plant caused by *Cercospora moricola*.

The combined application of BSRTI recommended basal dose of NPK + LF (B+LF) reduced the incidence of powdery mildew, leaf spot and tukra compared to the other treatments may be due to the availability of maximum macro and micro nutrients both from additional used of basal dose of NPK and foliar spray of liquid fertilizer. That might be induced the enzyme activities, increased phenol contents, development of cell wall, affect physiological and morphological process, harding the cell wall against the pathogen through nutritious growth and development. Resulting, the B+LF treated mulberry plant could be created mechanical defences against the fungal pathogen beside liquid fertilizer also may have direct antifungal effect on fungal pathogen. Thus the incidence of foliar diseases in mulberry plant treated by the B+LF treatment was comparatively reduced followed by the other treatments.

5.4.4. Soil available nutrients also affect mulberry plant production

The experimental soil physical and chemical findings suggested that existing soil health condition was not enough to get reasonable mulberry plant production (Table 5.1; Figure 5.1 to Figure 5.8). That's why the improve fertilizer was applied to obtain good yield. Generally for mulberry plant production study showed that soil physical and chemical properties like optimum pH range 6.2 to 6.8, soil organic matter content 10% are ideal. But the soil condition of experimental plot was only 1.01% organic matter, soil pH 8.5, nitrogen was 0.06%, Zinc 0.94 ppm etc which was not suitable for mulberry production. According to Anonymous (2011), nitrogen fertilizer in soil is controlled by several physical, chemical and biological factors. The percentage of recovery of nutrients varies between the different types of fertilizers reported as 50-60, 5-15 and 75% of NPK respectively and nitrogen deficiency is observed in plants grown in soils with low organic matter (< 0.4% organic carbon) and also reported that nearly 62% soils are deficient in nitrogen which is line with this experimental soil. Subbaswamy (1994) confirmed that in general, mulberry plant chemical fertilizers are applied to maintain and enhance the quality and productivity per unit area.

However frequent use of chemical fertilizers for prolonged period of time not only deteriorates soil proportion but also affect the availability and uptake of nutrients in a plant. In terms adversely affect the eco-system and increase in prices of agricultural inputs (Patil *et. al.,* 2006*)*. Foliar application is an admirable way to supplement instant nutrients to the plants for quick boost, or if it shows any symptoms of nutrient deficiency. Therefore, it is an effective method for correcting the soil deficiencies and to overcome soils inability, to mobilize nutrients to the plants. It was found very effective in improving the leaf yield, quality and quantity of mulberry which is also an important factor for optimum growth and development of silkworm, *Bombyx mori* (Bose *et. al.,* 1995b). This finding was closely related with my experimental findings. Tejada & Gonzalez (2004) were determined that foliar fertilization dose not replace soil-applied fertilizer completely but it does increase the uptake and hence the efficiency of the nutrients applied to the soil, which was also positively related with this result. Thus, this study justified that foliar application of chemical fertilizer can improve growth and yield of mulberry plant on top of the basal dose application to soil.

5.5. CONCLUSIONS

The results of this experiment revealed that the integrated application of BSRTI recommended basal dose of NPK with liquid fertilizer (B+LF) increased the growth and leaf yield of mulberry plant. Even the combined application of B+LF increased the leaf yield were 55.28 and 31.13 % compared to the control and single basal dose of NPK respectively. Consequently, it was demonstrated that the foliar spray of liquid fertilizer along with basal dose of NPK also improved the nutritional parameters of mulberry leaf viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar contents. Furthermore, the same fertilizer (B+LF) management reduced the incidences of foliar diseases viz: powdery mildew, leaf spot and tukra in mulberry crop. Hence, the presence of maximum plant nutrients (macro and micro) in liquid fertilizer and additional used of NPK as a basal dose could have increased the mulberry plant productivity and suppresses of foliar diseases at foliar spray of liquid fertilizer on mulberry plant. This study concluded that the liquid fertilizers in combination with recommended basal dose of NPK can be used to get optimum leaf yield, quality and reduction of foliar diseases in mulberry plant. Though the performances of combined application of inorganic nutrients (B+LF) were better for mulberry cultivation, but previous researchers remarks that only the use of inorganic fertilizers as well as excessive use of chemical fertilizer and other agrochemicals creates diminution in soil fertility, pollution in surface water, soil nutrient and increase the soil acidity with nitrification and causes diseases in mulberry plant. So, the modern agricultural concept towards on the integrated (organic plus inorganic) nutrient management for the agricultural production.

Several study found that 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. Farm yard manure (FYM) is an available and reasonable source of organic matter as well as other macro and micro nutrients. Besides, the information of farmyard manure application for mulberry plant production was hardly available. Therefore, the utilization of FYM may have a good prospect for sericulture farmers to promote the mulberry plant production. For this perceptive, further study will be conducted to evaluate the impact of farmyard manure on mulberry plant production as well as reduction of foliar diseases in the next chapter (Chapter 6).

Chapter 6

Potential benefits of farm yard manure as an organic source for mulberry plant production

Chapter 6

Potential benefits of farm yard manure as an organic source for mulberry plant production

6.1. INTRODUCTION

Mulberry (*Morus* spp.) is the backbone of the sericulture industry. It is a very important plant for the development of sericulture industry both economically and traditionally. Mulberry leaves are basic food material for silkworm *Bombyx mori* L. (Ravikumar, 1988). Nutritional quality of mulberry leaves supplied as food has a great influence on silkworm growth and cocoon yield (ESCAP, 1993). Besides, feeding good quality mulberry leaves to silkworm larvae results in lower mortality of silkworm (FAO, 1990). It was reported that feeding of nutrient-deficient mulberry leaves to developing silkworms led to 17.11 % cocoon production loss (Singhvi *et. al.,* 2007). So, silkworms should be fed with good quality mulberry leaves in abundant quantity for the successful silk cocoon production (Vijaya *et. al.,* 2009).

Mulberry is a perennial, heterozygous and high biomass producing hardy deciduous plant continues to grow throughout the year for leaves production as a sole food of mono phages insect silkworm, *Bombyx mori* L. (Aggarwal *et. al.,* 2004). However, the nutritive value of mulberry leaf is influenced by the soil nutrient status (Bongale, 2006). The continuous production of mulberry for a long time results in a gradual reduction in leaf yield and quality (Rashmi *et. al.,* 2009). Mulberry plant requires the macro and micronutrients 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 the mulberry leaf are directly influenced by the application of manures and fertilizers to soil (Murarkar *et. al.,* 1998).

Farmyard manure (FYM) refers to the decomposed mixture of dung and urine of farm animals along with litter and leftover material from roughages or fodder fed to the cattle. On average, well-decomposed FYM contains 0.5 percent N, 0.2 percent P_2O_5, and 0.5 percent K_2O (Tnau, 2016). The FYM supplies all major nutrients (N, P, K, Ca, Mg, S) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu, and Zn). Hence, it acts as a mixed fertilizer. The FYM improves soil physical, chemical, and biological properties. Improvement in the soil structure due to the FYM application leads to a better environment for root development. The FYM also improves water holding capacity in soil. Kunj *et. al.,* 2018). In addition, the FYM rich in organic matter contains most of the nutrients viz: nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, zinc, and copper (Venugopal *et. al.,* 2010). Combined application of FYM with inorganic fertilizer NPK has a great impact on leaf yield and quality of mulberry plant (Waktole *et. al.,* 2013). Application of FYM in mulberry plants exhibited better results in maintaining the diseases than the other organic amendments due to containing more amounts of organic nutrients and makes resistance against the fungal diseases of mulberry (Ranadive *et. al.,* 2011). But the utilization of farmyard manure for mulberry production in Bangladesh was a core researchable issue. Besides, the information on FYM irrespective of mulberry cultivation and disease management was scarcely available, especially in Bangladesh.

That's why the present study was undertaken to estimate the effect of FYM on soil properties, leaf yield, quality, and suppress of foliar diseases of the mulberry plant. It was hypothesized that FYM will be the best-suited eco-friendly nutrient management practice for sustainable leaf production, improving the leaf quality and suppression of foliar diseases of the mulberry plant.

6.2. MATERIALS AND METHODS

6.2.1. Experimental area

This experiment was conducted in the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh which is located at the 24°22′29″ N and 88°37′84″ E.

6.2.2. Experimental plant

Mulberry (*Morus spp*) plant, variety BM-11 (BM = Bangladesh Mulberry) and plantation system of high-bush were used for this study. Mulberry plant (*Morus ssp*) is a perennial, deep-rooted, small to medium-sized shrubs or trees with a thick tan-gray ridged trunk which is hardy in nature. Due to its perennial, deep-rooted, and hardy habit, mulberry is grown in a wide range of soil and agro-climatic conditions in Bangladesh.

6.2.3. Experimental condition

Generally, in Bangladesh four commercially silkworm rearing seasons are trailed for each year. Based on the silkworm rearing season, the mulberry garden was pruned four times each after 90 days interval. The fertilizer treatments were applied 20 DAPr (Days after Pruning) when the sprouting of the mulberry plant was started and the necessary cultural practices like irrigation, digging cum weeding, insect-pest management etc. were done as per requirement.

6.2.4. Experimental design and treatments combination

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 assigned experimental plots. The following fertilizer treatments were applied:

T_0: Control (Nothing was added).

T_1: BSRTI recommended basal dose of N, P, and K (N = 300 kg, P = 150 kg, and K = 100 kg) per hectare per year with four split doses.

T_2: Only 7 MT farmyard manure (FYM) per hectare per year.

T_3: 7 MT FYM/ha/yr + BSRTI recommended basal dose of N, P, and K (B+FYM)

6.2.5. Recorded growth attributes

Growth attributes namely, total branches number per plant, total branches height per plant (cm), nodes per meter, total shoots weight per plant (g), 10 leaves area per plant (cm^2), 10 leaves weight per plant (g), total leaves weight per plant and total leaf yield/ha/year (MT) were recorded for this study. Data were collected at 90 DAPr for each cropping season. A total of four times data was collected in a year and the annual yield was computed by pooling the two years data. The following formula was used for calculating the green leaf yield per hectare per year.

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2 \text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

6.2.6. Initial 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. The nitrogen level is not 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 presented in (Table 6.1).

Table 6.1. 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	0.53	0.05	11.00	3.71	8.80

6.2.7. Analysis of soil

The soil pH was determined in deionized 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 the 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). 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 methyl red and bromocresol green indicator and titrated with 0.02 N sulphuric acids (H_2SO_4) (Podder *et. al.,* 2012).

The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et. al.,* 2012). The available P of the soil was determined by a spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by the Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005). Sodium, calcium, and magnesium content were determined following the method of Tandon (1993) and copper was estimated by atomic absorption spectrophotometer (AAS) Tandon, (1993). Manganese was estimated by

Spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

6.2.8. 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 a 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), soluble carbohydrate (%) following Dubois *et. al.,* (1956) method, crude protein (%) following Kjeldahl's method (Wong, 1923), total mineral (%) following AOAC, (1980), Total sugar (%) following Miller (1972) and Loomis *et. al.,* (1937) procedure.

6.2.9. Analysis of disease incidence

The occurrence of disease incidence for two consecutive years in each replication 10 mulberry plants was taken into observation to study the incidence of foliar diseases viz: powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra (*Meconellicoccus hirsutus*) diseases respectively and data were collected at 60 days after pruning. Disease incidence (%) was assessed as the number of total mulberry leaves per plant was infected by powdery mildew, leaf spot, and tukra 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 the following:

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

6.2.10. Statistical analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1thed^{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 were used for representing the results as a figure form. The leaf quality and disease data were statistically analyzed and mean values were evaluated by DMRT test through using the Statistic-10 software. In the case of soil, the mean values of post-harvest soil properties were recorded for this study.

6.3. RESULTS

6.3.1. Effect of FYM and cropping years on physio-chemical properties of post-harvest soil

The soil organic carbon (SOC), N, P, K, Ca, Mg, Na, Mn, Cu, and Zn were significantly increased in soil treated with 7 MT FYM + BSRTI recommended basal dose of NPK followed by only the 7 MT FYM treated soil when compared to control. On the contrary, the SOC content was decreased due to the application of only the

BSRTI recommended basal dose of NPK (T_2) at the same time the soil pH was increased compared to T_2 and T_3.

Among the four types of treatments and between the two cropping years the maximum average SOC, N, P, K, Ca, Mg, Na, Mn, Cu, and Zn were found 3.25%, 224.33 kg/ha, 15.43 kg/ha, 269 kg/ha, 2.70%, 0.67%, 0.13%, 27 ppm, 13.95 ppm, and 33.80 ppm respectively in 2nd-year soil for the treatment of T_3. However, the minimum average SOC, 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%, 0.53%, 0.05%, 10.8 ppm, 3.17 ppm and 8.80 respectively in 1st-year soil by the T_0 treated plot. The soil pH was significantly reduced due to the application of FYM whereas the minimum soil pH was 7.71 in 2nd-year soil for the application of 7 MT FYM/ha/year (T_2) followed by the treatments of T_3, T_1, and T_0respectively (Table 6.2).

Table 6.2. Effect of FYM on post-harvest soil properties

Treatments	pH		Organic Carbon (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)		Ca (%)		Mg (%)		Na (%)		Mn (ppm)		Cu (ppm)		Zn (ppm)	
	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr
C	8.2a	8.10b	0.29cf	0.30c	129.00b	130.33b	11.10d	11.20d	204.00d	205.67d	1.69e	1.70de	0.53e	0.55d	0.05d	0.07cd	11.00d	10.8d	3.71d	3.74d	8.80c	8.93c
B	7.91c	7.84c	0.20d	0.222d	189.00a	201.67a	13.00c	13.10c	238.67c	240.33c	1.72cd	1.73c	0.53e	0.54de	0.06cd	0.07bc	11.20d	11.3d	4.5c	4.54c	10.40b	10.5b
FYM	7.72dc	7.71d	2.66b	2.68b	189.00a	190.67a	13.40b	13.50b	256.00b	257.67b	2.31b	2.33b	0.55d	0.56c	0.07cd	0.0.08b	17.c	18.9d	5.00bc	5.06b	10.50b	10.67b
B+FYM	7.86c	7.84c	3.23ab	3.25a	199.67a	224.33a	15.3a	15.43a	267.00a	269.00a	2.69a	2.70a	0.65b	0.67a	0.11a	0.13a	23.0db	27.0a	13.90a	13.95a	33.70a	33.80a

Here, C = Control, B = BSRTI recommended basal dose of NPK (BRBD), FYM = 7 MT FYM/ha/year and B+FYM = 7 MT FYM/ha/year + B. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

6.3.2. Effect of FYM and cropping years on growth and yield of mulberry plant

Total branches number per plant

The total branches number per plant was highly significant ($P \leq 0.001$) by the fertilizer treatments and the cropping years. The more remarkable increasing trend was observed for B+FM treatment. Between the two cropping years the recorded total branches number were 10.48, 11.80,11.89 and 13.62 in 1st year for the treatments of control, basal, FM and B+FM respectively. Similarly, in 2nd-year total branches number were 10.39, 12.20, 13.49 and 15.42 for the same treatments respectively (Figure 6.1; 6.3).

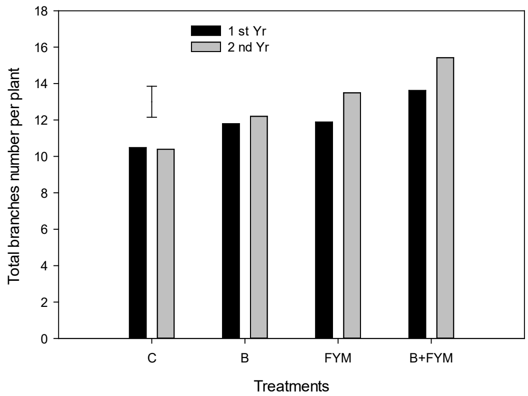

Figure 6.1: Total branches number per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years interactions.

Total branches height per plant (cm)

The highly significant ($P \leq 0.001$) trend was observed among the fertilizer treatments, the cropping years as well as their interactive effect irrespective to total branches height of the mulberry plant (Figure 6.2; Table 6.3). The B+FM treatment showed more increasing velocity among the treatments. However, in 1st year the total branches height were 784.34, 1012.71, 1063.37 and 1192.27 cm due to the application of control, basal, FM, and B+FM treatments respectively. Correspondingly, in 2nd year the total branches height were 783.57, 1014.08, 1244.37 and 1363.27 cm respectively for the above-mentioned treatments respectively (Figure 6.2; 6.3).

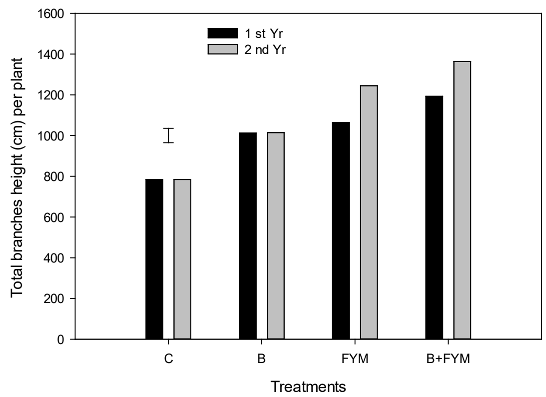

Figure 6.2: Total branches height per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years interactions.

Nodes per meter per plant

The nodes per meter of the mulberry plant was highly significant ($P \leq 0.001$) among the fertilizer treatments and between the two cropping years (Figure 6.3; Table 6.3). The more remarkable rising trend was found for the B+FM treatment. However, the recorded nodes per meter were 17.70, 19.79, 20.72 and 22.04 in 1st year for the treatments of control, basal, FM and B+FM respectively. Similarly, in 2nd-year nodes per meter were 17.99, 20.50, 22.92 and 24.44 respectively due to the same treatments (Figure 6.3; 6.3)

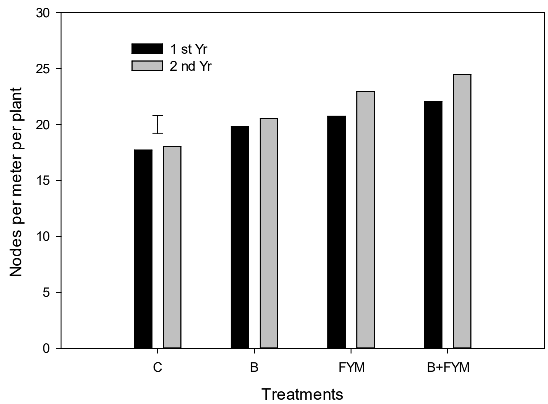

Figure 6.3: Nodes per meter in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years interactions.

Table 6.3. Level of significance for the main and interaction effect on fertilizer treatments and cropping years

Source of variation	Total branches number per plant	Total branches height per plant (cm)	Nodes per meter per plant	Total shoots weight per plant (g)	10 leaves area (cm) per plant	10 leaves weight (g) per plant	Total leaves weight per plant (g)	Total leaf yield/ ha/yr (MT)
Treatments	***	***	***	***	***	***	***	***
Cropping years	*	***	**	***	***	***	**	**
Treatments × Cropping years	n. s.	***	n. s.	***	***	**	**	**

Note. Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

Total shoots weight per plant (g)

The highly significant ($P \leq 0.001$) trend was found among the fertilizer treatments, between the two cropping years as well as their interactive effect (Figure 6.4; Table 6.3). The more marked increasing trend was found for the B+FM treatment. Nevertheless, in 1st year the total shoots weight was 351.78, 482.61, 500.78 and 555.45g respectively for the treatments of control, basal, FM, and B+FM respectively. At the same time, in 2nd-year total shoots weight was 352.28, 484.54, 525.54 and 598.13g respectively for those treatments (Figure 6.4; 6.3).

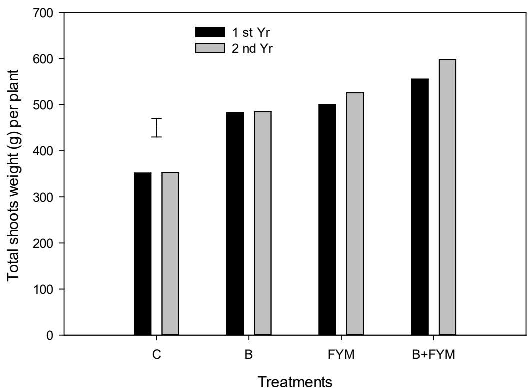

Figure 6.4: Total shoots weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years interactions.

10 leaves area (cm^2) per plant

The 10 leaves area of the mulberry plant was highly significant ($P \leq 0.001$) among the fertilizer treatments, between the cropping years as well as their interactive effect. The B+FM treatment showed the maximum increasing trend. However, the recorded 10 leaves area was 429.25, 530.27, 546.27 and 587.26 cm^2 respectively in 1st year for the treatments of control, basal, FM and B+FM respectively. Correspondingly, in 2nd year the 10 leaves area was 430.57, 530.47, 569.27, and 613.66 cm^2 respectively for the said treatments (Figure 6.5; Table 6.3).

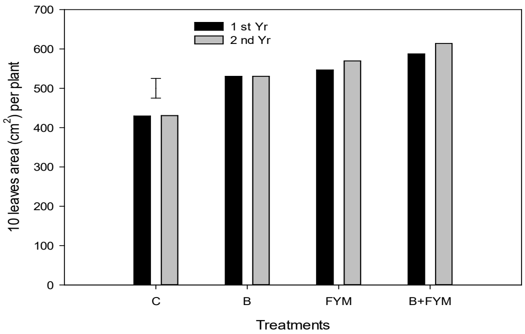

Figure 6.5: 10 leaves area per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years interactions.

10 leaves weight per plant (g)

The highly significant ($P \leq 0.001$) variation was found among the fertilizer treatments, between the cropping years as well as their interactive ($P \leq 0.01$) effect irrespect to 10 leaves weight of the mulberry plant. The more remarkable rising trend was found for B+FM treatment. However, in 1st year the 10 leaves weight was 20.30, 24.16, 26.11 and 33.51g for the treatments of control, basal, FM and B+FM respectively. Similarly, in 2nd year 10 leaves weight was 20.32, 24.42, 30.38 and 36.81 g for the above mentioned treatments respectively (Figure 6.6; Table 6.3).

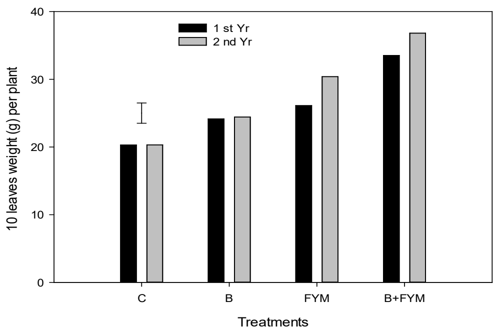

Figure 6.6: 10 leaves weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (P= 0.05) different fertilizer treatments and mulberry cropping years interactions.

Total leaves weight per plant (g)

The total leaves weight of the mulberry plant was significantly ($P \leq 0.001$) differed among the fertilizer treatments, between the cropping years ($P \leq 0.01$) as well as their interactive ($P \leq 0.01$) effect. The more marked trend was recorded for the B+FM treatment. However, the total leaves weight were 500.98, 574.01, 624.13 and 873.03 g in 1st year for the treatments of control, basal, FM, and B+FM respectively. Correspondingly, in 2nd-year total leaves weight were 496, 574.01, 647.13 and 902.81 g respectively for the said treatments (Figure 6.7; Table 6.3).

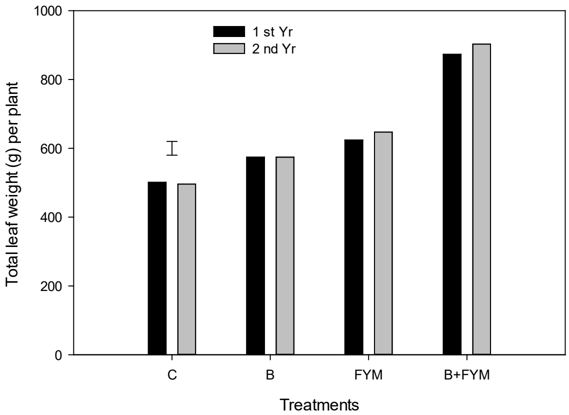

Figure 6.7: Total leaves weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (*P*= 0.05) different fertilizer treatments and mulberry cropping years interactions.

Total leaf yield/ha/yr (MT)

The highly significant ($P \leq 0.001$) trend was observed among the fertilizer treatments, between the cropping years ($P \leq 0.01$) as well as their interactive ($P \leq 0.01$) effect in respect of total leaf yield of the mulberry plant The more marked increasing trend was found for the B+FM treatment. However, between the two cropping years the leaf yields were 24.05, 27.55, 29.96, and 41.91 MT in 1st year due to application of control, basal, FM and B+FM treatments respectively. Similarly, in 2nd-year total leaf yields were 23.81, 27.55, 31.06, and 43.33 MT per hectare per year respectively for the same treatments (Figure 6.8; Table 6.3).

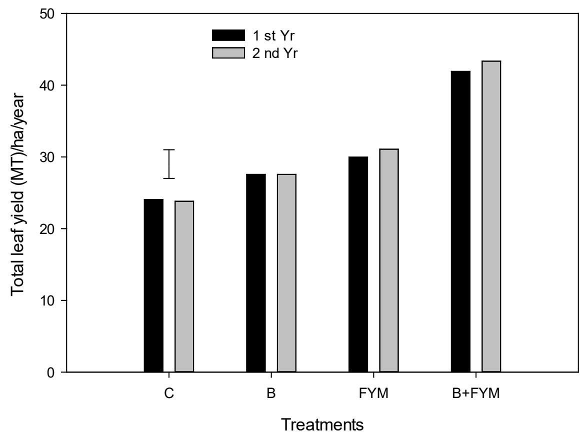

Figure 6.8: Total leaf yield per hectare per year in mulberry plants as influenced by the fertilizer treatments. Where, C = Control, B = BSRTI recommended basal dose of NPK, FYM = Only 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. The vertical bar represents LSD (*P*= 0.05) for different fertilizer treatments and mulberry cropping years interactions.

6.3.3. Effect of FYM and cropping years on leaf quality of mulberry

The biochemical constituents of mulberry leaf viz: moisture, soluble carbohydrate, crude protein, total mineral and total sugar percentages were significantly differed by the fertilizer treatments but similar trends were observed between the cropping years. However, between the two cropping years the maximum moisture, soluble carbohydrate, crude protein, total mineral and total sugar were 72.83%, 9.62%, 18.35%, 13.71% and 5.62% respectively in 2nd year for the treatment of B+FYM followed by the FYM, B and C treatments respectively. On the contrary, the minimum moisture, soluble carbohydrate, crude protien, total mineral and total sugar were 69.68, 7.26, 15.29, 7.88 and 3.62 percent respectively for the control treatment in 2nd year mulberry leaf except soluble carbohydrate and total mineral (Table 6.4).

Table 6.4. Effect of FYM on the biochemical properties of the mulberry leaf

Treatments	Moisture (%)		Soluble carbohydrate (%)		Crude protein (%)		Total mineral (%)		Total sugar (%)	
	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr
C	69.70b	69.68b	7.26a	7.29a	15.61bc	15.29c	7.88c	7.92c	3.65a	3.62a
B	69.81b	70.63ab	7.40a	8.06a	15.68bc	15.56bc	9.60bc	10.34bc	4.78a	5.24a
FYM	70.52ab	72.66a	7.50a	8.96a	16.85abc	17.88ab	9.98bc	10.80abc	4.89a	5.43a
FYM +B	70.77ab	72.83a	7.58a	9.62a	17.34abc	18.35a	11.85ab	13.71a	5.08a	5.62a

Here, C = Control, B = BSRTI recommended basal dose of NPK (BRBD), FYM = 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

6.3.4. Effect of FYM and cropping years on foliar diseases of the mulberry plant

The incidence percentage of foliar diseases viz: powdery mildew, leaf spot, and tukra of the mulberry plant were significantly ($P \geq 0.05$) differed among the fertilizer treatments and the cropping years. However, in the case of powdery mildew, the lowest incidence percentage was 3.29 in 2nd year's crop due to the application of B+FYM treatment. A similar trend was observed in the incidence percentage of 1st year for the treatment of FYM. On the other hand, the higher incidence percentage of powdery mildew was 11.39 in 1st year for the treatment of control. This incidence percentage was statistically similar with the incidence % of 2nd year for the same (control) treatment (Table 6.5).

Similarly, the lowest incidence of leaf spot disease was 3.93% for the treatment of B+FYM in 2nd year. This frequency percentage was statistically similar with the incidence percentage of 2nd year for the single application of FYM treatment. On the other hand, the higher occurrence% of leaf spot disease was 11.36 in 1st year for the treatment of control. A similar trend was found for the 2nd year also for the control treatment (Table 6.5).

Correspondingly, the minor incidence of tukra was 2.62 % for the treatment of B+FYM in 2nd year. This incidence percentage was statistically similar with the incidence % of 1st year for the B+FYM treatment and the incidence % of single applied FYM both for the 1st and 2nd years. However, the major occurrence for the tukra was 10.03% in 1st year which was statistically similar to 2nd year for the treatment of control (Table 6.5).

Table 6.5. Effect of FYM on foliar diseases of the mulberry plant

Treatments	Powdery mildew		Leaf Spot		Tukra	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
C	11.39a	11.33a	11.36a	11.28a	10.03a	9.99a
B	10.73a	10.67a	10.17a	10.09a	8.24b	8.19b
FYM	5.28b	3.52cd	6.46b	4.64c	4.33c	2.91c
B+FYM	5.03bc	3.29d	5.55bc	3.93c	4.16c	2.62c

Here, C = Control, B = BSRTI recommended basal dose of NPK (BRBD), FYM = 7 MT FYM/ha/year and B+FYM = B+7 MT FYM/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

6.4. DISCUSSION

6.4.1. Role of FYM on changes in physio-chemical properties of soil

Farmyard manure (FYM) has a positive impact on improving soil properties. Findings showed that among the four types of fertilizer management the application of FYM significantly increased the content of organic carbon (OC), N, P, K, Ca, Mg, Na, Mn, Cu, and Zn in soil. The, unlike soil pH, was significantly reduced due to the application of only 7 MT FYM/ha/yr. These pH values were increased due to the application of basal treatment followed by the combined application of B+FYM treatment. The above findings were similar with the previous findings of Devi *et. al.,* (2018). They found that the soil pH was significantly reduced due to the application of only 8-10 MT FYM/ha/yr and also the combined application of 25% inorganic fertilizer plus 8-10MT FYM/ha/yr. They speculated that due to the accumulation of organic acids from microbial metabolism or from the production of fulvic and humic acid decomposition by the soil-applied FYM the soil pH was reduced. Similarly, Kunj *et. al.,* (2018) also found that the soil pH value (7.40) was reduced due to the application of FYM + NPK fertilizer treatments, respectively as compared to the pH values of 7.75 and 7.81 in NPK fertilizer and control treatments respectively. They reported that the soil pH was decreased may be due to the release of organic acids and carbon dioxide (CO_2) into the soil during the decomposition of the manure. In this study the soil pH was reduced in FYM treated soil might be due to the decomposition and mineralization of organic matter through applied organic FYM and produce of organic acids which were closely related with the previous findings of Sing *et. al.,* (1980). They reported that the application of FYM decreased the soil pH due to the decomposition and mineralization of organic matter.

The experimental result showed that the combined application of 7 MT FYM/ha/yr with BSRTI recommended dose of NPK treatment and only 7 MT FYM/ha/yr treated soil gave the significantly higher percentage of organic carbon content, 3.25%, and 2.68% respectively over the control (0.30%). This finding was similar with the previous findings of Kunj *et. al.,* (2018). They found that the application of FYM either alone or in combination with NPK increases in build-up soil organic carbon under FYM and FYM + NPK treatments. These increased were 43.1 and 27.5 percent respectively greater over the NPK fertilizer and control treatments respectively.

The quantities of the available form of all the three major soil nutrients viz: nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) were found comparatively higher (224.33, 15.43 and 269) respectively due to the combined application of B+FYM treatment followed by the other treatments that were similar with the previous findings of Devi *et. al.,* (2018). They found that the combined application of 75% reduced dose of recommended N and P + 8-10 MT/ha/yr FYM soil content the maximum N (217.36 kg/ha), P (35.06 kg/ha) and K (337.30 kg/ha) respectively compared to the only recommended doses of chemical fertilizers. Their speculation was the organic carbon content increased could be due to attribute the higher contribution of biomass to the soil in the form of stubble and residues of FYM and oxidation of organic matter microbes.

In addition, the highest content of available nutrients viz: N, P, and K might be due to the improvement of physical and chemical properties and better nitrogen-fixing capacity of Azotobacter, P solubilization and mobilization by *A. awamori* and *T. harzianum* in presence of FYM. However, in my study, the combined application of FYM + NPK could provide adequate biomass through more decomposition as a feed for the microbes and helps in increasing the microbial population in the soil. In terms, the count of all the microbes was sustainably increased resulting in the soil nutrients viz OC, N, P, and K content were comparatively higher followed by the other treatments. In addition, farmyard manure may stimulate biological N_2 fixation in the soil. That may have been responsible for increased the soil N and increase in available K in plots receiving FYM applied either alone or in combination with NPK may be ascribed to the direct potassium addition in the potassium pool of the soil. Kunj *et. al.,* (2018) also found that the increase in Olsen- P in plots receiving FYM applied either alone or in combination with NPK 33.22 % and 52.26 % respectively than control. Their assumption was due to the release of organically bound P during decomposition of organic matter, solubilization of soil P by organic acids produced during decomposition of organic matter. The above concept was agreed by Prabhuraj *et. al.,* (2005). They found that different types of organic manures provide adequate biomass as feed for the microbes and helps in increasing microbial population in the soil beside the combination of FYM with NPK recorded a significantly higher population of inoculated phosphate solubilizing microorganism and N-fixing bacteria.

The others soil micronutrients viz: calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), cupper (Cu) and zink (Zn) were also increased due to the combined application of 7 MT FYM/ha/yr with BRBD of NPK (T_3) (Table 6.1). Likewise, Pratab *et. al.,* (2016) found that due to the application of 100% RDF (NPK+$ZnSO_4$) + 10 t/ha FYM increased the Zn (0.65 ppm) content in soil compared to control (0.33 ppm). In another study, Zhang *et. al.,* (2015) found that the soil micronutrients viz: Iron (Fe), Mn, Cu, and Zn were increased due to the management of organic matter (straw) + NPK over to the control treatment. The soil-applied FYM with BSRTI recommended basal dose of NPK may be content maximum amount of organic matter with high levels of total and available nutrients. These effects improved the soil microbial population as well as enhanced the organic matter decomposition rate, changed the soil structure, increased availability of nutrients, and decreased the soil pH content within the soil. In terms of the soil micronutrient status viz: Ca, Mg, Na, Mn, Cu, and Zn were increased in B+FYM treatment than the others. This concept was similar, with the previous finding of Brady *et. al.,*(2002). They found that if the soil pH decreased than the solubility of plant-available Fe, Mn, Zn, and Cu were increased. Similarly, Mahmood *et. al., (*2017) reported that the application of organic manures increased micronutrient availability in soil.

6.4.2. FYM enhances growth and leaf yield of the mulberry plant

Remarkable variation was found on growth and leaf yield of the mulberry plant due to the utilization of FYM for mulberry plant production (Table 6.3). Among the different fertilizer management, maximum total branches number, total branches height, nodes per meter, total shoots weight, 10 leaves area, 10 leaves weight and total leaves weight per plant, as well as total leaf yield/ha/year, were recorded for the treatment of 7 MT FYM/ha/yr with BSRTI recommended basal dose of NPK (B+FYM) followed by the FYM, basal and control treatments respectively. The maximum leaf yield was found 43.33 MT ha/year for B+FYM treatment followed by the FYM, basal and control treatments respectively. This leaf yield was 39.50%, 57.28%, and 80.17%

respectively greater compared to the maximum leaf yield of the only FYM, basal and control-treated plots correspondingly. The above finding was similar with the earlier findings of Ram *et. al.,* (2017). They found that the combined application of 5 MT/ha FYM + 2 MT/ha press mud treated mulberry plot showed the maximum number of total shoots/plant, total length of shoots/plant, total leaves/plant and total leaf yield MT/ha per year. In the same way, Chowdhury *et. al.,* (2009a) found that the mulberry plot treated by the 20 MT FYM/ha/year plus N_{336}:P_2O_{180}:K_2O_{112} kg/ha/year gave the maximum number of branches per plant, plant height, leaf area and leaf yield/kg/ha/crop compared to control treatment. Ranadive *et. al.,* (2011) found that the leaves weight and leaf area of the mulberry plant were increased due to farmyard treated mulberry plants.

Furthermore, they also showed that the leaves weight was positively correlated with the dose (1.98 g to 2.98 g) of farmyard manure respectively. The beneficial effect of FYM + inorganic nutrients on growth attributes and leaf yield of the mulberry plant could be due to higher content of nutrients, proper or balanced decomposition, mineralization, solubilizing and availability of sufficient essential nutrients for the plant. These positive combined effects enhanced the balanced nutrient management, helped better soil physical environment coupled with the sufficiency of water, nutrients uptake as well as improved nutritious growth and establishment of the mulberry plant. So, the yield contributing characters and leaf yield of the mulberry plant was optimum in the combined application of B+FYM treatment followed by the single application of FYM, basal and control-treated plant respectively. The above speculation was aggregated with the previous findings (Kunj *et. al.,* 2018). They reported that the deficiency of essential nutrients in soil has caused nutritional, anatomical, and histological disorders in the mulberry plant.

In addition, unbalanced nutrient management has an adverse effect on crop productivity, conversely, nutrient availability as well as proper decomposition, mineralization, solubilizing, and availability of maximum nutrients effect of organic manure (FYM) has a beneficial effect on growth attributes and leaf yield of the mulberry plant. They also reported that the application of FYM either alone or in combination with NPK was higher N-68.51%, 69.75%, P-64.73%, 65.7%, and K-51.2%, 58.36% respectively, resulted in considerable changed, N, P and K uptake by the mulberry plant. That was affected by balanced fertilizer application and hence the yield was increased in FYM treatment compared to control.

6.4.3. FYM improves leaf quality of mulberry plant

Farmyard manure had an important impact on the improvement of the leaf quality of the mulberry plant. The above leaf nutritional result revealed that the combined application of 7 MT FYM/ha/year along with BSRTI recommended basal dose of NPK (B+FYM) was increased the moisture, soluble carbohydrate, crude protein, mineral and total sugar contents were 4.49, 31.96, 17.55, 73.11 and 53.97 percent respectively over the maximum values of control treatment. Interestingly, crude protein and mineral content in B+FYM treated mulberry plant were statistically higher among all treatments except the single application of FYM. Besides, the result for a single application of FYM was better followed by the basal and control treatments respectively. The above finding was similar with the earlier findings of Ram *et. al.,* (2017). They found that the application of 5 MT FYM/ha with 1 MT press mud/ha gave the higher 76.84% moisture, 1.67 mg/g total chlorophyll, 25.78 mg/g total soluble protein, and 34.85 mg/g total soluble sugar among all treatments. In the same way, Umesha *et. al.,* (2014) found that the application of (50 % of Rec. FYM) + FYM (50% of Rec. FYM) + N-biofertilizer + P-biofertilizer + 200N + 110P + 140 K kg/ha/yr showed the better leaf moisture followed by sheep manure (Equivalent to 50% of Rec. FYM) + FYM (50 % of Rec. FYM) + N-biofertilizer + P-biofertilizer + 200N + 110P + 140 K kg/ha/yr and over to the control. In this study, the moisture percentage was greater may be due to the more moisture absorption and increased the soil fertility status for treated the soil by 7 MT FYM/ha/year + basal treatment. This concept was lined with the previous concept of Rao *et. al.,* (2011). They reported that the enhancement of leaf moisture due to the application of organic manures (FYM) might be due to the enhancement of organic matter and water holding capacity in the soil, thereby, absorption of water by the plant was increased.

Similarly, Umesha *et. al.,* (2014) also found that the application of (50 % of Rec. FYM) + FYM (50% of Rec. FYM) + N-biofertilizer + P-biofertilizer + 200N + 110P + 140 K kg/ha/yr treated mulberry garden statistically more total sugar content followed by sheep manure (Equivalent to 50% of Rec. FYM) + FYM (50 % of Rec. FYM) + N-biofertilizer + P-biofertilizer + 200N + 110P + 140 K kg/ha/yr and over to control-treated plot. They speculated that due to the improved mineralization resulting in enhanced production of plant growth substances and enzyme activity in mulberry through the (50 % of Rec. FYM) + FYM (50% of Rec. FYM) + N-biofertilizer + P-biofertilizer + 200N + 110P + 140 K kg/ha/yr treated mulberry garden. That was enhanced total sugar content in mulberry leaf. Similarly, Rashmi *et. al.,* (2009) also found the higher total sugar content in mulberry due to the application of chemical fertilizers along with FYM. In another study, Devi *et. al.,* (2018) found that the protein and carbohydrate content percentage was significantly increased due to the application of 8-10 MT FYM/ha/year.

In the same way, in this study the protein and carbohydrate content were increased could be due to the combined application of 7 MT FYM/ha/year with BSRTI recommended basal dose of NPK. Because, this combined application fertilizer dose may contain the maximum amount of organic matter, macro, and micronutrients in available forms. These mutual effects enhanced the proper decomposition of organic matter, balanced uptake, and growth of mulberry plant as a result the protein and carbohydrate content were higher in B+FYM treated mulberry plot compared to the other fertilizer treatments.

6.4.4. FYM application suppresses foliar diseases of the mulberry plant

Farmyard manure significantly reduced the infestation of foliar diseases viz: powdery mildew, leaf spot, and tukra of the mulberry plant. The results showed that among the four types of fertilizer management the incidence of leaf spot, powdery mildew, and tukra diseases were comparatively low for 7 MT FYM/ha/yr + BSRTI recommended basal dose of NPK (B+FYM) treated mulberry plant over the control. The experimental results revealed that the powdery mildew and leaf spot diseases severity were 71.30 and 65.40 % respectively lower in 7 MT FYM/ha/yr + BRBD of NPK treated mulberry plot followed by the maximum incidence of the control-treated plot. The above findings were similar with the previous findings of Maji *et. al.,* (2013). They found that the infestation of powdery mildew and leaf spots were 4.47 and 4.40 percentage respectively for 20 MT/ha/yr FYM + NPK (336: 180: 112 kg/ha/yr) treated mulberry plant, whereas the infestation of powdery mildew and leaf spot in control treatments were 10.06 and 15.22 percent respectively. They speculated that the reduction of Powdery mildew and leaf spot disease severity on the recommended dose of FYM and NPK may be due to the application of balanced organic (FYM) and inorganic (NPK) fertilizers. That helps to enriched soil beneficial mycoflora and supply of nutrients for the robust growth of plants. That might be brought forth resistance to diseases.

Similarly, Ranadive *et. al.,* (2011) found that the infestation of fungus population was reduced due to the application of farmyard manure in the soil. The incidence of tukra disease caused by mealybug (*Maconellicoccus hirsutus*) was also significantly reduced due to the same (B+FYM) fertilizer management. The maximum incidence percentage was 10.03 in control treatment which was statistically 73.88 % greater than the B+FYM treated mulberry plant. In a previous study, Samuthiravelu *et. al.,* (2012) found that the average incidence of pest tukra mealybug was minimum in the treatment of organic fertilizer (Panchakavya 10 %) which was more or less similar with this experimental finding.

However, in this study, the incidence of foliar diseases viz: powdery mildew, leaf spot, and tukra were considerably reduced in B+FYM treated mulberry plant might be due to more amounts of organic nutrients contain by the applied farmyard manure. Because, these nutrients are essential for microbes, plant growth, and produced of phenolic compounds both within the soil and plant. These synergic impacts could be enriched by the beneficial bacterial population. Resulting in the successive growth and establishment of the mulberry plant as well as induction of systemic resistance against the fungal foliar diseases and pest was enlarged in B+FYM treated mulberry plant. Thus the combined application of 7 MT FYM/ha/yr + BRBD of NPK in mulberry garden reduced the incidence of mulberry foliar diseases viz: powdery mildew, leaf spot, and tukra.

6.4.5. Effect of cropping year on soil properties, productivity, leaf quality and foliar diseases of the mulberry plant

In respect of the application duration of farmyard manure (FYM), the soil physio-chemical properties were some extent to differ in soil. The experimental results showed that most of the soil physicochemical properties viz: N, P, K, Ca, Mg, Na, Mn, Cu and Zn except soil pH were some extent to increased in 2nd year due to the amendment of 7 MT FYM/ha/yr + BSRTI recommended basal dose of NPK. The maximum soil pH was 8.2 in 1st year for control treatment but the minimum pH was 7.71 in 2nd year for the treatment of FYM. This value of soil pH was statistically similar with the soil pH value 7.84 for the treatment of B+FYM in 2nd year. However, in 2nd year the soil pH was 5.97% reduced in soil treated by the only 7 MT/ha/yr FYM over the control treatment. The maximum nitrogen content was recorded in 2nd-year soil for B+FYM treated soil which was statistically similar with the FYM and basal treatments respectively treated soil of 1st year (Table 6.2).

The maximum OC, N, P, K, Ca, Mg, Na, Mn, Cu, and Zn were recorded in 2nd-year soil for B+FYM treated soil. These values were 0.62%, 12.35%, 0.85%, 0.75%, 0.37%, 3.08%, 18.18%, 17.39%, 0.36% and 0.30% respectively greater than the 1st year soil for the same (B+FYM) treatment. A similar trend was observed by Malle *et. al.,* (2017). They found that in the year of 2008 the P, K and Mg content in soil was 195, 140 and 64 mg/kg respectively but in the year of 2014 the P, K and Mg content in soil was 210, 152 and 99 mg/kg respectively due to application of FYM and also the organic carbon content was increased due to FYM application irrespective to application duration. In the same way, Musaida *et. al.,* (2013a) also found that increasing the organic matter application duration, the P content was increased by more than 80 ppm, K content was increased by more than 14 ppm and Cu content increased 8.0 ppm in soil. Because P does not exist in an elementary form and most of the P was insoluble in the organic compost (FYM) and unavailable to the soils and plants. But the increase of K due to the good nutrient absorbing properties of clay-loam soil and the micro-organisms in the FYM reloaded the soil with more K ions that hence the K increased in soil.

Similarly, increased the soil Cu content due to increased organic matter that resulted in improved soil aeration and microbial activity in the soil. In this study, it could be due to the application of farmyard manure both in the 1st year and 2nd year soil the total applied quantity of organic material was increased as well as the soil micro-organisms activities were abundant in 2nd year soil than the 1st year soil. This beneficial effect improved the Zn and Mn content because FYM is a rich organic material that is lined with the previous findings of Mortvedt (2000). He reported that the presence of organic material in the soil increased the micro-organisms activities as well as improved the soil aeration due to the movement thereby increasing Zn and Mn content availability in soil. However, irrespective of application duration FYM may be promoted to the steady and slow release of nutrients in the soil. In addition, the combined application of inorganic NPK along with FYM as a basal dose for each year the overall soil nutrients quality viz: OC, N, P, K, Ca, Mg, Na, Mn, Cu, and Zn were comparatively increased in 2nd year than the 1st year soil.

The growth, leaf yield and leaf quality of the mulberry plant were showed a significant trend between the cropping years due to the application of farmyard manure in the soil. Between the two cropping years the maximum growth and yield parameters of mulberry viz: total branches number per plant, total branches height, nodes per meter, total shoots weight, 10 leaves area, 10 leaves weight and total leaves weight per plant, as well as total leaf yield/ha/year, were in 2nd year for the combined application of B+FYM treatment followed by the FYM, basal and control treatments respectively. Even the recorded above mentioned growth parameters were 13.22, 14.34, 10.89, 7.68, 4.5, 9.85 and 3.41 percent respectively greater in 2nd year than the maximum values of 1st year. However, the leaf yield was 3.39% greater in 2nd year compared to 1st year.

Similarly, the leaf quality parameters viz: moisture, soluble carbohydrate, crude protein, total mineral and total sugar were 2.91, 26.91, 5.82, 15.70 and 3.54 % respectively greater in 2nd-year mulberry leaf than the maximum values of 1st-year mulberry leaf for the same fertilizer management. It may be due to the reasons that with respect to farmyard manure application duration along with inorganic NPK the decomposition of organic matter, microbial diversity, and populations of micro-organisms were improved in 2nd year. In addition, these positive impacts enhanced the soil physio-chemical properties, soil water holding capacity, soil fertility status; release of plant nutrients (Macro and micro) in the soil, as well as the availability of soluble macro and micronutrients, might be improved in 2nd year soil than the 1st year soil. Thus, the essential plant nutrient and growth regulators uptake by the 2nd year mulberry plant was sufficient quantity and balanced proportion than 1st year. Resulting the growth, development and establishment of mulberry plant was healthier in 2nd year than the 1st year. In terms the growth and leaf yield, as well as the leaf quality parameters viz: moisture (%), soluble carbohydrate (%), crude protein (%), total mineral (%) and total sugar % were increased in 2nd year than the 1st year crop.

The incidences of foliar diseases in the mulberry plant were comparatively reduced irrespective of the application duration of farmyard manure. The incidence of foliar diseases viz: leaf spot, powdery mildew, and tukra were observed in two different cropping years. The results showed that increasing the FYM application duration the intensity of mulberry foliar diseases viz: leaf spot, powdery mildew, and tukra were reduced from 1st year to 2nd-year crop. However, the incidence of all the three diseases viz: powdery mildew, leaf spot, and tukra were 34.59, 29.19, and 37.02 % respectively reduced in 2nd year compared to the minimum incidence percentage of 1st-year crop irrespective to B+FYM treatment. Furthermore, the lower incidences of powdery mildew, leaf spot, and tukra diseases were 71.12, 65.40 and 73.88 % respectively reduced in 2nd year compared to the maximum incidences percentage of 1st year irrespective to control treatment.

The reduction of foliar diseases in the mulberry plant irrespective of FYM application duration could be due to the slow decomposition and slow release of organic nutrients. Because these nutrients are essential for microbes, created phenolic compounds and plant growth regulators as well as the production of maximum various growth substances or hormones irrespective of application duration of FYM + inorganic NPK in 2nd-year soil than to 1st year. Thus the mutual application of FYM + BRBD of NPK treated mulberry plant created more resistance and defense mechanism against the fungal pathogens as well as the mealybug pest of tukra in 2nd year than the 1st year. Resulting, the incidences of powdery mildew, leaf spot, and tukra diseases were comparatively reduced in 2nd year than the 1st year crop. The above concept was lined with the earlier findings of Sharma *et. al.,* (1994). 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 pathogen.

6.5. CONCLUSIONS

The current study revealed that organic amendments like farmyard manure (FYM) with inorganic fertilizers (NPK) have a sound effect on mulberry plant productivity and suppresses of foliar diseases due to application interval. Furthermore, increasing the application duration and combined utilization of the farmyard manure + basal dose of NPK have contributed to the higher leaf yield and quality of mulberry leaf as compared to only the BSRTI recommended basal dose of NPK. This chapter concluded that the mutual application of B+FYM improves the fertilizer use efficiency and soil nutrient status in terms of yielding ability, leaf quality as well as reducing the incidence of foliar diseases of mulberry irrespective to application duration.

The performance of FYM utilization in terms of mulberry plant production was better than the findings from the previous chapters. The aimed of this PhD work to find out the advanced fertilizer management technique for mulberry cultivation to attain the sustainable mulberry plant production. However, the previous researchers reported that vermi-composts are the microbial composting organic wastes through earthworm activity to form organic fertilizer that contain a higher level of organic matter, organic carbon, total, and available N, P, K and micronutrients compared to the farmyard manure. Though the information on the impact of vermicompost for other agricultural crops was available but the utilization of vermicompost for mulberry plant production was scarcely available especially in Bangladesh. That’s why further investigation will be conducted to determine the effect of vermicompost on plant productivity and suppression of foliar diseases for mulberry in the following chapter (Chapter 7).

Chapter 7

Impact of vermi-compost on productivity and suppresses of foliar diseases of mulberry plant

Chapter 7

Impact of vermi-compost on productivity and suppresses of foliar diseases of mulberry plant

7.1. 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). They have greatly increased surface areas, providing more micro sites for microbial decomposing organisms, strong adsorption, and retention of nutrients (Shi-wei *et. al.,* 1991). Vermi-composts is the microbial composting of organic wastes through earthworm activity to form organic fertilizer which contain a 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). It contains most of the nutrients in plant-available forms such as nitrates, phosphorus, exchangeable calcium, and soluble potassium (Orozco, 1996). Due to its different production processes, vermi-compost might exhibit different physical and chemical features that might influence plant growth and morphology in diverse ways. It may be increased nutrient uptake status by the mulberry plant for the utilization of vermin-compost.

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). The continuous production of mulberry for a long time results in a gradual reduction in leaf yield and quality (Rashmi *et. al.,* 2009). 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). Hence, the quality of the mulberry leaf is one of the basic prerequisites of sericulture and plays a pivotal role in successful silkworm cocoon crop (Guttierrez *et. al.,* 1997).

Mulberry plant requires the macro and micronutrients 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 the mulberry leaf are directly influenced by the application of manures and fertilizers to soil (Murarkar *et. al.,* 1998). 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 the mulberry plant. The role of vermi-compost in improving the soil structure and thereby the bumper yields of conventional crops and the mulberry plant has been amply documented by Murarkar *et. al.,* (1998). Besides many studies have been demonstrated the effectiveness of vermi-compost in providing protection against various plant diseases (Chaoui, 2002).

The previous chapter showed that farmyard manure (FYM) enhances growth and yield of the mulberry plant. Likewise, utilization of FYM improves the leaf quality of the mulberry plant. Further, FYM suppresses common foliar disease of the mulberry plant (Chapter 6). Another organic fertilizer source like vermi-compost needs to be utilized for mulberry plant production. Regardless of that information on vermi-compost impact for mulberry plant production and suppression of foliar disease was hardly available particularly in Bangladesh. Though the vermi-compost was sporadically used for mulberry cultivation in other countries of the world but in Bangladesh it was totally new thought especially for mulberry cultivation. In this aspect, the present study was undertaken to estimate the impact of vermi-compost on soil properties, leaf yield, quality, and suppression of foliar diseases in the mulberry plant. It was hypothesized that vermi-compost will be enhanced the leaf yield, quality as well as suppress of foliar diseases in the mulberry plant through improving the better soil properties.

7.2. MATERIALS AND METHODS

7.2.1. 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). Based on Agro-Ecological Zone (AEZ), BSRTI, Rajshahi falls under the Active Ganges Floodplain-10 and High Ganges River Floodplain-11.

7.2.2. 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 was applied 20 DAPr (Days after Pruning) when the sprouting of the 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 was used as a testing plant. The plantation system was high bush. The plot size was 8 m × 3 m. Each plot contains 20 plants.

7.2.3. Experimental design and treatments

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

I. Control (C): (No input was applied).

II. Basal (B): Only the BSRTI recommended a basal dose of N_{300} P_{150} K_{100} kg/ha/year.
III. VC: Only 5 MT vermi-compost/ha/year.
IV. B+VC: B + 5 MT vermi-compost/ha/year.

7.2.4. Recorded growth parameters

Growth attributes namely, total branches number per plant, total branches height per plant (cm), nodes per meter, total shoots weight per plant (g), 10 leaves area per plant (cm^2), 10 leaves weight per plant (g), total leaves weight per plant and total leaf yield/ha/year (MT) were recorded crop-wise. Data were collected at 90 DAPr for each cropping season. Four times data was collected in a year. The annual yield was computed by pooling the four-season data. The green leaf yield per hectare per year was determined by the following formula:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2 \text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

7.2.5. 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 8.8. 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. The 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 the initial experimental plot soil are shown in Table 7.1.

Table 7.1. Initial basic physic-chemical 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

7.2.6. Analysis of soil

The soil pH was determined in deionized 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 the 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).

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). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et. al.,* 2012). The available P of the soil was determined by a spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by the Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005). Sodium, calcium, and magnesium content were determined following the method of Tandon (1993) and copper was estimated by atomic absorption spectrophotometer (AAS) Tandon, 1993). Manganese was estimated by Spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

7.2.7. 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 a 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), soluble carbohydrate (%) following Dubois *et. al.,* (1956) method, crude protein (%) following Kjeldahl's method (Wong, 1923), total mineral (%) following AOAC, (1980), total sugar (%) following Miller (1972) and Loomis *et. al.,* (1937) procedure (Mahewarappa *et. al.,* 1999).

7.2.8. 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*) and tukra (*Meconellicoccus hirsutus*) diseases respectively and data were collected at 60 days after pruning. Disease incidence (%) was assessed as the number of total mulberry leaves per plant was infected by powdery mildew, leaf spot and tukra diseases with any visible symptom of respective disease. The percentage of disease incidence (PDI) was calculated by using the formula of Rai and Mamatha (2005) which was as follows:

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

7.2.9. Statistical analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1thed^{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 were used for representing the results as a figure form. The leaf quality and disease data were statistically analyzed and mean values were evaluated by Duncan Multiple Range Test (DMRT) test through using the Statistic-10 software. In the case of soil, the mean values of post-harvest soil properties were recorded for this study.

7.3. RESULTS

7.3.1. 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 5 MT vermi-compost/ha/yr + BSRTI recommended basal dose of NPK (B+VC) followed by the other treatments (Table 7.2).

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 2^{nd}-year soil treated by the T_3 (BSRTI recommended basal dose of NPK + 5 MT vermi-compost/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 1^{st} year soil for the control treatment. The maximum average soil pH was 8.20 in 2^{nd}-year soil for control treatment whereas the minimum soil pH was 7.55 in 2^{nd}-year soil for the treatment of B+VC. Soil physicochemical properties were similar between cropping seasons except for soil pH and OC (Table 7.2).

Table 7.2. Post-harvest soil properties under different fertilizer treatments and two cropping years

Treatments	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
C	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
B	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
VC	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
B+VC	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, C = Control, B = BSRTI recommended basal dose of NPK, VC = 5 MT vermi-compost/ha/year, B+VC = B + 5 MT vermi-compost/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

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

Total branches number per plant

The total branches number per plant of mulberry was highly significant ($P \leq 0.001$) for the fertilizer treatments, cropping years, and their interactive effect (Table 7.3). The higher increasing trend was found for the application of B+VC treatment and the 2nd year's crop. However, the total branches numbers per plant were 10.45, 12.09, 12.53 and 13.98 in 1st year for the treatments of control, basal, VC, and B+VC respectively. Similarly, in 2nd year the total branches numbers were 10.39, 12.20, 15.93, and 17.58 respectively for the same treatments (Figure 7.1).

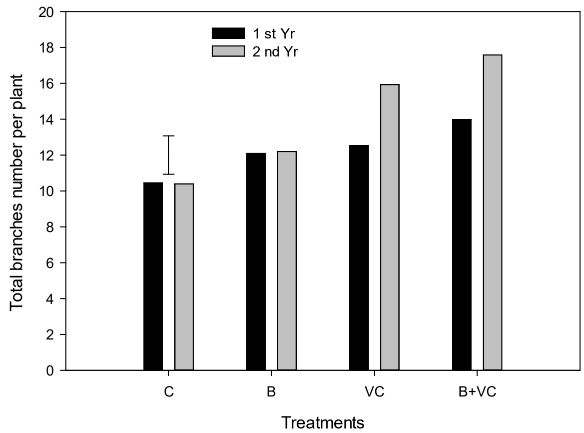

Figure 7.1: Total branches number per plant as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. The vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

Total branches height per plant (cm)

The highly significant ($P \leq 0.001$) trend was found among the fertilizer treatments, cropping years and their interactive effect irrespective to total branches height per plant of mulberry (Table 7.3). However, this rising development was more marked in B+VC treatment and 2nd year's crop. Between, the two cropping years in 1st year total branches height were 783.68, 1010.79, 1089.63 and 1248.08 cm for the application of control, basal, VC, and B+VC treatments respectively. Correspondingly, in 2nd year were 785.48, 1011.32, 1287.63 and 14.85.08 cm respectively for the mentioned treatments (Figure 7.2).

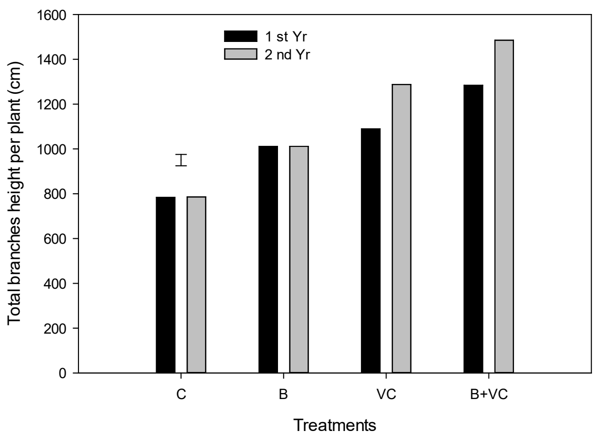

Figure 7.2: Total branches height per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. Vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

Nodes per meter per plant

The nodes per meter of mulberry was highly significant ($P \leq 0.001$) differed among the fertilizer treatments (Table 7.3). Similarly, the nodes per meter differed significantly ($P \leq 0.05$) between the cropping years. However, the B+VC fertilizer treatment and 2nd year's crop showed a more marked increasing trend. The average nodes per meter were 17.47, 20.47, 20.92 and 23.25 in 1st year due to management of control, basal, VC, and B+VC treatments respectively. Similarly, in 2nd-year nodes per meter were 17.23, 20.66, 22.92, and 25.25 respectively for those treatments (Figure 7.3; Table 7.3).

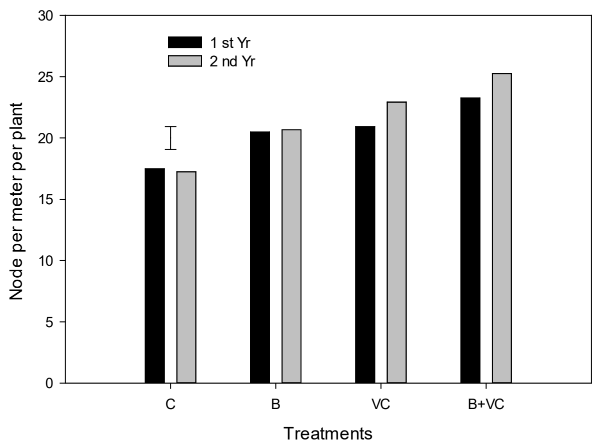

Figure 7.3: Nodes per meter in mulberry plants as influenced by fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. The vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

Table 7.3. Level of significance for the main and interaction effect on fertilizer treatments and cropping years

Source of variation	Nodes per meter per plant	Total branches number per plant	Total branches height per plant (cm)	Total shoots weight per plant (g)	10 leaves area (cm) per plant	10 leaves weight (g) per plant	Total leaves weight per plant (g)	Total leaf yield/ ha/yr (MT)
Treatments	***	***	***	***	***	***	***	***
Cropping years	*	***	***	***	***	***	***	***
Treatments × Cropping years	n.s.	***	***	***	***	***	***	**

Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

Total shoots weight per plant (g)

The application of fertilizer treatments, cropping years and their interactive effect was highly significant ($P \leq 0.001$) irrespective to the total shoots weight of the mulberry plant. This increasing trend was more noticeable for the B+VC treatment and the 2nd year's crop. However, the total shoots weights were 349.82, 481.95, 509.64 and 577.60 g in 1st year for the treatments of control, basal, VC and B+VC respectively. On the other hand, in 2nd year total shoots weights per plant were 350.31, 483.47, 544.30 and 645.77 g respectively for the same treatments (Figure 7.4; Table 7.3).

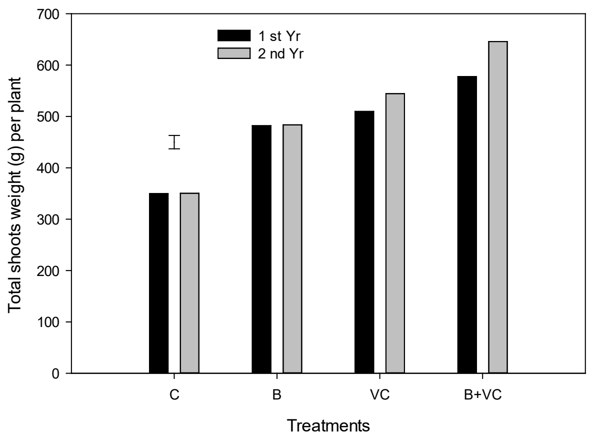

Figure 7.4: Total shoots weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. The vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

10 leaves area (cm^2) per plant

The 10 leaves area of mulberry plant was significantly ($P \leq 0.001$) increased due to the fertilizer treatments, cropping years and their interactive effect. However, the B+VC treatment and 2nd year's crop more presented this increasing trend. The 10 leaves areas were 428.40, 530.44, 562.27 and 590.43cm^2 in 1st year due to application of control, basal, VC and B+VC treatments respectively. Correspondingly, in 2nd year 10 leaves areas were 429.27, 530.37, 589.67 and 625.09 cm^2 respectively for the identical treatments (Figure 7.5; Table 7.3).

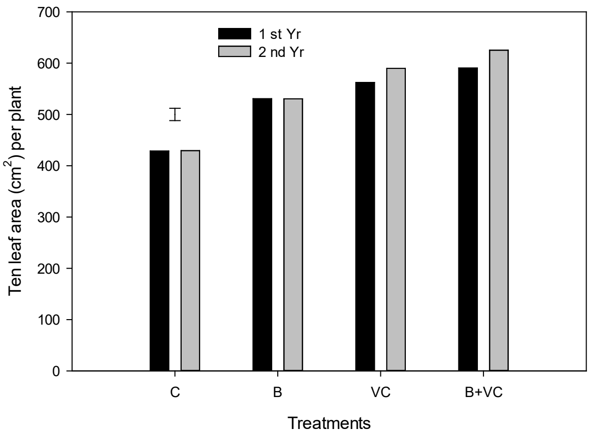

Figure 7.5: 10 leaves area per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. The vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

10 leaves weight per plant (g)

The highly was significant ($P \leq 0.001$) difference was found among the fertilizer treatments, cropping years and their interactive effect. This difference was more marked in B+VC treatment and 2nd year's crop. However, in 1st year the 10 leaves weights were 19.82, 24.38, 26.72 and 38.56 g for the treatments of control, basal, VC and B+VC respectively. Similarly, in 2nd year 10 leaves weights were 20.32, 24.42, 35.72 and 47.16 g for the same treatments (Figure 7.6; Table 7.3).

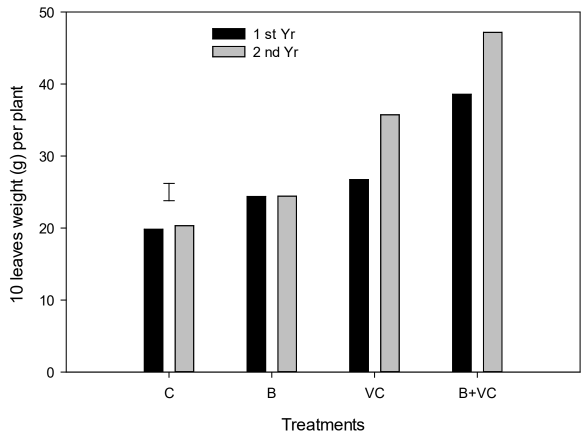

Figure 7.6: 10 leaves weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. Vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

Total leaves weight per plant (g)

The total leaves weight per plant was significantly ($P \leq 0.001$) increased due to the fertilizer treatments, cropping years, and their interactive effect. The B+VC treatment and 2nd year's crop presented this increasing trend more. However, the total leaves weights per plant were 498.18, 576.16, 646.75 and 1016.40 g in 1st year for the treatments of control, basal, VC and B+VC respectively. In the same way, in 2nd year total leaves weight per plant were 499.60, 581.78, 655.75, and 1052.36 g respectively for those treatments (Figure 7.7; Table 7.3).

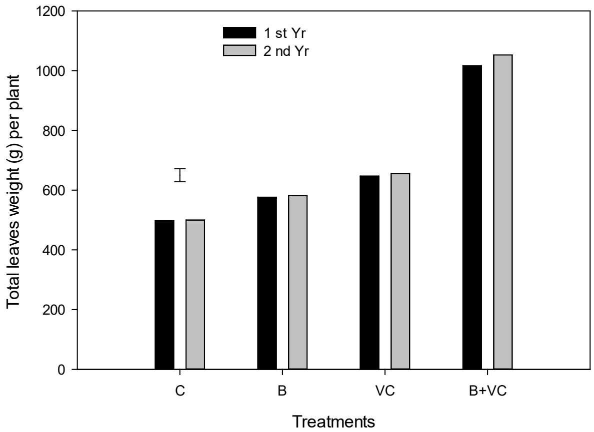

Figure 7.7: Total leaves weight per plant in mulberry plants as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. The vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

Total leaf yield/ha/yr (MT)

The highly significant ($P \leq 0.001$) increasing trend was found among the fertilizer treatments, cropping years, and their interactive effect. However, this increasing trend was more marked in B+VC treatment and 2nd year's crop. Between the two cropping years the total leaf yields were 23.91, 27.65, 31.04, and 48.79 MT/ha/yr in 1st year due to the application of control, basal, VC, and B+VC treatments, respectively. Similarly, in 2nd-year total leaf yields were 23.98, 27.92, 31.48, and 50.51 MT per hectare per year for the same fertilizer managements (Figure 7.8; Table 7.3).

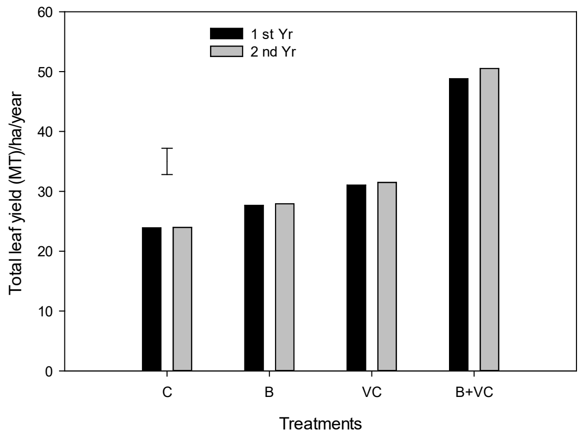

Figure 7.8: Total leaf yield per hectare per year as influenced by the fertilizer treatments. Where, C = control, B = BSRTI recommended basal dose of NPK, VC = Only 5 MT vermi-compost/ha/year, B+VC = BRBD + 5 MT vermi-compost/ha/year. Vertical bar represents LSD ($P \geq 0.05$) different fertilizer treatments and mulberry cropping year's interactions.

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

A statistically significant trend was found among the fertilizer treatments and between the cropping years irrespective of the leaf quality of the mulberry plant. The remarkable increasing trend was found for the B+LF treatment and 2nd year's crop. However, between the two cropping years the maximum moisture, soluble carbohydrate, crude protein, mineral, and total sugar were 74.10%, 11.31%, 20.10%, 14.20% and 6.77% respectively in 2nd year for the treatment of B+LF followed by the VC, basal and control treatments respectively. On the other hand, the minimum moisture, mineral and total sugar were 69.66%, 6.94% and 3.63 % respectively in 2nd year and minimum soluble carbohydrate and crude protein (%) were 7.29% and 15.28% respectively in 1st year for the treatment of control (7.4).

Table 7.4. Effect of vermi-compost on mulberry leaf quality

Treatments	Moisture (%)		Soluble Carbohydrate (%)		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
C	69.68c	69.66c	7.29d	7.30d	15.28d	15.31d	7.86e	6.94e	3.64cd	3.63d
B	69.82c	70.62bc	7.42d	8.05cd	15.35d	15.57d	9.62d	10.35cd	4.8bcd	5.26abcd
VC	71.62b	73.74a	8.60cd	10.66ab	16.60cd	18.70ab	10.51cd	13.17ab	4.86bcd	5.64ab
B+VC	71.92b	74.10a	9.25bc	11.31a	17.94bca	20.10a	11.83bc	14.2a	5.37abc	6.77a

Here, C = Control, B = BSRTI recommended basal dose of NPK, VC = 5 MT vermi-compost/ha/yea, B+VC = B + 5 MT vermi-compost/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

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

The incidences of foliar diseases of the mulberry plant were significantly reduced with irrespective of fertilizer treatments and cropping years. However, the more marked declined trend was observed for the treatment of B+LF and the crop of 2nd year. Among the six types of fertilizer treatments and between the two cropping years the lower incidences percentage of powdery mildew, leaf spot and tukra were 2.65, 2.76, and 2.21 respectively in 2nd year for the treatment of B+LF. Consequently, the higher incidence of powdery mildew and leaf spot were 11.36 and 11.31 % for 1st year and the tukra was 9.99 % in 2nd year for the control treatment (Table 7.5).

Table 7.5. Incidence of foliar diseases under different fertilizer treatments and two cropping years

Treatments	Powdery mildew		Leaf Spot		Tukra	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
C	11.36a	11.33a	11.31a	11.28a	9.96a	9.99a
B	10.71a	10.66a	10.15a	10.08a	8.20b	8.17b
VC	4.37b	3.03b	4.77b	3.43bc	3.67c	2.53c
B+VC	3.67b	2.65b	3.98bc	2.76c	3.01c	2.21c

Here, C = Control, B = BSRTI recommended basal dose of NPK, VC = 5 MT vermi-compost/ha/yea, B+VC = B + 5 MT vermi-compost/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

7.4. DISCUSSION

7.4.1. Effect of vermi-compost on soil physicochemical properties

Vermi-compost has a great impact on the improvement of soil properties. The application of 5 MT/ha/yr verimi-compost with a full dose of NPK (B+VC) increased the availability of OC, N, P, K, Ca, Mg, Na, Mn, Cu and Zn contents in soil among the treatments (Table 7.7). 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 the application of 5 MT vermi-compost/ha/yr (VC) whereas the maximum average soil pH was 8.20 for the control treatment. These findings were similar to the previous findings of Manivannan *et. al.,* (2009). They found that the application of vermi-compost @ 5 tones ha^{-1} in clay loam soil reduced the soil pH about (1 to 1.02 units). They also found that the others soil physio-chemical properties viz: 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) were increased due to vermi-compost amendment in soil. They speculated that due to 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. They also reported that due to a higher amount of organic carbon (OC) content in vermi-compost and reduces the losses of nutrients through leaching from the soil through changing the soil physicochemical properties the others mentioned nutrients were increased in soil.

However, in this experiment, the mutual applied vermi-compost + BSRTI recommended basal dose of NPK (B+VC) could be contain the maximum amount of organic carbon and high levels of total and available nitrogen, phosphorus and potassium. Those results improved the soil physicochemical properties and enhanced the availability of NPK in (B+VC) treated soil. In terms of soil physiochemical properties viz: OC, N, P, K, Ca, Mg, Na, Mn, Cu, and Zn contain B+VC treated soil was comparatively improved than the other treatments. This concept was lined with the previous finding of Sreenivas *et. al.,* (2000). They reported that vermi-compost increased the organic carbon, microbial populations, dehydrogenase activity of the soil, resulting in significantly increased the amounts of soil nitrogen, P, and K availability.

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

The growth and leaf yield of the mulberry plant was significantly ($P \geq 0.05$) increasing due to the vermi-compost amendment in soil. Findings showed that the growth and yield contributing characters of mulberry plant viz: total branches number, total branches height, nodes per meter, total shoots weight, 10 leaves area, 10 leaves weight and total leaves weight per plant were 68.23, 80.07, 44.53, 84.34, 45.62, 132.09 and 110.64 percent respectively greater for the B+VC treatment over the control treatment. However, the maximum leaf yield for control, basal, VC and B+VC treatments were 23.98, 27.92, 31.48 and 50.51 MT per hectare per year respectively. Even the leaf yield of B+VC fertilizer treatment was 110.63 % and 80.91 % respectively higher followed by the maximum leaf yield of control and basal treatments respectively. The above finding was similar to the previous finding of Murarkar *et. al.,* (1998).

They found that the application of vermi-compost @ 6000 kg/ha with a full dose of NPK (300:120:120) significantly increased the number of branches, the height of the plant, number of leaf per plant and the leaf yield per plant of mulberry as compared to control treatment. Correspondingly, Gururaj (2005) observed that the mulberry garden treated with vermin-compost @ 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 vermin-compost treated mulberry garden.

The combination of vermi-compost with BSRTI recommended basal dose of NPK could be contained high levels of total & available NPK and micronutrients which are essential for soil available nutrients and enhanced the growth regulators of the mulberry plant. This positive effect changed the nutrient availability as well as changes the enzyme's activity within the soil. Resulting, the soil properties viz: the soil pH, the soil microbial activities, the soil cation exchange capacity were improved in B+VC treated soil compared to the other treatments. Furthermore, it might be enhanced plant growth regulators such as N, P, K and micronutrient status of soil in available forms, as a result the plant uptake these essential nutrients in maximum and balanced proportion. So the growth and development of the mulberry plant were better in B+VC treated mulberry plot, in terms, the leaf yield was increased than the other fertilizer management.

7.4.3. Utilization of vermi-compost improved the mulberry leaf quality

Vermi-compost had a considerable impact on improving the leaf quality of mulberry. The experimental findings showed that among all treatments the application of 5 MT vermi-compost with BSRTI recommended basal dose of NPK (B+VC) treatment was markedly increased the leaf quality parameters like moisture, soluble carbohydrate, crude protein, total mineral and total sugar contain of mulberry leaf. Even the moisture, soluble carbohydrate, crude protein, total mineral and total sugar were 6.34, 54.93, 31.29, 80.66 and 85.99% respectively increased in B+VC treatment over the control. A similar trend was observed by Umesha *et. al.,* (2014). They 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 vermin-compost 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 percentage was increased.

This could be due to the improvement of the water holding capacity in the soil, the moisture uptake by the plant as well as the mulberry leaf was greater through the combined application of B+VC treatment. Due to the better and nutritious growth of the mulberry plant through the mutual application of B+VC treatment enhanced the production of plant growth substances and enzyme activities of the mulberry plant.

Regardless of that improved the mineralization attributes as well as increased the total sugar content in B+VC treated mulberry plant that was lined with the previous findings of Rashmi *et. al.,* (2009). They obtained a higher level of total sugar in mulberry leaf when it was treated by the combined dose of chemical fertilizer and vermi-compost.

Similarly, Ranadive *et. al.,* (2011) found that the soluble protein and carbohydrate content in mulberry were higher due to the combined application of vermi-compost + NPK fertilizer. They thought it may be more amounts of organic nutrients essential for microbes and plant growth contain by the applied vermi-compost. Due to the maximum amount of macro and micronutrients contained in available forms through the combined applied B+VC treatment enhanced the balanced uptake and growth of the mulberry plant. As a result, the protein and carbohydrate content were higher in B+VC treated mulberry plot. This assumption was more or less lined with the previous findings of Ranadive *et. al.,* (2011).

7.4.4. Vermi-compost reduced the severity of common foliar diseases in mulberry plant

The highly significant interaction was found for the reduction of foliar disease intensity in mulberry plants both for the combined application of B+VC and a single application of VC (Table 7.5). Findings showed that among the four fertilizer treatments the incidence of powdery mildew, leaf spot, and tukra diseases were significantly lower by the combined application of 5 MT vermi-compost/ha/yr plus BSRTI recommended basal dose of NPK (B+VC) followed by the only 5 MT vermi-compost/ha/yr (VC), basal and control treated mulberry plant respectively. However, in the case of powdery mildew and leaf spot the lower incidences were 2.65 and 2.76 % respectively for the treatment of B+VC. These incidences were 76.61 and 75.53 % respectively lower in B+VC treatment followed by the minimum incidences of control treatment. Similarly, the single application of VC treatment reduced the incidences of powdery mildew and leaf spot were 73.26 and 69.59 % respectively followed by the minimum incidences of control treatment.

A similar finding was observed by Maji *et. al.,* (2013). They found that the lowest incidence of powdery mildew and leaf spot foliar diseases in the mulberry plant were 4.07 and 5.39 respectively due to the application of 15 MT/ha/yr vermi-compost with NPK (168:90:56). But the maximum incidences were 10.06 and 15.22 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 that might be contributed factors for reduction of disease severity. In this experiment the incidences of powdery mildew and leaf spot were reduced could be due to the combined application of vermi-compost + NPK or a single application of vermi-compost might be enhanced activities of antagonistic microbes increased the competition against the pathogens for resources.

That causes fungistatsis release of fungi toxic 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. That why, the incidences of powdery mildew and leaf spot were reduced in vermi-compost through the application with or without NPK compared to the other treatments.

In the case of tukra disease mealybug pest (*Maconellicoccus hirsutus*) the minimum incidences were 2.21 and 2.53 % respectively for the B+VC and VC treatments respectively. These incidences were 77.81 and 74.6% respectively lower for the B+VC and VC treatments over the minimum incidence of control. This finding was more or less similar to the previous finding of Samuthiravelu *et. al.,* (2012). They found that the incidence of tukra mealy bug *Maconellicoccus hirsutus* was minimum for the application of 15% vermiwash (a liquid form of vermi-compost) than the panchakavya and control treatments respectively. They opined that the vermi-compost or vermiwash could be attributed to the changed the biochemistry of plant. That would have made the plant system defensive against pest infestation. In my study, the infestation of tukra disease was reduced might be due to the applied vermi-compost could be released the essential plant nutrients gradually throughout the growth period. This beneficial effect induced the development of resistance in both the B+VC or VC treated mulberry plant which may subsequently help in escaping the infestation of the mulberry mealy bug as well as reduced the infestation of tukra disease.

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

Application of vermin-compost in soil varied soil physio-chemical properties to some extent irrespective of cropping year. Findings showed that most of the soil physicochemical properties viz: N, P, K, Ca, Mg, Na, Mn, Cu, and Zn were slightly increased due to vermi-compost amendment in 2nd year. In contrast, the OC was significantly reduced in 2nd year than the 1st year for the application of 5 MT vermi-compost/ha/yr + BSRTI recommended basal dose of NPK (B+VC) treatment. 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 (B+VC) fertilizer treatment. A similar trend was observed by Musaida *et. al.,* (2013b). 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 was increased by 8.0 ppm in soil. Because P does not exist in an elementary form and most of the P was insoluble in the vermi-compost and unavailable to the soils and plants. But the 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 that hence the K increased in soil. Similarly, it increased the soil Cu content due to increase organic matter which resulted in improved soil aeration and microbial activity in the soil. In my study, the total quantity of vermi-compost may be increased as well as the activities of living micro-organisms were abundant in 2nd year soil due to the application of vermi-compost both the 1st year and 2nd year. In terms of the Zn and Mn content in 2nd-year soil was increased because vermi-compost is rich in organic material. In addition, it may be as vermi-compost promoted the steady and slow release of nutrients in the soil. Furthermore, 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 were improved in 2nd year than the 1st year soil.

The significant increasing trend was observed for the growth, leaf yield and leaf quality of the mulberry plant between the cropping years due to the application of vermi-compost in soil. Between the two cropping years the growth parameters viz: total branches number, total branches height, nodes per meter, total shoots weight, 10 leaves area, 10 leaves weight and total leaves weight per plant were 68.23, 89.50, 44.53, 84.6, 45.91, 137.94 and 111.24 % respectively greater in 2nd year for the maximum growth of B+VC treatment followed by the growth of 1st year for the treatment of control. Even the 2nd year's leaf yield was 109.54 % greater for the B+VC treatment over the minimum leaf yield of 1st year for control treatment. The maximum leaf yield of 2nd year was 50.51 MT and 1st year 48.79 MT per hectare year respectively for the B+VC treatment which was 3.53% higher from 1st year to 2nd year.

Similarly, the leaf quality viz: moisture, soluble carbohydrate, crude protein, mineral and total sugar were 6.34, 55.14, 31.54, 80.66 and 85.99 % respectively greater in 2nd-year mulberry leaf for B+VC treatment compared to the control treated mulberry leaf of 1st year. It may be due to the reasons that irrespective to vermi-compost application duration in 2nd year the decomposition of organic matter, microbial diversity, and populations of micro-organisms were relatively improved. That could be enhanced the soil structure, soil water holding capacity, release of nutrients in the soil, soil fertility as well as the soluble plant macro and micronutrient availability 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 and balanced proportion. Consequential the growth and development of the mulberry plant was better and nourishing in 2nd year crops than the 1st year. In terms, the growth and leaf yield as well as the leaf quality of the mulberry plant was significantly greater in 2nd year crop than the 1st year crop.

A similar trend was observed for the incidence of foliar diseases in mulberry plants irrespective of cropping year. The experimental results showed that increasing the vermi-compost application duration the severity of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra were reduced slightly in 2nd year followed by the 1st year. Between the two cropping years the lower infestation of powdery mildew, leaf spot and tukra diseases were 2.65, 2.76, and 2.21 % respectively in 2nd year for the B+VC treatment. Similarly, in 1st year the minimum incidences percentage of powdery mildew, leaf spot, and tukra diseases were 3.67, 3.98 and 3.01 respectively also for the B+VC treatment. These incidences were 27.79, 30.65 and 26.58 % respectively lower in 2nd year than the 1st year for the same (B+VC) fertilizer management. The reduction of foliar disease incidences in the mulberry plant irrespective to vermi-compost application duration might be due to the slow decomposition and slow release of nutrients from the applied vermi-compost. That improved the soil nutrient status as well as increased the production of optimum diverse growth substances or hormones by the mutual applied vermi-compost plus nitrogen (as a basal dose) in 2nd year than 1st-year soil. Resulting, the 2nd year mulberry plant was enabled to create more resistance power against the pathogens which could be reduced the incidences of foliar diseases than the 1st year. This assumption was lined with the previous findings of Sharma *et. al.,*(1994). 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 a certain pathogen.

7.5. CONCLUSIONS

The present 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 reduce the infestation of foliar diseases in the mulberry plant. The soil properties, mulberry leaf yield, leaf quality and the incidences of foliar diseases viz: leaf spot, powdery mildew and tukra were drastically reduced in the second year compared to the 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 the 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 frequency of powdery mildew, leaf spot and tukra diseases were found in the second year than the first year for the same fertilizer management.

This study concluded that vermi-compost regulates growth, leaf yield and quality of mulberry. Additional soil fertility and foliar diseases suppress occurred due to vermi-compost amendments. Application of organic matter in the soils has been undoubtedly credited for better soil health and plant growth response all over the world, particularly in the tropical soils having comparatively lower organic matter content. Vermi-compost is one of the organic fertilizer which showed better performance for mulberry plant productivity as well as maintained the soil health. But the objective of this Ph.D. work was to introduce modern and time needed fertilizer management system for advanced mulberry plant production as well as retain the soil heath due to climate change. Though the vermi-compost practicing was new idea for mulberry cultivation in Bangladesh, more fertilizer management tools required comprising with the world fertilizer management technique.

Further, Biochar is a modern and time need a highly stable and recalcitrant form of organic matter produced by heating biomass in an oxygen-limited condition, and the paralysis process is a burning issue. Modern day's objective to use biochar in soils is mainly for carbon sequestration purposes. Biochar can effectively be sequestered in soil for hundreds to thousands of years. In addition, several researchers opined that it can mitigate the agricultural emission of greenhouse gases as well as can be an effective option for the amend problem of soils. Increased yield of crops has been reported by many studies since biochar has been introduced as an organic fertilizer tool. The information of biochar application on other agricultural crops was available but in the case of the mulberry plant, it scarcely existed. In this perspective, further study was conducted to investigate the effect of biochar on mulberry plant production, suppress foliar diseases, and improvement of soil properties. Therefore, further research about the biochar amendment will be focused on mulberry plant production in the following chapter (Chapter 8).

Chapter 8

Biochar enhances productivity and suppresses foliar diseases of mulberry plant

Chapter 8

Biochar enhances productivity and suppresses foliar diseases of the mulberry plant

8.1 INTRODUCTION

Biochar is a source of organic fertilizer that is receiving attention by researchers all over the world (Lehman *et. al.,* 2003). The process of biochar production is known as pyrolysis and it results in a very stable carbon-enrich material not only capable of improving physical and chemical soil properties but also increasing soil carbon storage on a large scale (Sohi *et. al.,* 2010; Kookana *et. al.,* 2011). Among soil organic amendments, biochar is considered more stable nutrient source than others (Chen *et. al.,* 2007). Organic carbon contents in biochar have been reported up to 90%, depending upon its feedstock which enhances carbon sequestration in soil (Yin and Xu, 2009).

Different types of biochar can be used for increasing the agricultural production. Out of them rice-husk and mineral enriched biochar was used in this study. Biochar application to soil changes yield components of different crops. Agboola and Moses (2015) showed that the growth and yield of soybean was increased due to addition of rice husk biochar. Likewise, soil properties like soil pH, organic carbon, soil nitrogen, calcium, magnesium, potassium, sodium changes due to the application of rice husk biochar in soil. Similarly, Gebremedhin (2015) found that biochar was significantly increased grain and straw yields of wheat by 15.7 % and 16.5% respectively over the NPK application.

Biochar amendment may not only improve the soil properties but also suppress disease infestation on various crops. Mercado-Blanco and Bakker (2007) found that biochar addition to the potting medium of strawberry plants suppressed foliar diseases caused by fungi having *Pseudomonas* in several crops. Elad, *et. al.,* (2011) demonstrated that biochar addition in soil shifts towards beneficial microorganism populations that promote plant growth and resistance to biotic stresses. However, the impact of biochar on mulberry plant production with common disease incidence and changes in soil physical and chemical properties is not known yet in Bangladesh.

The previous chapter showed that vermi-compost application increased the growth and leaf yield of the mulberry plant. Similarly, vermi-compost improved soil physiochemical properties as well as improve the leaf qualities of mulberry. In addition, vermi-compost reduced the incidences of mulberry foliar diseases (Chapter 7). But, biochar is a modern and carbon-enrich an extra organic fertilizer source. Besides, the information on biochar application as an organic source for mulberry cultivation was scarcely available. That's why it was the time needed demand to be applied biochar for mulberry plant production. Therefore, the focus of this investigation was to quantify the response of enrich husk and mineral enriched biochar on yield components, leaf yield, and disease incidences of the mulberry plant. This study was also quantified the long term effect of biochar on changes in soil physical and chemical properties. It was hypothesized that biochar will be increased the leaf yield, leaf quality and reduction of common foliar diseases incidences of the mulberry plant through changing the soil properties.

8.2 MATERIALS AND METHODS

8.2.1. Experimental location

This experiment was conducted in the experimental field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh (24^0 22′ 29″ North and 88^0 37′ 3.84″ East). BSRTI falls under the Active Ganges Floodplain-10 and High Ganges River Floodplain-11 as well as AEZ-11.

8.2.2. Soil condition

The soils of the experimental plot were mainly loamy in nature, having normally alkaline characteristics with pH ranging from 7.2 to 7.6 in water. 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 plot. The nitrogen level is not in balance with carbon. This is more prominent in the farm area where mulberry is cultivated for years. Toxic metals are present in traces but they are well below the harmful levels. The average two years pre-treated basic physical and chemical properties of the experimental soils are presented in Table 8.1.

Table 8.1. Average of two years of data of the experimental soil before applied the treatments

Soil pH in H_2O	Nitrogen (%)	Phosphorus ($mgkg^{-1}$)	Potassium (Cmol/kg)	Sulphur ($mgkg^{-1}$)	Zinc ($mgkg^{-1}$)	Organic matter (%)
8.4	0.1	13.9	0.1	12.6	0.9	1.1

8.2.3. Sample plant material

Mulberry plant was used as a sample planting material for this experiment. This plant is perennial, deep-rooted and hardy in nature. Due to its perennial, deep rooting and hard habit, mulberry is grown in a wide range of soil and agro-climatic conditions. The used mulberry variety was BM-11. The plantation system was high bush.

8.2.4. Taxonomy of mulberry plant

Mulberry belongs to the genus *Morus*. Mulberry is a highly heterozygous and outbreed in nature. Different workers from different corners of the world classified the genus *Morus* L. in different ways. Linnaeus (1753) recognized 7 species under the genus *Morus* L. presently of which only 5 viz. *M. alba, M. nigra, M. rubra, M. india* and *M. tartarica* fit into the circumscription of the genus. Based on female inflorescence and fruit character, the French Botanist E. Bureau (1873) recognized 5 species, 19 varieties, and 11 sub-varieties of the genus *Morus*.

8.2.5. Experimental condition

Four commercial silkworm rearing seasons are followed each year. Based on silkworm rearing seasons mulberry garden was pruned four times in a year each after 3 months interval.

8.2.6. Experimental design

The experiment was executed in a randomized complete block design (RCBD) with three replications. The plot size was 5m long × 4 m wide. Each plot consists of 20 mulberry plants. The fertilizer management was done for each replicated plot. The same experiment was repeated for the next year.

8.2.7. Treatments

There were six treatments for these experiments which are as follows:

i. Control: No fertilizer was applied.
ii. BSRTI recommended basal dose: The recommended basal dose of BSRTI is 300 kg N, 150 kg P and 100 kg K per hectare per year respectively with four split doses each after three months interval.
iii. Rice husk biochar (RB): Only the rice husk biochar was applied at a time @ 3.5 MT per hectare per year. In this case, the 2^{nd} dose was applied after a year interval.
iv. Mineral enriched biochar (MB): Only the mineral enriched biochar was applied at a time @ 3.5 MT per hectare per year. The 2^{nd} dose was applied after one year.
v. Recommended basal dose + rice husk biochar (B+RB): BSRTI (Bangladesh Sericulture Research and Training Institute) recommended basal dose of NPK with four split doses each after three months interval in a year and @ 3.5 MT rice husk biochar per hectare per year at a time was applied for mulberry cultivation.
vi. Recommended basal dose + mineral enriched biochar (B+MB): BSRTI (Bangladesh Sericulture Research and Training Institute) recommended basal dose of NPK with four split doses each after three months interval in a year and @ 3.5 MT mineral-enriched biochar per hectare per year at a time was applied for mulberry cultivation. The 2^{nd} dose was applied after one year.

8.2.8. Chemical properties of Biochar

Biochar is the carbon-enrich solid product resulting from the heating of biomass in an oxygen-limited environment. Due to its highly aromatic structure, biochar is chemically and biologically more stable compared with the organic matter from which it was made. Generally, the properties of biochar vary widely, depending on the source of biomass used and the conditions of production of biochar (Lehman and Joseph, 2009).In this experiment, two types of biochar like rice husk and mineral enriched biochar was used, which was collected from China. The chemical properties of our applied biochar obtained from a manufacturing company in China are given in Table 8.2.

Table 8.2. Properties of rice husk and mineral enriched biochar used in the experiment

Elements	Rice husk biochar	Mineral enriched biochar
pH	8.0	8.9
Total N (%)	1.7	2.1
Total P (%)	0.2	0.5
Total K (%)	0.2	1.1
OC (g/kg)	54.0	67.0
Total Na (%)	0.2	0.6
S (mg/kg)	0.2	0.4
Fe (mg/L)	7.8	8.7
Ca (mg/L)	213.0	273.0
Cu (mg/L)	0.1	0.1
Al (mg/L)	0.9	1.0
Mn (mg/L)	4.4	5.1
Ash (%)	50.3	39.7

Source: Analysis by the Department of Soil Science, Bangladesh Agricultural Research Institute, Jaydapur, Gazipur, Dhaka, Bangladesh.

8.2.9. Experimental procedure

The treatments were randomly assigned in the experimental plot for each replication. Each year and every case according to the treatment all the fertilizers like basal, rice husk biochar, mineral enrich biochar, basal + rice husk biochar and basal + mineral enriched biochar were applied 15 days after pruning (DAP) on the mulberry plant when sprouting was started. Both the biochar (Rice husk and mineral enriched) were applied through the surface application method in the root zone area of the plant and then incorporated with soil by the digging method. Other intercultural cultural practices like digging cum weeding and irrigation were done as per requirement for each year.

8.2.10. Data collection

According to the treatments, data were collected on the growth and yield parameters, leaf quality, disease incidence percentage, and soil properties for every two years.

8.2.11. Growth parameters

For determining the growth and yield impact data was collected on the following headed:

i. Total branches number per plant: The number of branches per plant was determined by counting the number of branches manually for each of the plants each after 90 days of pruning.

ii. Total branches height per plant (cm): All the branches height for a plant was measured by the measuring tape and adding each after 90 days of pruning.

iii. Nodes per meter per plant: The number of nodes per meter was determined by counting the number of nodes per meter manually for each of the plants each after 90 days of pruning.

iv. 10 leaves area per plant (cm^2): Randomly selected 10 leaves per plant were measured by the Green Leaf Area Meter.

v. 10 green leaves weight per plant (g): Randomly selected 10 leaves for each plant and weighted by using the weighting balance each after 90 days of pruning.

vi. Total shoots weight per plant (g): All the shoots of a plant except leaf were weighted by using the weighting balance each after 90 days of pruning.

vii. Total green leaves weight per plant (g): All the green leaves of a plant except shoots were weighted by using the weighting balance each after 90 days of pruning.

viii. Total leaf yield (Metric ton/hectare/year): After the maturity of the leaf (after 90 days of pruning) the total green leaf yield per hectare per year was determined by the following formula:

$$\text{Leaf yield (MT/hectare/year)} = \frac{Leafweight(g)ofperm^2plant \times nulberofcropseasonperyear \times 10000\ m^2}{1000\ g \times 1000\ kg}$$

8.2.12. Analysis of soil

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). 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 acids (H_2SO_4) (Podder*et. al.,* 2012).

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). The available P of the soil was determined by a spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by the Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005). Sodium, calcium, and magnesium content were determined following the method of Tandon (1993) and copper was estimated by atomic absorption spectrophotometer (AAS) (Tandon, 1993). Manganese was estimated by spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

8.2.13. 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 (Days after Pruning) and composite leaf samples were made. Then, the prepared leaf samples were shade dried for three days and again dried in a 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), soluble carbohydrate (%) following Dubois *et. al.,* (1956) method, crude protein (%) following Kjeldahl's method (Wong, 1923), total mineral (%) following AOAC, (1980), total sugar (%) following Miller (1972) and Loomis *et. al.*, (1937) procedure.

8.2.14. Disease incidence

The incidence of diseases per plant was recorded for two consecutive years each after 60-65 days of pruning through randomly selected 10 plants for each replication. Foliar diseases such as powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra caused by Mealy bug pest (*Meconellicoccus hirsutus)* were recorded during this period. Studies on percent incidence (PI) irrespective to powdery mildew, leaf spot and tukra diseases were recorded and the data during both the years were pooled and analyzed. The percent (PI) incidence was calculated followed by the Rai and Mamatha (2005) formula.

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

8.2.15. Statistical analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1thed^{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 were used for representing the results as a figure form. The leaf quality and disease data were statistically analyzed and mean values were evaluated by Duncan Multiple Regression Test (DMRT) through using the Statistic-10 software. In the case of soil, the mean values of post-harvest soil properties were recorded for this study.

8.3 RESULTS

8.3.1. Effect of fertilizer application and cropping years on bulk soil properties

The effect of treatment application on the post-harvest soil properties is presented in Table 3. The addition of different fertilizers as a soil amended significantly ($P \leq 0.001$) increased the organic matter, phosphorus, sulphur and zinc contain percentage in soil. However, only the organic matter ($P \leq 0.001$) and sulphur ($P \leq 0.05$) contain percentage were significantly differed by the cropping years. The interactive effect of cropping years × treatments were also significantly influenced by the sulphur ($P \leq 0.01$) and zinc ($P \leq 0.001$) contains percentage in soil (Table 8.3).

Table 8.3. Level of significance for the main and interactive effect on season and treatments for soil properties

Source of variation	Soil pH	Organic matter (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Zinc (%)
Cropping years	n. s.	***	n. s.	n. s.	n. s.	*	n. s.
Treatments	n. s.	***	n. s.	***	n. s.	***	***
Cropping years × Treatments	n. s.	n. s.	n. s.	n. s.	n. s.	**	***

Where, * ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001 respectively. Values were means of three replicates.

However, the highest average percentage of organic matter was 1.96% in second-year soil due to the application of biochar (mineral enriched) @ 3.5 ton/hectare/year. The maximum phosphorus contains was 30.73% in second-year soil for the treatment of 3.5 MT/hectare/year rice husk biochar. The highest sulphur contains percentage was 9.27 in the second year for biochar (mineral enriched) @ 3.5 ton/heater/year treated soil. The maximum zinc percentage was 1.79 also in the second year for 3.5 MT/heater/year biochar (rice husk) @ treatment (Table 8.4). On the other hand, the soil properties like soil pH, nitrogen, and potassium percentage were not significantly influenced by the cropping seasons, treatments, and their interactive effect (Table 8.3 and Table 8.4).

Table 8.4. The mean percentage of post-harvest soil properties of the mulberry garden

Treatments	pH		Organic matter (%)		N (%)		P (%)		K (%)		S (%)		Zn (%)	
	Yr-1	Yr-2	Yr-1	Yr-2	Yr-1	Yr-2	Yr-1	Yr-2	Yr-1	Yr-2	Yr-1	Yr-2	Yr-1	Yr-2
C	8.2	8.3	1.1	1.1	0.1	0.1	18	17.7	0.2	0.2	8.9	8.4	1.1	1.0
B	8.2	8.1	1.2	1.2	0.1	0.1	28.5	28.2	0.2	0.2	9.0	9.2	1.4	1.4
RB	8.3	8.3	1.1	1.1	0.1	0.1	30.5	30.7	0.2	0.2	8.6	8.9	1.8	1.8
MB	8.2	8.4	1.9	2.0	0.03	0.05	27.2	27.3	0.2	0.2	7.3	7.5	0.8	0.8
B + RB	8.2	8.4	0.7	0.8	0.03	0.04	21.3	21.6	0.2	0.2	7.9	8.1	0.7	0.7
B + MB	8.3	8.4	0.8	0.8	0.03	0.05	23.2	23.4	0.2	0.2	9.1	9.3	0.5	0.5

Where, C = control, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

8.3.2. Effect of fertilizer application and cropping years on growth and yield attributes of the mulberry plant

Total branches number per plant

The total branches number per plant was highly significant ($P \leq 0.001$) both for the fertilizer treatments and the cropping years (Table 8.5). The more marked increasing trend was observed for the B+MB treatment and the 2nd year's crop. However, between the two cropping years in 1st year, total branches number per plant were 10.93, 12.15, 12.43, 12.35, 13.40 and 13.78 for the treatments of control, basal, RH, MB, B+RH and B+MB respectively. Correspondingly, in 2nd year were 10.93, 12.41, 12.93, 14.15, 15.52 and 15.78 respectively for the same treatments (Figure 8.1; Table 8.5).

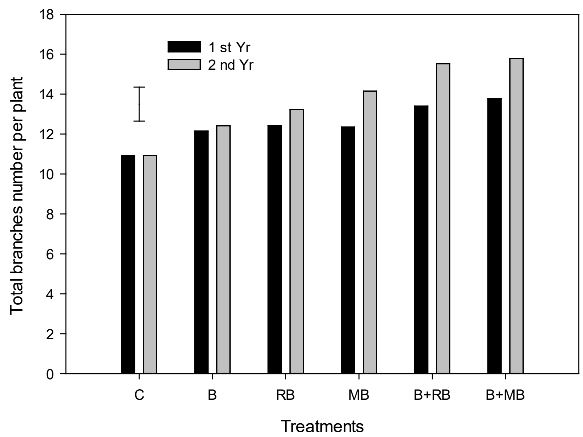

Figure 8.1: Effect of fertilizer management on total branches number per plant of mulberry (*Morus spp)*.Vertical bar represent LSD ($P \geq 0.05$) for various fertilizers management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

Total branches height per plant (cm)

The highly significant ($P \leq 0.001$) difference was found among the fertilizer treatments, cropping years, and their interactive effect irrespective of total branches height per plant of mulberry. The notable significant increasing trend was observed for the B+MB treatment and the 2nd year's crop. The total branches height were 788.47, 1011.22, 1072.81, 1106.77, 1175.37 and 1221cm respectively in 1st year due to the application of control, basal, RH, MB, B+RH and B+MB treatments respectively. Similarly, in 2nd year total branches height were 789.45, 1014.39, 1174.81, 1228.77, 1335.37 and 1335.76 cm respectively for the above-mentioned treatments (Figure 8.2; Table 8.5).

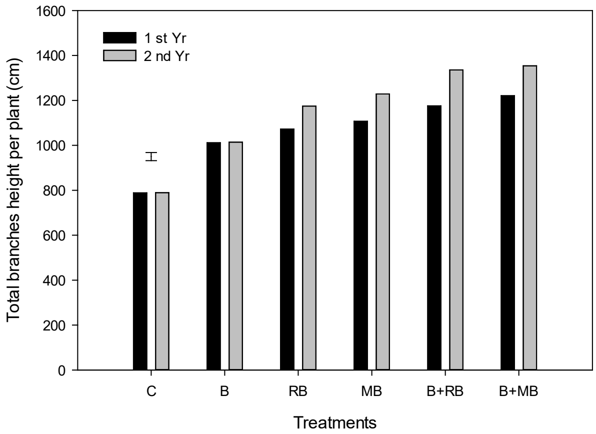

Figure 8.2: Effect of fertilizer management on total branches height per plant of mulberry (*Morusspp)*.Vertical bar represent LSD (*P*≥ 0.05) for various fertilizers management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

Nodes per meter

The nodes per meter was significantly ($P \leq 0.001$) increased forthe fertilizer treatments, cropping years ($P \leq 0.001$), and their interactive ($P \leq 0.05$) effect of mulberry. The B+MB treatment and the 2ndyear's crop were showed the most remarkable increasing tendency. Between the two cropping years in 1st year recorded nodes per meter were 17.29, 20.47, 20.76, 20.80, 21.25 and 21.97 for the control, basal, RH, MB, B+RH and B+MB treatments respectively. Conversely, in 2nd year were 17.62, 20.51, 22.76, 22.86, 23.25 and 25.97 respectively for the same fertilizer management (Figure 8.3; Table 8.5).

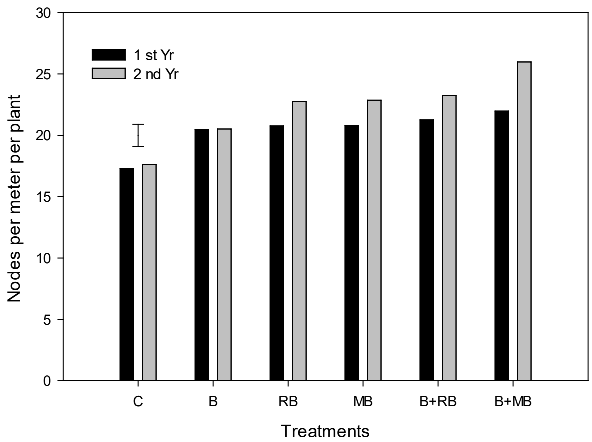

Figure 8.3: Effect of fertilizer management on nodes per meter per plant of mulberry (*Morus spp)*.Vertical bar represent LSD ($P \geq 0.05$) for various fertilizers management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

Table 8.5. Level of significance for the main and interaction effect on fertilizer treatments and cropping years.

Source of variation	Nodes per meter per plant	Total branches number per plant	Total branches height per plant (cm)	Total shoots weight per plant (g)	10 leaves area (cm) per plant	10 leaves weight (g) per plant	Total leaves weight per plant (g)	Total leaf yield / ha/yr (MT)
Treatments	***	***	***	***	***	***	***	***
Cropping years	***	***	***	***	***	***	***	***
Treatments × Cropping years	*	n.s	***	***	**	***	***	***

Where, * ** and *** represent probability of >0.05, ≤0.05, ≤0.01 and ≤ 0.001 respectively. Values were means of three replicates.

Total shoots weight per plant (g)

The highly significant ($P \leq 0.001$) trend was found among the fertilizer treatments, cropping years, and their interactive effect irrespective to total shoots weight of mulberry. The more marked trend was recorded for the B+MB treatment and the 2ndyear's crop. However, the recorded total shoots weight per plant were 351.44, 476.38, 501, 518.47, 549.84 and 572.46 g in 1st year due to management of control, basal, RH, MB, B+RH and B+MB treatments respectively. Similarly, in 2nd year were 351.91, 480.96, 507.98, 525.47, 577.38 and 607.12 g respectively for the aforementioned treatments (Figure 8.4; Table 8.5).

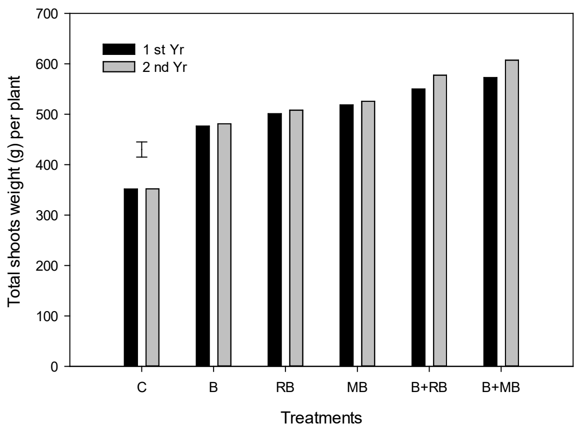

Figure 8.4: Effect of fertilizer managementon on total shoots weights per plant of mulberry (*Morus spp).*Vertical bar represent LSD ($P \geq 0.05$) for various fertilizers management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

10 leaves area per plant (cm^2)

Statistically highly significant ($P \leq 0.001$) difference was observed among the fertilizer treatments, cropping years, and their interactive effect ($P \leq 0.01$) irrespective to 10 leaves area of the mulberry plant. The B+MB treatment and the 2ndyear's crop were presented with a more remarkable increasing trend. In 1st year the 10 leaves area were 427.74, 526.91, 534.54, 557.60, 582.70 and 595.80 due to management of control, basal, RH, MB, B+RH and B+MB treatments respectively. Conversely, in the 2nd year, 10 leaves area were 428.11, 530.41, 545.37, 567.60, 592.70 and 607.80 cm^2 respectively due to the same fertilizers management (Figure 8.5; Table 8.5).

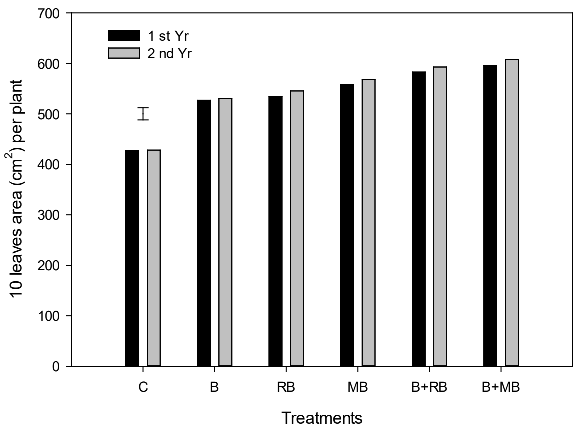

Figure 8.5: Effect of fertilizer managementon 10 leaves area per plant of mulberry (*Morus spp)*.The vertical bar represents LSD ($P \geq 0.05$) for various fertilizers management. Where, C= control, Basal= BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal +3.5 MT rice husk biochar/ha/year and B+MB= Basal + 3.5 MT mineral enriched biochar/ha/year.

10 leaves weight per plant (g)

The 10 leaves weight of the mulberry plant were highly significant ($P \leq 0.001$) by the treatments, cropping years and their interactive effect. The more marked increasing range was recorded for the B+MB treatment and 2ndyear's crop. However, in 1st year 10 leaves weights were 20.30, 23.43, 24.18, 24.2, 30 and 31.80 g for control, basal, RH, MB, B+RH, and B+MB treatments respectively. Similarly, in 2nd year 10 leaves weights were 20.70, 22.91, 31.04, 34.98, 39.18, and 47.80 g respectively for the aforementioned treatments (Figure 8.6; Table 8.5).

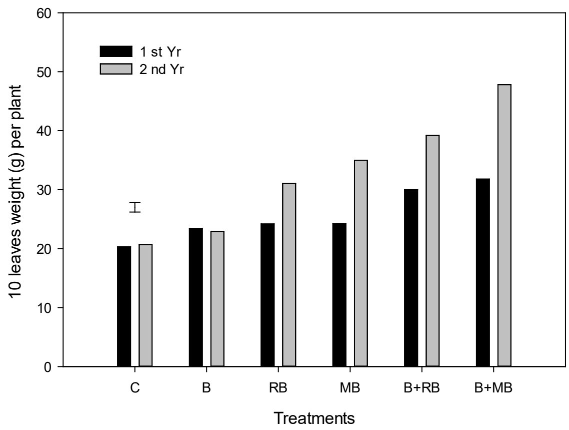

Figure 8.6: Effect of fertilizer managementon 10 leaves weight per plant of mulberry (*Morus spp)*.Vertical bar represent LSD ($P \geq 0.05$) for various fertilizers management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

Total leaves weight per plant (g)

The highly significant $P \leq 0.001$ trend was observed among the treatments, cropping years, and their interactive effect irrespective to the total leaves weight of the mulberry plant. The most significant increasing difference was found for the B+MB treatment and 2ndyear's crop. Between the two cropping years in 1st year, total leaves weight per plant was 507.74, 584.03, 603.96, 623.79 and 769.88g due to the application of control, basal, RH, MB, B+RH and B+MB treatments respectively. Correspondingly, in 2nd year, were 509.10, 586.37, 633.96, 665.79, 840.54 and 1085.29g respectively for the above-mentioned treatments (Figure 8.7; Table 8.5).

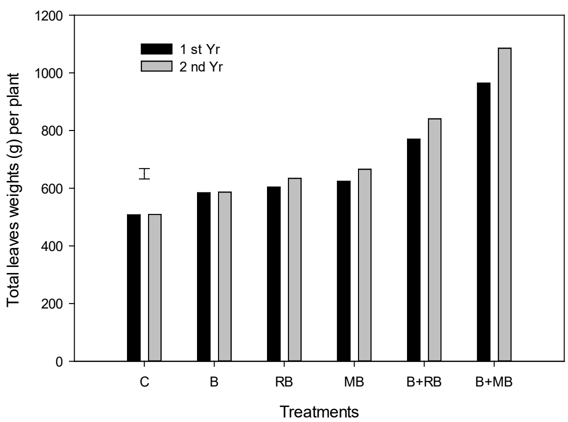

Figure 8.7: Effect of fertilizer management on total leaves weight per plant of mulberry (*Morus spp)*. Vertical bar represent LSD ($P \geq 0.05$) for various fertilizer management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year.

Total leaf yield/ha/yr (MT)

The total leaf yield of the mulberry plant was highly significant ($P < 0.001$) by the fertilizer treatments, cropping years, and their interactive effect on the mulberry plant. The more marked increasing trend was observed for the B+MB treatment and 2^nd^year's crop. In 1^st^-year total leaf yields per hectare per year was 24.37, 28.03, 28.99, 29.94, 36.95, and 46.29 MT for the control, basal, RH, MB, B+RH and B+MB treatments, respectively. Similarly, in 2^nd^-year leaf yields were 24.44, 28.14, 30.43, 31.96, 40.35 and 52.09 respectively, MT/ha/yr for the same treatments (Figure 8.8; Table 8.5).

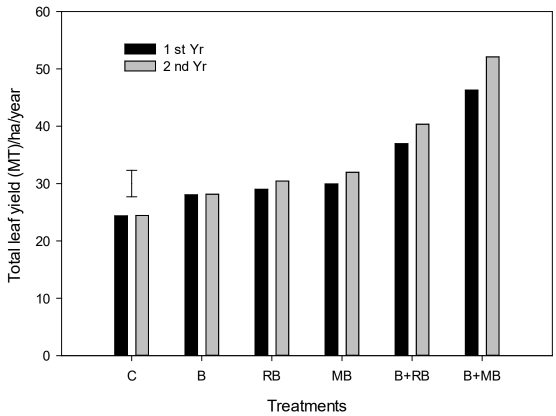

Figure 8.8: Effect of fertilizer managementon total leaf yield per hectare per year of Mulberry (*Morus spp*). The vertical bar represents LSD ($P \geq 0.05$) for various fertilizer management. Where, C = control, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral-enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral-enriched biochar/ha/year.

8.3.3. Effect of biochar application and cropping years on leaf quality of mulberry

The leaf quality was significantly differed by the fertilizer treatments and cropping years of the mulberry plant. Between the two cropping years the leaf quality viz: moisture, soluble carbohydrate, crude protein, mineral and total sugar percentage were statistically higher in 2^nd^ year's crop due to the combined application of B+MB treatment followed by the B+RB, MB, RB, basal and control treatments and the leaf of 1^st^ year's crop respectively.

However, between the two cropping years, the maximum average moisture, soluble carbohydrate, crude protein, mineral and total sugar percentage were 73.59, 10.92, 18.98, 14.04 and 6.86 respectively in 2^nd^ year for the B+MB treatment followed by the B+RB, MB, RB, basal and control treatments respectively. Conversely, the minimum average moisture, soluble carbohydrate, crude protein, mineral, and total sugar were 69.69, 7.27, 15.27, 6.96, and 3.65 % respectively in 1^st^ year for the control treatment (Table 8.6).

Table 8.6. Leaf nutrient status of mulberry under various fertilizers management

Treatments	Moisture (%)		Soluble Carbohydrate (%)		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
C	69.69e	69.70e	7.27c	7.31c	15.27e	15.30de	6.96e7	.84e	3.65c	3.67c
B	69.84e	70.61cde	7.41c	8.03bc	15.37de	15.58cde	9.6d	10.33cd	4.83bc	5.23abc
RB	70.21de	72.27abc	7.57bc	8.83bc	15.81cde	17.15bc	9.82d	10.96cd	4.86bc	5.4ab
MB	70.62cde	72.76ab	8.08bc	9.11b	16.75bcde	17.52ab	10.42cd	11.59c	4.85bc	5.18abc
B+RB	71.22bcde	71.96abc	8.13bc	8.55bc	16.89bcde	17.63ab	11.23cd	13.41ab	4.92bc	5.58ab
B+MB	71.53bcd	73.59a	8.74bc	10.92a	16.96bcd	18.98a	11.90bc	14.04a	5.12bc	6.86a

Where, C = control, B = BSRTI recommended basal dose of N300P150K100 kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

8.3.4. Effect of biochar application and cropping years on the incidence of mulberry foliar diseases

The incidence of foliar diseases significantly differed among the treatments and the cropping years of mulberry. In the case of powdery mildew disease, the minimum incidence was 4.64% in the 2nd year. This incidence % was statistically similar to the incidence % of 1st year for the treatment of B+BM.A similar trend was observed both for the incidence percentage of 2nd year for the B+RB treatment and the incidence % of 1st year for MB treatment. However, the maximum incidence % of powdery mildew was 11.34 in 1st year and % of 2nd year for control treatment both was statistically similar. The incidence % of powdery mildew both for 1st and 2nd year for basal treatment was statistically similar to the control treatment. However, in 1st year the maximum incidence of powdery mildew was 11.34 and a minimum 4.91 % for control and B+MB treatments, respectively. Conversely, in 2nd year the maximum incidence of powdery mildew was 11.31 and a minimum 4.64 percent for control and B+MB treatments, respectively (Table 8.7).

The significant ($P \geq 0.05$) difference was observed for the incidence percentage of leaf spot disease in the mulberry plant due to fertilizer treatments and the cropping years. Between the two cropping years the minimum incidence % of leaf spot disease was 3.24 in 2nd year for the treatment of B+MB. This incidence percentage was similar to the incidence % of 2nd year's crop for the treatment of MB. The maximum incidence of leaf spot disease was 11.33 in 2nd-year crop for the control treatment. This incidence percentage was also similar to the incidence % both for the 1st and 2nd year due to the basal treatment. However, in 1st year the maximum incidence of leaf spot was 11.29 for control and a minimum 5.06 % for B+MB treatment, respectively. Conversely, in 2nd year the maximum incidence of leaf spot was 11.33 and a minimum 3.24 % for the control and B+MB treatments, respectively (Table 8.7).

The incidence percentage of tukra disease in the mulberry plant was significantly differed by the fertilizer treatments and the cropping years. The more remarkable trend was observed for the B+MB treatment and 2nd year's crop. Between the two cropping years the statistically lower incidence of tukra disease was 2.4% in 2nd year and 3.94 % in 1st year for the B+MB treatment which were statistically similar. The higher incidence of leaf spot was 10.01 in 2nd year and 9.98 % in 1st years respectively for the control treatment, both were statistically similar. However, in 1st year the significantly higher incidence of tukra was 9.98 for control and lower incidence was 3.94 % for B+MB treatment. Conversely, in 2nd year the maximum incidence of tukra was 10.01 for control and minimum 2.4 % for B+MB treatment respectively (Table 8.7).

Table 8.7. Effect of FYM on foliar diseases of the mulberry plant

Treatments	Powdery mildew		Leaf Spot		Tukra	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
C	11.34a	11.31ab	11.29a	11.33a	9.98a	10.01a
B	10.69ab	10.70ab	10.13ab	10.10ab	8.23b	8.19b
RB	9.65b	6.99c	9.0bc	6.46de	7.99b	5.53cd
MB	4.83d	3.01ef	5.51e	3.73fg	4.44d	2.70e
B+RB	7.09c	4.91d	7.80cd	5.58e	6.19c	4.01de
B+MB	4.91d	4.64de	5.06ef	3.24g	3.94de	2.4e

Where, C = control, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, RB = 3.5 MT rice husk biochar/ha/year, MB = 3.5 MT mineral enriched biochar/ha/year, B+RH = Basal + 3.5 MT rice husk biochar/ha/year and B+MB = Basal + 3.5 MT mineral enriched biochar/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

8.4. DISCUSSIONS

8.4.1. Effect of biochar application on post-harvest physio-chemical properties of soil

Soil nutrient availability increased due to the biochar amendment within the soil. Biochar application improved soil nutrient availability by rising soil pH, organic matter, phosphorus, sulphur and zinc contents within the soil (Table 8.4). Though the soil pH was not significantly increased, but the average soil pH was increased due to the soil treated with only the biochar application (mineral enriched and enrich husk). Similarly, a study found that the soil treated with biochar significantly increased soil pH, electrical conductivity (EC), exchangeable Ca, Mg, K, Na, and P as compared to the control soil (Oguntunde *et. al.,* 2004). They also found that the relative K change observed up to 329% while organic C and total N decreased by 9.8% and 12.8%, respectively. They recommended that organic C and total N were highly correlated ($P < 0.01$) and both the parameters significantly ($P < 0.05$) depended on clay contents in soils. In addition due to the dominating effect of biochar residues while it reduction in soil organic C and total N contents depend on the effects at the severe fire during pyrolysis the soil pH, available P, electrical conductivity, base saturation, exchangeable K, Ca, Mg and Na were significantly higher in biochar treated soil than the control soil.

Likewise, Bayu *et. al.,* (2016) found that biochar increased the soil pH, electric conductivity (EC), cation exchange capacity (CEC), organic carbon (OC), organic matter (OM), total nitrogen (TN), exchangeable cations and available phosphorus of the soil. They speculated that biochar had a displacement of exchangeable acidity and high buffering capacity consequentially soil pH increased, high organic matter contents and enhanced decomposition rate when added biochar in soil. In terms of enriched soil organic matter and also biochar attributed to the improvement of soil pH. That ultimately reduces the activity of Fe and Al. Resulting in the phosphorus availability increased in soil due to the biochar treated soil.

The applied biochar both in mineral enriched and rice husk could directly content a high amount of soluble nutrients (macro and micro), ash containing organic matter, and some exchangeable elements. Besides, biochar itself may have a cation exchange and high buffering capacity with a high decomposition rate of organic matter. Resulting, the soil treated by the biochar (MB and RB) both as a single dose or combined application with BSRTI recommended basal dose of NPK could be absorbed maximum nutrients as per requirements and organic matter decomposition rate increased as well as improved the soil nutrient status.

8.4.2. Effect of biochar amendments on growth and leaf yield of the mulberry plant

Biochar amendments along with BSRTI recommended basal dose of NPK improved the growth and leaf yield of the mulberry plant. Findings showed that the yield attributing characters of the mulberry plant were significantly ($P \geq 0.05$) increased due to the combined application of biochar (MB and RB) with BSRTI recommended basal dose of NPK than the other treatments. Between the two types of biochar amendments, the combined application of mineral enriched biochar with BSRTI recommended basal dose of NPK was showed better performances. The maximum leaf yield was 52.09 MT/ha/year for B+MB treatment. This yield was 113.13 % and 85.11% respectively greater over the maximum leaf yield of control and basal treatments respectively.

Similarly, the 2nd highest leaf yield was 40.35 MT/ha/year due to the application of B+RB. This leaf yield was also 65.10 % and 43.39 % respectively greater over the maximum leaf yield of control and basal treatments, respectively. However, a similar type of finding for the mulberry plant was not available. But studies were available in the literature for the combined application of inorganic fertilizer and biochar in other crops. Likewise, Gebremedhin *et. al.,* (2015) was applied four types of fertilizer treatments viz: 100 kg urea + 100 kg DAP, 100 kg urea+100 kg DAP+4 ton biochar, 100 kg urea+100 kg DAP+7 ton compost and 100 kg urea+100 kg DAP+2 ton biochar + 3.5 ton compost for wheat production. They found that among the four treatments the application of 100 kg urea+100 kg DAP+4 ton biochar gave the maximum plant height (66.8 cm), spike length (10.30 cm), the total number of tillers per 15 plants (36.7), grain yield per 15 plants (24.87 g), straw yield/15 plants (36.30 g), root yield/15 plants (6.07 g) and 100 seed weight (6.83 g) followed by the other treatments. The above finding was similar with this experimental finding. They also speculated that this could be due to the presence of plant nutrients and charcoal in the applied biochar. That may have increased the soil fertility status and water retention intern's wheat productivity was increased at biochar treated soils.

In addition, Igarashi (2002) reported that rice husk biochar application increased the yield of maize, soybean and peanut in Indonesian soil. In this study, the growth and yield of the mulberry plant were increased could be due to the reason that biochar (mineral enriched and enrich husk) contents most of the plant nutrients (macro and micro). Regardless of that biochar amendment increased some of the soil properties like organic matter, sulphur, zinc, and phosphorus content in the soil. That may have improved the soil texture, water holding capacity, soil aggregation, and soil moisture retention capacity. These causes improved the nutrient uptake status of mulberry plants. Resulting in the growth attributes and leaf yield of the mulberry plant was increased due to biochar amendment.

This could be due to the fact that combined application of organic biochar (mineral enriched and enrich husk) with inorganic BSRTI recommended basal dose of NPK treated mulberry plant might be more capable of nutrient uptake both from the organic and inorganic sources. Consequential the mutual applied B+MB treatment has improved the growth and development of the mulberry plant as well as increased the leaf yield compared to the other treatments. Because, Lehmann and Rondon (2006) found that the addition of high rates of biochar in the environment has been associated with increased plant uptake of P, K, Ca, Zn, and Cu.

8.4.3. Effect of biochar application on leaf quality of mulberry plant

The biochar amendment in soil has a great impact on improving the leaf quality of the mulberry plant. The experimental finding showed that among the six types of fertilizer treatments the maximum leaf quality viz: moisture, soluble carbohydrate, crude protein, mineral and total sugar percentage were statistically higher due to the combined application of BSRTI recommended basal dose of NPK + 3.5 MT mineral enriched biochar/ha/year (B+MB) treated mulberry plant followed by the B+RB, MB, RB, basal and control treatments. Even the moisture, soluble carbohydrate, crude protein, mineral and total sugar percentage were 5.58, 40.77, 24.05, 79.08 and 86.92 % respectively greater over the maximum leaf quality of control treatment for the same (B+MB) treatment (Table 8.6). However, a similar type of finding in the mulberry crop was limited. But this finding was similar to the previous finding of Kwaku *et. al.,* (2019) in carrot vegetable. They used 5 ton biochar/ha with recommended NPK 15:15:15@200 Kg/ha, 10 ton biochar/ha with recommended NPK 15:15:15 @ 200 Kg/ha, only 5 ton biochar/ha, only 10 ton biochar/ha and control (no biochar used) for the cultivation of carrot (*Daucus carota* L.). They found that fat, fiber, ash, moisture, protein, carbohydrates, β-carotene and total carotenoid contents in carrot were significantly affected by the treatments.

In this study, the combined application of BSRTI recommended basal dose of NPK + 3.5 MT mineral enriched biochar/ha/year (B+MB) gave the better quality of mulberry may be due to the presence of maximum plant nutrients (macro and micro) is available form in applied mineral enriched biochar. In addition, the additional use of NPK with mineral enriched biochar increased the overall essential nutrients uptake both from the organic and inorganic sources by the mulberry plant. Regardless of that the growth and development of B+MB treated mulberry plant was better and nutritious compared to the other treatments. That might be improved the leaf qualities than the other fertilizer management.

8.4.4. Application of biochar in soil reduces common diseases in mulberry plant

Biochar application within the soil diminishes the incidence of common foliar diseases in the mulberry plants. This experimental finding presented that the maximum incidence of powdery mildew was 11.34 % in the control treatment and the minimum incidence was 4.64% for the combined application of B+MB treatment. The overall incidence of powdery mildew was 59.08 and 56.64% reduced in B+MB treatment followed by the control and basal treatments, respectively. Similarly, the incidence of leaf spot disease was significantly ($P \geq 0.05$) reduced due to the biochar application in soil. The highest incidence of leaf spot disease was 11.33% for the control treatment and the lowest incidence was 3.24% for the same (B+MB) fertilizer management. The leaf spot incidence was 71.40 and 68.02 % lower in B+MB treatment over the control and basal treatments respectively.

In the case of tukra disease, the occurrence was also drastically reduced due to the application of biochar in soil. Among the six types of fertilizer management, the lowest incidence of tukra was 2.4% in B+MB treatment. Conversely, the highest incidence was 10.01% for the control treatment. The incidence of tukra was 76.02 and 70.84% lower in B+MB treatment followed by the control and basal treatments, respectively (Table 8.7). The reduction of foliar diseases incidences happened could be due to the availability of all essential macro and micronutrients within the mineral enriched biochar which was verified by Huber, *et. al.,* (1999). They stated that essential nutrients are vital for plant growth, development, soil microbial activities, and most important factors for diseases control. They also mentioned that all the essential nutrients can affect the diseases severity of plants. Furthermore, mineral enriched biochar may be increased the levels of soil microbial activity leading to increased competition and antagonism in the rhizosphere which may have the contributing factors for reduction of powdery mildew, leaf spot and tukra diseases incidence in the mulberry plant.

Regardless of that biochar might be influenced the microbial populations. That increased in beneficial microorganisms that directly protect against pathogens by producing antibiotics, by out-competing the pathogens, or by grazing on the pathogens. In addition, chemical compounds (NPK) in the residual tars that are added to the soil with the biochar (B+MB) may have direct toxic effects on soil pathogens.

This assumption was more or less closely related to the previous findings of Graber *et.al.,*(2010). They identified a number of biochar compounds that are known to adversely affect microbial growth and survival. These include ethylene glycol and propylene glycol, hydroxy-propionic and butyric acids, benzoic acid and o-cresol, quinones (recorsinol and hydroquinone), and 2-phenoxyethanol. Low levels of these toxic compounds could suppress sensitive components of the soil microbiota thereby resulting in proliferation of resistant microbial communities. Furthermore, the applied biochar could be improved soil nutrient status and produces direct antibiotic against microorganisms, which reduced the common diseases incidence.

Similarly, Graber *et. al.*, (2010) reported biochar improved plant nutrition and microorganisms which excel at degrading toxic organic contaminants generally are more resistant to a variety of toxic organic compounds. Also, antibiotic and volatile organic compound producers are often resistant to a multitude of antibiotics (Laskaris *et. al.*, 2010). Antibiotic producers (*Pseudomonas mendocina* and *P. aeruginosa* strains) were identified in biochar-amended soil by (Graber *et. al.*, 2010).

8.4.5. Effect of biochar application duration on soil, mulberry plant production and suppresses of foliar diseases

Biochar application duration had a great impact on soil properties. Findings showed that the maximum soil pH, organic matter, nitrogen (N), phosphorus (P), sulphur (S) and zinc (Zn) were 8.4, 2, 0.05, 30.7, 9.3 and 1.8% respectively in 2^{nd} year except for potassium which was statistically higher than the 1^{st} year. Similarly, in respect of biochar application duration, the growth attributes and leaf yield of the mulberry plant were significantly ($P \geq 0.05$) enhanced. Between the two cropping years the maximum node per meter, total branch number per, total branch height, total shoot weight, 10 leaf area, 10 leaf weight, and total leaf weight per plant were obtained in the 2^{nd} year. Even the highest leaf yield was 52.09 MT/ha/year in 2^{nd} year whereas the maximum leaf yield in 1^{st} year was 46.29 MT/ha/year. The 2^{nd} year leaf yield was 12.53% higher than the leaf yield of 1^{st}year.

The leaf quality of mulberry plant viz: moisture, crude protein, total sugar, soluble carbohydrate, and mineral were 2.88, 11.91, 33.98, 24.94, and 17.98% respectively greater in 2^{nd}years than the 1^{st} year's mulberry leaf. In the same way, the incidence of powdery mildew, leaf spot, and tukra diseases were 5.5, 35.97, and 39.09 % respectively lower in 2^{nd} year compared to the lowest incidence percentage of 1^{st} year. The similar type's findings were unavailable for the mulberry crop. However, Major *et. al.,*(2010) found that a single application of 20 t ha^{-1}biochar to a Colombian savanna soil resulted in an increase in maize yield by 28 to 140% as compared with the unamended control in the 2^{nd} to 4^{th} years after application. They stated that the decomposition rate of biochar can be increased in the 4^{th} year as compared to 2^{nd} year that results increased in maize production. The speculation of this experiment was the combined application of mineral enriched biochar with BSRTI, recommended basal dose of NPK (B+MB) could be provided a suitable habitat for a large and diverse group of soil microorganisms in respect of point in time. This reason might be improved the microbial decomposition of mineral enriched biochar and nutrients availability in 2nd year. Resulting, B+MB treatment may increase soil organic matter, improved soil structure, improved the soil's ability to retain moisture, prevents nutrient leaching, increased soil pH, improved the biological condition of soils, increased soil microbial biomass and supports beneficial organisms like earthworms compared to the first year. As a result, the nutrients uptake, induced resistance agents, growth promoters, promotion of plant nutritious and vigorous growth as well as induction of systemic resistance against the fungal foliar by the 2nd year crop was comparatively advance than the first year. Regardless of that the soil properties, growth attributes, and leaf yield was improved as well as reduced the incidences of foliar diseases in 2nd year compared to the 1st year crop.

8.5. CONCLUSIONS

This study demonstrated that the application of biochar in soil either with or without BSRTI recommended basal dose of inorganic NPK fertilizers can improve soil fertility and productivity, increases the leaf productivity, improves leaf quality, and suppresses the incidence of the foliar diseases in the mulberry plant. The soil properties, mulberry plant productivity, leaf quality, and disease incidences rate was significantly differed from the first year to the second year due to the addition of biochar in soil either with or without BSRTI recommended basal dose of NPK application. However, the highest leaf yield and leaf quality was found in the combined application of biochar (mineral enriched) with BSRTI recommended basal dose of NPK in 2nd-year crop. Comparatively the lowest incidence of powdery mildew, tukra, and leaf spot diseases were recorded in the second year than the first year due to the same fertilizer management. Based on the findings of this experiment biochar can be used for better mulberry production as well as remain the soil fertility. However, this study needs further validation to examine the advanced and stable fertilizer management technique for quality and quantity mulberry leaf production as well as the reduction of mulberry foliar diseases through other biochar type's utilization.

Several researchers reported that Seri-waste compost prepared from the sericultural by-products, that contain 30 % moisture, 13.88% crude protein, 2.90% N, 0.94 % phosphorus, and 1.5-1.8 % potash besides zinc, iron, manganese and copper as micronutrient. But this valuable sericultural farm wastage residue is totally unused in Bangladesh. If this by-product can be used as seri-waste compost then it will be more economical for the farmer's, especially for sericultural farmers of the country. In addition it will be a trend as a vastly valuable alternative source of organic nutrients for farm production. Furthermore, the information on seri-waste compost use for mulberry plant production was hardly available in the world especially in Bangladesh. In this perspective, further study of Seri-waste compost use efficiency for mulberry plant production and suppression of foliar diseases will be focused in the next chapter (Chapter 9).

Chapter 9

Utilization of seri-waste as a source of nutrients for production and suppression foliar diseases of mulberry

Chapter 9

Utilization of seri-waste as a source of nutrients for production and suppression foliar diseases of mulberry

9.1 INTRODUCTION

Seri-waste could be used as a compost to obtain comparable yields to that obtained with inorganic fertilizers (Heenkende *et. al.,* 2010). The healthy growth and economic traits of the silkworm are largely influenced by the nutritional status of mulberry leaves fed to silkworm (Krishnaswami *et. at.,* 1973). Quality leaf production in mulberry is highly dependent on supply of various inputs especially nitrogen and phosphorus fertilizers (Nasreen *et. al.,* 1999). Application of inorganic fertilizers though increased the leaf yield substantially but cannot sustain the soil fertility status (Bhardwaj *et. al.,* 1994). The intensive mulberry cropping system causes depletion of nutrients in soil and excess usages of inorganic fertilizers and pesticides caused deleterious effect on soil health (Shashidhar *et. al.,* 2009). Recently a great attention was drawn towards the application of organic farming to avoid the heavy use of agrochemicals that resulted in numerous environmental dilemmas (Lampkin, 1990). The organic waste materials mainly animal and plant origin are potential sources of organic matter and plant nutrient (Adeniran *et. al.,* 2003). In these perspectives, Seri-waste can be used as a organic source for mulberry plant production.

The waste in sericulture contains organic matter like larval excreata, leaf litter, dead larvae, moth and cocoons (Kamili *et. al.,* 2000). The Seri-waste which rich in organic matter are not utilized properly for any productive proposes by the tribal farmers. But presently the organic wastes from animal and plant origin are best utilized for vermi-composting by indigenous and exotic earthworms (Nath *et. al.,* 2009). The manures derived from animal wastes like other organic manures have been found to be more economical than commercial fertilizers for plant nutrients. Seri waste compost contains approximately 2.00-2.24% N, 0.93-1.00% P and 1.5-1.8% K besides Zn, Fe, Mn and Cu as micronutrient (Ravikumar *et. al.,* 2014). The application of compost manure produce out of sericulture waste including of silkworm litter is highly beneficial for mulberry cultivation and is much effective than conventional use of farm yard manure (Bhogesha *et. al.,* 1997). Since the pupae contains high amount of nitrogen and protein, there is potential for the bio conversion of pupal waste to enriched compost and utilization as a nutrient source (Singhal *et. al.,* 2001). But the information on utilization of Seri-waste compost for agricultural production was hardily avaliable in the literature. A study was conducted in India and found that Seri-waste compost is rich in nutrient content than the farm yard manure and vermin-compost (Sangeetha *et. al.,* 2012).

The previous chapter showed that biochar amendment in soil improved the soil physio-chemical properties and enhanced the mulberry plant productivity. Furthermore, the leaf qualities of mulberry were improved by the utilization of biochar in soil. Similarly, biochar amendement in soil also reduced the foliar diseases incidences of mulberry plant (Chapter 8). However, the effect of silkworm rearing waste as compost has not been recognized yet in Bangladesh. Hence, this study was undertaken to quantify the impact of silkworm rearing waste compost on changes of soil physio-chemical properties, productivity and suprression of foliar disease incidence in mulberry plant. It was hypothesized that the soil available nutrient status, leaf yield and leaf quality of mulberry will be improved as well as mulberry foliar diseases incidence will be reduced through utilization of Seri-waste compost.

9.2 MATERIALS AND METHODS

9.2.1. Experimental site and design

The experiment was carried out in the experimental field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh (24^0 22′ 29″ North and 88^0 37′ 3.84″ East). This experiment was conducted in randomized complete block design (RCBD) with three replications. Same experiment was repeated for the following year.

9.2.2. Experimental condition

Three years old high-bush mulberry plantation system was used for this study. The mulberry variety BM-11 was used as a testing plant. Mainly four commercial silkworm rearing seasons are followed in a year for Bangladesh. So, the mulberry leaves are required four times each year for silkworm rearing. According to the above needed mulberry garden was pruned four times in a year each after 3 months interval.

9.2.3. Experimental treatments

I. C = Control (Nothing was added).
II. B = BSRTI recommended basal doses of NPK @ 300 kg N, 150 kg P and 100 kg K per hectare per year respectively with four split doses each after three months interval.
III. CD = Cow dung compost @ 10 MT/ha/yr.
IV. SW = Seri-wastes compost @ 10 MT/ha/yr.
V. B+CD = B + Cow dung compost @ 10 MT/ha/yr and
VI. B+SW = B+ Seri-wastes compost @ 10 MT/ha/yr.

9.2.4. Data collection

Data was collected on the growth, leaf yield, leaf quality and diseases incidences percentage of mulberry plant.

9.2.5. Growth and yield contributing characters

Total branches number per plant, total branches height per plant (cm), nodes per meter, total shoots weight per plant (g), 10 leaves area (cm^2) per plant, 10 leaves weight per plant (g), total leaves weight per plant (g) and total leaf yield/ha/yr (MT). The green leaf yield was determined by the following formula:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2 \text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

9.2.6. Leaf quality parameter

The leaf quality parameters viz: moisture, crude protein, mineral, total sugar and soluble carbohydrate percentage were estimated for this study.

9.2.7. Foliar diseases

Common foliar diseases of mulberry plant viz: powdery mildew, leaf spot and tukra incidences percentage were measured for this study.

9.2.8. Analysis of physical and chemical properties of soil, cow dung compost and seri-wastes compost

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). The nitrogen content of the samples was determined by distilling soil with alkaline potassium permanganate solution (Subhaiah *et. al.,* 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 acids (H_2SO_4) (Podder *et. al.,* 2012).

Available S (mg/kg) of soil, cow dung and seri-wastes compost were determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen, 1996). The available K of soil, cow dung and seri-wastes compost were determined was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et. al.,* 2012). The available P of soil, cow dung and seri-wastes compost were determined by spectrophotometer at a wavelength of 890 nm. The samples were extracted by Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq *et. al.,* (2005). 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). After extracting with DTPA, the Zn% in the soil sample, cow dung and silkworm rearing wastes compost were measured by an atomic absorption spectrophotometer (AAS) (Soltanpour *et. al.,* 1979) (Table 9.1).

Table 9.1. Chemical compositions of matured cow dung compost and seri-wastes compost

Parameters Organic manure	Organic matter (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg/kg)	Cu (mg/kg)	Crude protein (%)
Cow dung compost	13.5	1.30	0.58	2.15	0.99	0.52	129	128	13.07
Seri-wastes compost	16.08	1.60	1.00	1.50	0.38	0.37	24.00	45	18.73

9.2.9. Analysis of bio-chemical constituents of mulberry leaf

The leaf samples of mulberry plant was collected in paper bags at 70 days after pruning at different heights of the plant (top, middle and bottom) and composite leaf samples were made. The collected leaves were shade dried for three days and then dried in hot air oven at 70°C for one hour and were ground into powder for chemo-assay. The leaves obtained from different treatments were used for estimation of bio-chemical and mineral constituents viz: leaf moisture contents (%) by Vijayan *et. al.,* (1996) method. Total mineral (%) by the method of (A.O.A.C., 1980). Total sugar content by Dinitrosalicylic acid (DNS) method of Miller, (1972) and procedure of Loomis *et. al.,* (1973). The crude protein contents by Wong, (1923). The soluble carbohydrate content was estimated by Dubois *et. al.,* (1956).

9.2.10. Analysis of disease incidence

The occurrence of disease incidence was recorded for two consecutive years with three replications. Each replication 10 mulberry plants were taken into observation the incidence of foliar diseases viz: powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra (*Meconellicoccus hirsutus*) diseases respectively. The data were collected at 60 days after pruning. Disease incidence (%) was assessed as number of total mulberry leaves per plant was infected by powdery mildew, leaf spot and tukra 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:

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

9.2.11. Statistical Analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1thed^{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. The mean values were evaluated by Duncan Multiple Range Test (DMRT) through using the Statistic-10 software. In case of soil the mean values of post-harvest soil properties were recorded for this study.

9.3 RESULTS

9.3.1. Effect of seri-waste compost on soil physical and chemical properties

Among the six treatments the percentage of nitrogen, phosphorus, potassium, sulphur, zinc and organic matter were highest for BRBD+SWC treatments followed by the BRBD+CDC, BRBD, SWC, CDC and control treatments respectively. The percentage of nitrogen, phosphorus, potassium, sulphur, zinc and organic matter were 0.12, 15.29, 0.39, 18.13, 0.49 and 1.83 respectively for BRBD+SWC treated soil. The maximum soil pH was 8.27 in control plot. However, the soil pH of control plot was comparatively higher than the other treatments treated plot (Table 9.2).

Table 9.2. Post harvest soil properties for various fertilizers treatments

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Zinc (%)	Organic matter (%)	Soil pH
C	0.06±0.006	12.90±0.17	0.16±0.003	9.80±0.06	0.35±0.012	1.42±0.02	8.27±0.066
CD	0.07±0.003	15.07±0.15	0.33±0.14	11.73±0.12	0.61±0.005	1.70±0.01	8.20±0.057
B	0.09±0.012	14.93±0.09	0.26±0.005	11.73±0.09	0.47±0.008	1.56±0.02	8.10±0.057
B+CD	0.10±0.005	15.16±0.09	0.34±0.008	11.40±0.06	0.71±0.011	1.75±0.01	8.17±0.033
SW	0.09±0.003	15.17±0.08	0.30±0.006	9.90±0.06	0.49±0.014	1.53±0.01	8.13±0.12
B+SW	0.12±0.003	15.29±0.06	0.39±0.011	18.13±0.09	0.49±0.008	1.83±0.03	8.23±0.088

Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year

9.3.2. Effect of Seri-waste compost on growth and yield of mulberry plant

Total branches number per plant

The total branches number per plant was highly significant ($P \geq 0.001$) by the fertilizer treatments. The more marked increasing trend was found for the B+SW treatment. However, the total branches number per plant were 10.36, 12.11, 14.51, 15.88, 17.17 and 18.12 for control, basal, CD, SW, B+CD and B+SW treatments, respectively (Figure 9.1; Table 9.2).

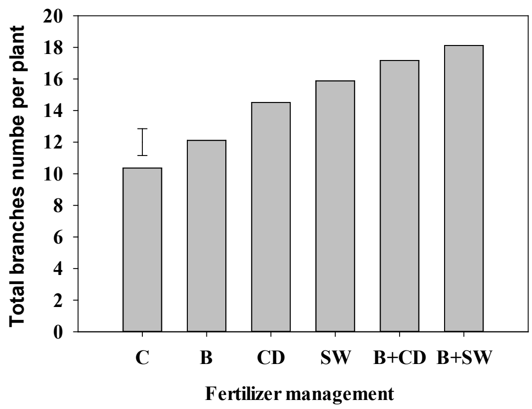

Figure 9.1: Effect of fertilizer management on total branches number per plant of mulberry. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatments. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

Total branches height per plant (cm)

Statistically highly significant ($P \leq 0.001$) trend was found among the fertilizer treatments irrespect to total branches height per plant of mulberry. The more remarkable rising trend was recorded for the B+SW treatment. However, the total branches height per plant were 785.47, 1011.57, 1209.33, 1227.89, 1467.43 and 1521.67 cm for the application of control, basal, CD, SW, B+CD and B+SW treatments, respectively (Figure 9.2; Table 9.2).

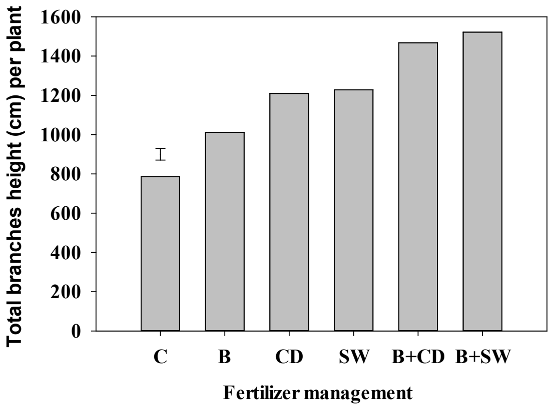

Figure 9.2: Effect of fertilizer management on total branches height per plant of mulberry. Vertical bar represent LSD (*P* ≥ 0.05) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

Table 9.3. Significance levels from the analysis of variance for the main effects of growth and yield parameters among various fertilizers management

Sources of variation	Total branches number/ plant	Total branches height/plant (cm)	Nodes/ meter	10 leaves area (cm^2)/plant	10 leaves weights (g)/plant	Total shoots weight/ plant (g)	Total leaves weight/ plant (g)	Total leaf yield/hectare/year (MT)
Treatments	***	***	***	***	***	***	***	***

Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001 respectively. Values were means of three replicates.

Nodes per meter

The nodes per meter was highly significant (*P* ≥ 0.001) by the fertilizer treatments. The B+SW treatment presented the more increasing trend. However, the nodes per meter were 17.85, 20.64, 22.18, 24.47, 24.83 and 26.57 due to the treatments of control, basal, CD, SW, B+CD and B+SW treatments, respectively (Figure 9.3; Table 9.3).

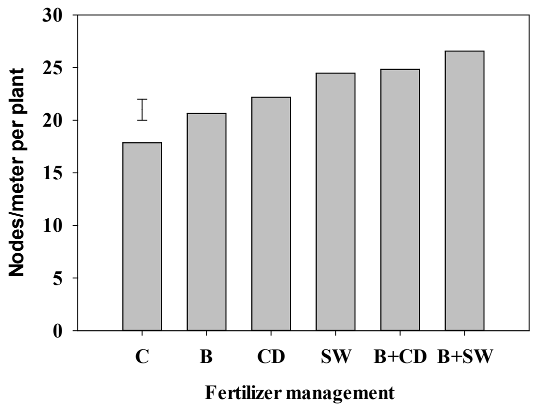

Figure 9.3: Effect of fertilizer management on nodes per meter of mulberry plant. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

Total shoots weight per plant (g)

The highly significant ($P \geq 0.001$) difference was found among the fertilizer treatments irrespect to total shoots weight per plant of mulberry. The more increasing trend was noted for the B+SW treatment. However, the recorded total shoots weight per plant were 349.65, 479.77, 546.67, 557.53, 643.33 and 691.77 g for the control, basal, CD, SW, B+CD and B+SW treatments respectively (Figure 9.4; Table 9.3).

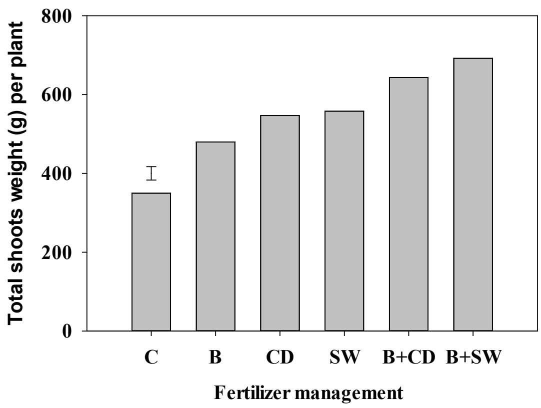

Figure 9.4: Effect of fertilizer management on total shoots per plant of mulberry plant. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

10 leaves area (cm^2) per plant

Statistically highly significant ($P \geq 0.001$) variation was observed among the fertilizer treatments irrespect to 10 leaves area of mulberry plant. The more marked rising rate was observed by the B+SW treatment. However, the 10 leaves area were 428.23, 530.76, 591.7, 595.93, 621.77 and 637.39 cm^2 due to management of control, basal, CD, SW, B+CD and B+SW treatments, respectively (Figure 9.5; Table 9.3).

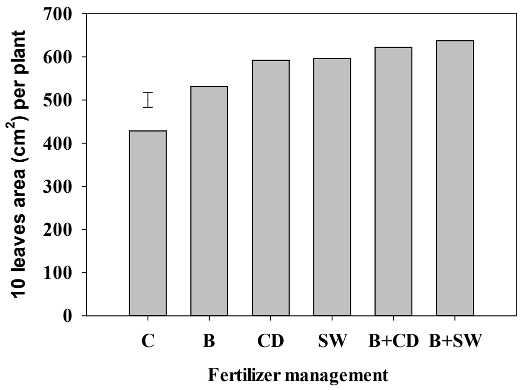

Figure 9.5: Effect of fertilizer management on 10 leaves area of mulberry plant. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

10 leaves weight per plant (g)

The highly significant ($P \leq 0.001$) difference was observed among the fertilizer treatments with respect to 10 leaves weight of mulberry plant. The most significant trend was recorded for the B+SW treatment. However, the 10 leaves weight per plant were 20.57, 25.23, 38.84, 40.8, 46.6 and 49.09 g for the application of control, basal, CD, SW, B+CD and B+SW treatments, respectively (Figure 9.6; Table 9.3).

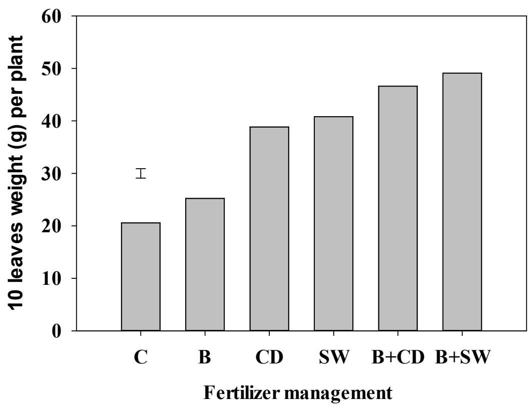

Figure 9.6: Effect of fertilizer management on 10 leaves weight per plant of mulberry. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

Total leaves weight per plant (g)

The total leaves weight per plant was highly significant ($P \leq 0.001$) by the fertilizer treatments. The B+SW treatment showed the maximum increasing trend. However, the total leaves weight were 505.93, 583.77, 841.25, 878.96, 1044.58 and 1088.13 g for the treatments of control, basal, CD, SW, B+CD and B+SW, respectively (Figure 9.7; Table 9.3).

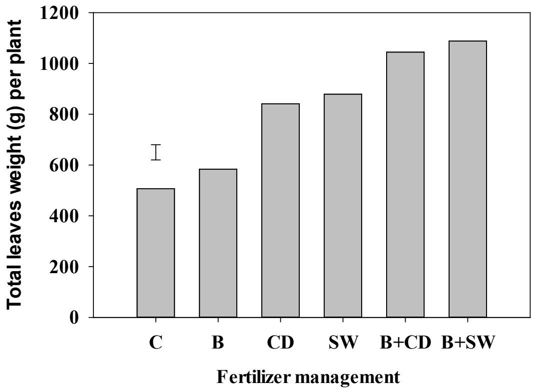

Figure 9.7: Effect of fertilizer management on total leaves weight per plant of mulberry. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

Total leaf yield/ha/year (MT)

Statistically highly significant ($P \leq 0.001$) trend was found among the fertilizer treatments with respect to total leaf yield of mulberry plant. The more marked increasing trend was found for the B+SW treatment. However, the total leaf yields per hectare per year were 24.33. 28.02, 40.38, 42.19, 50.14 and 52.23 MT/ha/year for the treatments of control, basal, CD, SW, B+CD and B+SW respectively (Figure 9.8; Table 9.3).

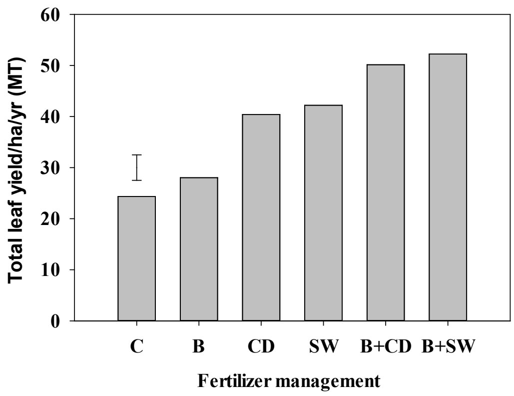

Figure 9.8: Effect of fertilizer management on total leaf yield per hector per year of mulberry plant. Vertical bar represent LSD ($P \geq 0.05$) for several fertilizer treatment. Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year.

9.3.3. Impact of Seri-waste compost on bio-chemical constituents of mulberry leaf

The leaf quality of mulberry plant was differed significantly ($P \geq 0.05$) among several fertilizer treatments. Among the six types of fertilizer treatments the more increasing percentage of moisture, crude protein, mineral, total sugar and soluble carbohydrate were found for the B+SW treatment followed by the B+CD, SW, CD, B and control treatments, respectively. However, the maximum average moisture, crude protein, mineral, total sugar and soluble carbohydrate were 76.63, 20.54, 13.78, 6.29 and 10.81 percent respectively for the combined application of B+SW treatment. Interestingly, the moisture and crude protein percentage were statistically similar both for the B+SW and B+CD treatments. Conversely, the minimum average moisture, crude protein, mineral, total sugar and soluble carbohydrate were 69.69, 15.30, 7.87, 3.65 and 7.23% respectively for the control treatment. The leaf quality of control treatment was statistically similar with the leaf qualities of B treatment except mineral percentage (Table 9.4).

Table 9.4. Bio-chemical constitutions of mulberry leaf for various fertilizers management

Treatments	Moisture (%)	Crude Protein (%)	Mineral (%)	Total Sugar (%)	Soluble Carbohydrate (%)
C	69.69d	15.30d	7.87c	3.65b	7.23b
B	70.24d	15.49d	10.0b	4.99ab	7.73b
SW	74.33bc	18.47bc	13.22a	5.89a	10.28a
CD	73.19c	18.45c	12.75a	5.77a	9.77a
B+SW	76.63a	20.54a	13.78a	6.29a	10.81a
B+CD	75.97ab	20.23ab	13.66a	6.11a	10.51a

Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

9.3.4. Impact of seri-waste compost on foliar diseases of mulberry plant

The incidence of foliar diseases of mulberry plant was statistically reduced by the fertilizer treatments. In case of powdery mildew disease, the minimum incidence % was 2.07 for the B+SW treatment. This incidence percentage was statistically similar with the incidence percentage of B+CD, SW and CD treatments respectively. However, the statistically higher incidence % of powdery mildew was 11.37 for the control treatment. This incidence was statistically similar with the incidence percentage of basal treatment. The lower incidence percentage of leaf spot disease was 1.07 also for the same (B+SW) fertilizer management. But this incidence percentage was statistically similar both for the incidence percentage of B+CD and SW treatments, respectively. However, statistically maximum incidence percentage of leaf spot was 11.28 for the control treatment. This incidence was statistically similar with the incidence of B treatment. In case of tukra disease, incidence percentage was similar among B+SW, SW, B+CD and CD treatments. However, the lower occurrence percentage of tukra was 1.02 due to the B+SW treatment. This occurrence percentage was statistically lower than the control and B treatments respectively. Conversely, the higher incidence percentage of tukra was 9.99 for the control treatment. The tukra incidence percentage of B treatment was statistically similar with the incidence of control treatment (Table 9.5).

Table 9.5. Effect of various fertilizers management on incidence of foliar diseases of mulberry

Treatments	Powdery mildew	Leaf spot	Tukra
C	11.37a	11.28a	9.99a
B	10.67a	10.15a	8.22a
SW	3.11b	2.36bc	1.07b
CD	3.36b	3.06b	1.87b
B + SW	2.07b	1.07c	1.02b
B +CD	2.18b	2.49bc	1.32b

Where, C = control, B = BSRTI recommended basal doses of NPK, CD = 10 MT cow dung compost/ha/year, SW = 10 MT seri-waste compost/ha/year, B+SW= BSRTI recommended basal doses of NPK + 10 MT seri-waste compost/ha/year and B + CD = BSRTI recommended basal doses of NPK + 10 MT cow dung compost/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

9.4. DISCUSSIONS

9.4.1. Effect of seri-wastes on soil properties

Seri-waste compost has a potential effect on soil properties. The combined application of seri-waste compost and recommended dose of inorganic fertilizer provide highest NPK value as compared to the other treatments. Highest N, P and K percentage were 0.12, 15.80 and 0.39 respectively for the BSRTI recommended basal dose of N P K plus Seri-waste compost treated soil. This finding was similar with the previous finding of Heenkende *et. al.,* (2010). They found that the combined application of 50 % N recommended dose of fertilizer + 50 % N seri-compost increased the nitrogen, phosphorus and potassium contents in soil compared to the application of only 100 % N through seri-compost, inorganic recommended dose of fertilizer + farmyard manure 25t/ha and 50 % N recommended dose of fertilizer + 50 % N farmyard manure.

However, they did not observed the others soil properties status in soil. But in this study, the other soil properties were observed, where the highest sulphur (18.13%), zinc (0.49 %) and organic matter (1.83%) were found also in soil treated by the combined application of BSRTI recommended basal dose of NPK + seri-waste compost among the all treatments. This could be due to the highest available residual nitrogen, phosphorus and potassium contents with higher decomposition and releasing rate of seri-wastes compost. That enhanced the nutrient availability within soil as compared to the other treatments. Likewise, Ramakrishna (2001) utilized the silkworm litter as an organic fertilizer and analyzed the silkworm excreta. He reported that the silkworm excreta contain higher composition of nitrogen, phosphorus, potassium, sodium and carbon when compared to cow dung or FYM compost. Correspondingly, Das *et. al.,* (1997) reported that 12-15 million tons of seri-waste has a tremendous manorial value of nitrogen (280-300 kg), phosphorus (90-100 kg) and potassium (150-200 kg) as well as micronutrients like iron, zinc, copper etc.

In this study the combined application of recommended basal dose of NPK plus seri-waste compost (B+SW) might be contains comparatively maximum amount of plant nutrients (macro and micro) with higher decomposition rate within shorter period of time. In addition, seri-waste compost also enhanced the population of some beneficial micro flora or microorganisms like bacteria, fungi, actinomycetes etc. In terms, B+SW treatment was enhanced the mineralization and decomposition rate of seri-waste compost in soil with available nutrients as well as improved the nutritional status of soil compared to the other treatments.

9.4.2. Effect of seri -waste compost on plant growth and leaf yield

Application of seri-waste compost had a significant impact on mulberry plant production. Findings showed that among the six types of fertilizer management the combined application of B+SW treatment showed the maximum growth attributing performances of mulberry plant viz: total branches number, total branches height, 10 leaves area, 10 leaves weight, nodes per meter, total shoots weight per plant, total leaves weight per plant and total leaf yield followed by the B+CD, SW, CD, basal and control treatments respectively. The performance of single applied seri-waste compost was better compared to the single applied cow dung compost (CD), basal and control treatments respectively, except the combined result of B+CD treatment. However, B+SW treated mulberry plot gave the maximum leaf yield 52.23 MT/ha/year. This leaf yield were 4, 23.8, 29.35, 86.40 and 114.67% greater followed by the B+CD, SW, CD, B and control treatments, respectively.

The above finding was similar with the previous finding of Sudhakar *et. al.,* (2018). They applied 5 MT seri-rearing residue compost with 350 kg N, 140 kg P and 140 kg K/ha/year for mulberry plant production and obtained the maximum plant height, number of branches per plant, number of leaves per plant, single leaf area and leaf yield kg/ha/crop followed by the combined application of 20 MT FYM + 350 kg N, 140 kg P and 140 kg K/ha/year. Their speculation was due to the superior nutrient status of seri-rearing residue compost improving the plant growth and leaf yield compared to the other compost. In the same way, Sangeetha *et. al.,* (2012) conducted a field experiment by using the silk-worm litter-pupal waste compost for mulberry plant production. They found that after 60 days of pruning the silkworm litter – pupal waste compost (SLPW) treated mulberry plant gave the maximum average plant height was 153.8 cm and average leaves number per plant was 140. Their assumption was that the applied SLPW compost might have increased the release of macro as well as micronutrients. Resulting increased the production of dry matter, plant height and nutrient uptake by the SLPW treated mulberry plant, interms, influenced the higher leaf production in mulberry plant.

In this study the combined application of 10 MT/ha/year seri-waste compost with BSRTI recommended basal dose of NPK (B+SW) showed the better performances irrespect to mulberry growth attributes and leaf yield could be due to the combined application of BRBD plus SW compost released maximum amount of macro and micro nutrients for mulberry plant uptake within the soil. In addition, might be due to the mineralization of N during the decomposition of seri-waste compost would have enhanced the N availability in soil. Resulting B+SW treated mulberry plant enhanced the N uptake both from the additional applied of NPK as basal dose and applied seri waste compost. In terms, the beneficial effect would have promoted higher yield attributes and leaf yield through B+SW treated mulberry plant compared to the other treatments. In addition, due to amendment of soil through seri-waste compost could be attributes to the potential effect of soil viz: improving beneficial microbial activity, water holding capacity, micronutrients and nutritional properties of soil. Resulting, the combined application of B+SW treated mulberry plant might be influenced the maximum amount of nutrients uptake from soil to the plants. These beneficial combined effects might be promoted higher yield attributes as well as increased the leaf yield of mulberry plant compared to the other treatments.

9.4.3. Effect of seri-waste compost on leaf quality

Seri waste compost enhanced the leaf quality of mulberry plant. Findings showed that among the six types of fertilizer treatments the maximum average moisture, crude protein, mineral, total sugar and soluble carbohydrate were found for the combined application of BSRTI recommended basal dose of NPK plus seri-waste compost treated mulberry plant followed by the other treatments. Even, the moisture, crude protein, mineral, total sugar and soluble carbohydrate were 9.96, 34.25, 75.09, 72.33 and 49.52 % respectively greater for the B+SW treated mulberry plant over the control.

Similar, Sangeetha *et. al.,* (2012) mutually used the seri-waste compost and NPK for mulberry plant production. They found that the average moisture percentage was significantly ($P \geq 0.05$) increased by the seri-waste compost treated mulberry plant and the maximum moisture percentage were 71.40. The experimental finding of this study was also similarly with the previous finding of Chakraborty *et. al.,* (2011). They applied combined silkworm rearing waste + Azotobacter (AZB) + 50% N + 40% P + 100% K to the experimental plot with other treatments like (FYM + NPK), weed compost + AZB + 50% N + 40% P + 100% K), (poultry manure + AZB + 50% N + 40% P +100% K) and pig manure + AZB + 50% N + 40% P + 100% K) for evaluating the leaf quality of mulberry plant. They found that among the five treatments the average leaf moisture content, leaf moisture retention capacity and leaf protein % were 72.31%, 88.83% and 17.96 mg/g fresh weight respectively for the leaf of silkworm rearing waste + AZB + 50% N + 40% P + 100% K treated mulberry plant. That was comparatively higher than the (FYM + NPK) and weed compost +

AZB + 50% N + 40% P + 100% K) treated plot. Their assumption was this could be due to the beneficial combined effect of silkworm rearing waste + AZB + 50% N + 40% P + 100% K to the soil fertility status, overall plant growth and biochemical constituents of mulberry leaf. Resulting the leaf quality was comparatively high than the other treatments. Similarly, Sudhakar *et. al.,* (2018) used 5 MT vermi-compost prepared from the seri-rearing residue along with 350 kg N, 140 kg P and 140 kg K/ha/year respectively for mulberry cultivation. They found that the maximum leaf moisture (76.50%), total chlorophyll (3.20 mg/g) and leaf protein (18.05%) which was comparatively higher than the other treatments.

In this study, the B+SW treated mulberry plant gave the better leaf quality may be due to the combined superior nutritive value of seri-waste rearing compost plus basal dose of NPK. That could be enhanced the organic matter content, water holding capacity and flourishing the various beneficial microorganisms activities within soil solution. These beneficial synergetic effects per have improved or produced more plant growth substances and enzyme activity within the B+SW treated mulberry plant. In terms, BSRTI recommended basal dose of NPK + 10 MT seri-waste compost/ha/year treatment might be improved the nutritional status of mulberry leaf compared to the other treatments.

9.4.4. Effect of seri-waste compost on foliar diseases of mulberry plant

Seri-waste compost had a positive impact on suppression of foliar diseases in mulberry plant. Among the six types of fertilizer treatments the combined application of BSRTI recommended basal dose of NPK plus 10 MT seri-waste compost/ha/year (B+SW) treatment was significantly ($P \geq 0.05$) reduced the incidence of foliar diseases of mulberry plant followed by the control and basal treatments, respectively (Table 9.4). Findings showed that the incidence percentage of powdery mildew, leaf spot and tukra diseases were comparatively minimum in B+SW treatment followed by the B+CD, SW, CD, B and control treatments, respectively. Even, the mutual application of B+SW treatment was reduced of powdery mildew, leaf spot and tukra diseases incidences were 81.76, 90.52 and 89.77% respectively over the control.

Similarly, in previous study Maji *et. al.,* (2013) was collectively used 15 t vermi-compost prepared by using the sericulture waste: silkworm liters, unused mulberry leaves, weeds of mulberry field where the nutrients sources were similar with this experimental seri-waste compost along with NPK (168:90:56) for mulberry cultivation. They found that the severity of powdery mildew and leaf spot diseases of mulberry plant were significantly ($P \geq 0.05$) reduced due to application of this compost. They also found that the incidence of powdery mildew and leaf spot diseases were 4.07 and 5.93% respectively for this compost. But the severity of powdery mildew and leaf spot diseases were 10.06 and 15.22% respectively for control treatment which was similar with this experimental finding. Their speculation was that could be due to the increasing of soil microbial activity, leading to increased competition and antagonism in the rhizosphere. That enriched soil beneficial mycoflora and supply of nutrient for robust growth and bring forth resistance to diseases under seri-waste compost plus inorganic NPK (168:90:56) treated mulberry plant. In terms, the severity of powdery mildew and leaf spot diseases may be reduced. Likewise, the more or less similar finding was observed by Samuthiravelu *et. al.,* (2012). They imposed 0.20 % seri-boost (Prepared by the seri-cultural wastages) through the foliar application was made 500L/ha with hand sprayer in the evening hours thrice at 15, 25 and 35 days after pruning. They found that the incidence of tukra mealy bug (*Maconellicoccus hirsutus*) were 46.12%, 43.56% and 18.18% respectively in 20, 30 and 40 days after pruning (DAPr) for 0.20% Seri-boost application. Convesrely, the incidence percentage of tukra mealy bug (*Maconellicoccus hirsutus*) were 48.25%, 47.85% and 21.15% respectively in 20, 30 and 40 DAPr for the control treatment.

However, in my study the mutual applied seri-compost with BSRTI recommended basal dose of NPK could be balanced organic and inorganic proportion. That might be helped to enrich the soil beneficial mycoflora and produced fungi toxic substances during organic matter decomposition or induction of systemic resistance in the host plant. For this possible reason the incidence of foliar diseases of mulberry plant viz: powdery mildew, leaf spot and tukra might be reduced in B+SW treatment compared to the other treatments.

9.5. CONCLUSIONS

The present study revealed that the combined application of seri-waste compost with BSRTI recommended basal dose of NPK (B+SW) have sound effect on the production of mulberry under field condition. Seri-waste compost has contributed the higher leaf yield, quality as well as reduction of foliar diseases of mulberry as compared to the other fertilizers management. However, the recorded maximum leaf yield was 52.23 MT/ha/year due to mutual application of BSRTI recommended basal dose of 300 kg N, 150 kg P and 100 kg K respectively with better soil properties. Similar, the better leaf qualities viz: moisture, crude protien, total sugar, total mineral and soluble carbohydrate was found also for the same fertilizer management. Furthermore, the mutual application of B+SW treatment was also optimum reduction of mulberry foliar diseases incidences.

The findings of this study indicated that the collective application of Seri-waste compost with BSRTI recommended basal dose of NPK would be an advisable treatment that produces quality, quaintly of mulberry leaf and maximum suppression of foliar diseases through improving the soil available nutrients. In my previous studies the partial incidences of foliar diseases with leaf yield and quality of mulberry plant were evaluated through different types of fertilizer management. But the normal or soul disease incidences of mulberry plant have not been evaluated previously. Besides, previous findings showed that mulberry varity and cropping season has a significant efferect on occurrence of mulberry foliar diseases. So, the further study will be conducted to examine the specific or core diseases incidences of mulberry plant irrespective to mulberry genotypes and copping seasons in the following chapter (Chapter 10).

Chapter 10

Cropping seasons and foliar diseases of mulberry plant differs in climatic conditions

Chapter 10

Cropping seasons and foliar diseases of mulberry plants differs in climatic conditions

10.1. INTRODUCTION

Mulberry (*Morus* sp.) is a hardy deciduous perennial tree or shrub used as a food source for the domesticated silkworm, *Bombyx mori* (Aggarwal *et. al.,* 2004). The most important factor is the mulberry leaf, contributing about 38.2% followed by climate (37.0%), rearing techniques (9.3%), silkworm race (4.2%), silkworm egg (3.1%) and other factors (8.2%) in producing good quality cocoons (Miyashata, 1986). 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). It has been estimated that, nearly 70% of the silk proteins are derived from mulberry leaves. Hence, silkworms should be fed with good quality mulberry leaves in abundant quantity for the successful cocoon production (Vijaya *et. al.*, 2009).

Incidences of diseases are one of the most key limiting factors for successful mulberry production. Because, like others agricultural crops mulberry plant is also affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et. al.*, 1990; Yashihiko, 1995). Common mulberry diseases in Bangladesh are powdery mildew, leaf spot and tukra (Rabbel, 1995). Powdery mildew is one of the major foliar fungal diseases caused by *Phyllactinia corylea* (Pers). Karst which is also known as *P. moricola* (P. Henn.) Homma (Takamatsu *et. al.*, 1982). Several studies found that the loss due to powdery mildew is around 12% besides causing depletion in nutritive value of mulberry (Teotia and Sen, 1994; Qadri *et. al.*, 1998). Likewise, the highest leaf infection of 56-70% resulted in 29-41% of disease severity in mulberry in Bangladesh (Rabbel, 1995). Sharma *et. al.,* (2009) also found that through leaf spot disease causes 10-12% leaf yield loss. Rabbel (1995) also observed that leaf infection was 44-55% with 17-21% disease severity in Bangladesh through the leaf spot disease. The symptoms of mealy bug infestation in mulberry collectively called as tukra (Misra, 1919). Similarly, the tukra (mealy bug) disease affected mulberry plantation three to six tones of leaf yield/ha/ year recorded by Kumar *et. al.*, (1992). However, Jindal *et. al.,* (2002) reported that the diseases infection rate of different mulberry accessions can be attributed to varietal characteristics ascribed to genetic inheritance. Likewise, climate is also a predominate factors for the development of diseases in mulberry plant (Wolf *et. al.,* 2005).

The previous chapter showed that seri-waste compost had a significant effect on growth and leaf yield of mulberry. Similarly, seri-waste compost improved the soil nutrient status as well as improved the leaf quality of mulberry. In addition, the incidences of mulberry foliar diseases were significantly reduced due to application of seri-waste compost. Though the seri-waste compost was reduced the incidence of mulberry foliar diseases but earlier research findings reported that the infestation of diseases significantly influenced by the impact of variety or genotypes, cropping season and climatic factors. In my previous studies only the partial incidences of foliar diseases were investigated irrespective to different fertilizers management along with only one mulberry variety (BM-11). But the soul infestation of mulberry foliar diseases in terms of cropping seasons, mulberry varieties or genotypes and climatic factors aspect has not been observed in my any previous studies. Besides, the information of foliar diseases incidences in mulberry plant irrespective to mulberry genotypes or varieties and cropping season as well as climatic factors or response was hardy available especially in Bangladesh. In this perspective, this study was undertaken to evaluate the impact of mulberry genotypes or varieties and cropping seasons on incidences of foliar diseases. It was hypothesized that the incidence of foliar diseases will be varied irrespective to mulberry genotypes or varieties as well as cropping seasons.

10.2. MATERIALS AND METHODS

10.2.1. Experimental duration and location

This study was conducted for two consecutive years in the experimental field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh. The two years average data were used for this study.

10.2.2. Basic soil physical and chemical properties

The soils of the experimental plots of BSRTI were mainly loam in nature, having normally alkaline characteristics with pH ranging from 7.2 to 8.8. 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 experimental soil were shown in the Table 10.1.

Table 10.1. Physical and chemical properties of the experimental soil

Soil pH	Nitrogen (%)	Phosphorus (ppm)	Potassium (Cmol/Kg)	Sulphur (ppm)	Zinc (ppm)	Organic matter (%)
8.5	0.07	29.0	0.26	2.6	2.36	1.24

10. 2.3. Sample material

Nine mulberry varieties viz: BM-1, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, BM-10 and BM-11 and three mulberry genotypes namely Black, S-13 and S-30 were used for this study as a sample testing materialas.

10.2.4. Recorded diseases

Three mulberry foliar diseases namely powdery mildew, leaf spot and tukra were recorded in this study.

10.2.5. Cropping seasons

The incidence of foliar diseases was observed in three cropping seasons viz: late autumn (October to December), summer (April to June) and rainy (June to August) season.

10.2.6. Experimental design

The experiment was laid out in randomized complete block design (RCBD) with three replications. The experimental design was twelve mulberry varieties or genotypes × three cropping seasons × three diseases.

10.2.7. Plot size

The plot size was 5 m long and 4 m wide. Plant-plant distance 0.92 m and line-line distance 0.92 m. The number of plants for each plot was 20.

10.2.8. Experimental procedure

For a period of two consecutive years, ten numbers of infected plants were randomly selected in every replication and each cropping seasons. The plantation system was high bush. In each cropping seasons data was collected 70 days after pruning. Disease incidence was assessed as number of total mulberry leaves per plant and number of total infected leaves per plant of a disease or any visible symptom of specific diseases in that plant.

10.2.9. Data collection

The necessary data was collected for each crop season from randomly selected disease infected plant. In case of late autumn season data was collected in October to November, in summer season March to April and in rainy season it was in June-July and July-August in each year. The incidence percentage of different diseases in mulberry leaf was calculated by following formula using by the Rai and Mamatha (2005).

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

Moreover monitoring of disease environment relation to epidemiological aspects of powdery mildew, leaf spot and tukra diseases have been carried out in this experiment. In these perspectives, the necessary meteorological data like air temperature, relative humidity (RH) and rainfall for the respective seasons were collected from local weather stations of Shampur, Rajshahi throughout the study period. The collected data were calculated for monthly mean of minimum and maximum temperature, mean of relative humidity and mean of rainfall of the respective locations and respective seasons.

10.2.10. Analysis of soil physical and chemical properties

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). 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).

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). The available P of the soil solution 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). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

10.2.11. Statistical analysis

Some statistical analysis was conducted using Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK). Also, some analysis was conducted by Statistix 10 software. Treatment means were separated by the least significant difference (LSD) at a 0.05% level of significance (Steel and Torrie, 1984). Other parameters were statistically analyzed and mean values were evaluated by Duncan Multiple Range Test (DMRT).

10.3. RESULTS

10.3.1. Incidence of mulberry foliar diseases among the cropping seasons

In this study 9 mulberry varieties and 3 mulberry genotypes have been used in summer (April to June months) season for each two year. In case of powdery mildew disease the maximum average incidence was 1.76% for the genotype of S-30 and the lowest incidence was 1.17 % in BM-7 variety. DMRT results showed that rest of the varieties or genotypes have no significant differences in disease occurrence (Table 10.2). In case of leaf spot disease the highest incidence was 1.73% for the BM-6 variety. The lowest incidence percentage was variety 0.47% for the genotype of Black. The maximum incidence of tukra disease was 0.63% in BM-4 variety. Conversely the lowest incidence of tukra was 0.15% both for the variety of BM-10 and BM-11. This tukra incidence percentage was statistically similar with the incidence percentage of genotypes S-13 and variety of BM-6 and BM-7 respectively (Table 10.2). This result also indicated that among the three diseases, powdery mildew was more occurrence than the other two diseases (Table 10.2).

Table 10.2. Incidences of mulberry diseases in different mulberry varieties/genotypes during summer (April-June) crop season

Name of the varieties/genotypes	Mean diseases incidence percentage (%)		
	Powdery mildew	Leaf spot	Tukra
Black	1.27^{ab}	0.47^{d}	0.31^{ab}
BM-1	1.60^{ab}	0.94^{bcd}	0.52^{ab}
BM-3	1.62^{ab}	1.30^{abc}	0.28^{ab}
BM-4	1.47^{ab}	1.70^{a}	0.63^{a}
BM-5	1.23^{ab}	1.35^{abc}	0.34^{ab}
BM-6	1.38^{ab}	1.73^{a}	0.16^{b}
BM-7	1.17^{b}	1.55^{ab}	0.19^{b}
BM-8	1.56^{ab}	0.90^{bcd}	0.21^{ab}
BM-10	1.37^{ab}	1.22^{abc}	0.15^{b}
BM-11	1.20^{ab}	0.67^{cd}	0.15^{b}
S-13	1.46^{ab}	1.54^{ab}	0.17^{b}
S-30	1.76^{a}	1.29^{ab}	0.30^{ab}

In a column, means followed by common letter are not significantly different at the 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

Similarly, the same nine mulberry varieties and three mulberry genotypes have been used in late autumn (October-December) season for each two year. The recorded maximum incidence of powdery mildew disease was 10.41% for the BM-7 variety. On the other hand the minimum incidence percentage of powdery mildew was 2.47 % and 2.94 % for the varieties of BM-8 and BM-11, respectively. The DMRT results showed that there were no significance differences for powdery mildew occurrences among rest of the varieties or genotypes (Table 10.3). In case of leaf spot disease, genotype S-13 showed the highest incidence 8.49 % and variety BM-8 showed lowest incidence 2.47%. However, both the leafspot incidences percentage was statistically similar with the leaf spot incidence percentage of variety BM-11 (Table 10.3).

Similarly, the recorded higher occurrence of tukra disease was 3.10 % in Black genotype. Conversely, the lower incidence of tukra was 0.53% for the variety of BM-8. The results also found that the incidence percentage of tukra disease was statistically similar among the genotypes or varieties except BM-1 variety (Table 10.3). The above result also showed that among the three diseases, the incidence of powdery mildew was higher also in late autumn season than the other two diseases (Table 10.3).

Table 10.3. Incidences of mulberry diseases in different mulberry varities/genotypes during late autumn (October–December) crop season

	Mean diseases incidence percentage (%)		
Name of the varieties/ genotypes	Powdery mildew	Leaf spot	Tukra
Black	3.41^{d}	3.53^{ef}	3.10^{a}
BM-1	5.26^{c}	5.65^{bcd}	1.49^{b}
BM-3	9.19^{ab}	4.89^{cde}	0.67^{bc}
BM-4	8.73^{b}	1.08^{bcd}	0.68^{bc}
BM-5	9.09^{ab}	4.81^{cde}	1.21^{bc}
BM-6	5.33^{c}	4.17^{def}	0.80^{bc}
BM-7	10.41^{a}	6.33^{bc}	1.09^{bc}
BM-8	2.47^{d}	2.80^{f}	0.53^{c}
BM-10	4.89^{c}	5.07^{cde}	1.14^{bc}
BM-11	2.94^{d}	2.36^{f}	0.63^{bc}
S-13	8.09^{b}	8.49^{a}	1.13^{bc}
S-30	6.21^{c}	6.94^{ab}	0.75^{bc}

In a column, means followed by common letter are not significantly different at the 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

Further, in rainy season (June-August) among the same 9 varieties and 3 genotypes the maximum average powdery mildew incidence was recorded in genotypes S-13 (3.88 %). Conversely, the lowest incidence was found in BM-11 variety (1.82 %). Results showed that there were no significant differences among rest of the varieties or genotypes irrespective to occurrences percentage of powdery mildew. Correspondingly, the highest occurrence of leaf spot disease was 4.54 % in variety of BM-1 which was statistically similar with the incidence percentage of BM-7 variety. Conversely, the lowest incidence of leaf spot was 1.24 % for the genotype of S-13.

However, in case of tukra disease the maximum incidence was 1.21% for the variety of BM-4. On the other hand the lowest incidence of tukra was 0.50% in variety of BM-10. However, there were no significant differences among the varieties or genotypes irrespective to tukra incidence percentage. The above result also showed that among the three foliar diseases, powdery mildew incidence was also higher followed by the leaf spot and Tukra diseases respectively in the rainy season (Table 10.4).

Table 10.4. Incidences of mulberry diseases in different mulberry varities/genotypes during rainy (June-August) crop season

Name of the varieties/genotypes	Mean diseases incidence percentage (%)		
	Powdery mildew	Leaf spot	Tukra
Black	1.97^{cde}	2.36^{bcd}	1.04^{a}
BM-1	1.93^{de}	4.54^{a}	1.13^{a}
BM-3	1.97^{de}	3.29^{cd}	1.11^{a}
BM-4	3.01^{abc}	1.64^{de}	1.21^{a}
BM-5	3.05^{abc}	3.90 ^{ab}	1.14^{a}
BM-6	2.81^{bcdf}	3.32^{abc}	1.18^{a}
BM-7	2.86^{bcd}	3.98^{a}	0.77^{a}
BM-8	2.31^{bcdf}	3.29^{abc}	1.07^{a}
BM-10	3.31^{ab}	3.31^{abc}	0.5^{a}
BM-11	1.82^{e}	1.73^{de}	1.08^{a}
S-13	3.88^{a}	1.24^{e}	0.83^{a}
S-30	1.93^{de}	1.67^{de}	0.85^{a}

In a column, means followed by common letter are not significantly different at the 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

10.3.2. Interaction of mulberry diseases, varieties or genotypes and the crops seasons

The interaction among the mulberry varieties or genotypes and cropping seasons was significantly ($P \leq 0.01$) differed only for the leaf spot disease. But, there was no significant ($P \geq 0.05$) difference was found in case of powdery mildew and Tukra diseases respectively. However, the incidence percentage of all the three diseases viz: powdery mildew, leaf spot and tukra were highly significant ($P \leq 0.001$) by the cropping seasons. Correspondingly, only the tukra incidence percentage was highly significant ($P \leq 0.001$) by the mulberry varieties or genotypes. But the similar trend was observed between the leaf spot and powdery mildew diseases irrespective of mulberry varieties or genotypes (Table 10.5).

Table 10.5. Level of significance for the main and interactive effect of varieties or genotypes and crop seasons among three diseases

Source of variation	Mean diseases incidence percentage (%)		
	Powdery mildew	Leaf spot	Tukra
Crop seasons	***	***	***
Varieties or genotypes	n.s.	n.s.	***
Varieties or genotypes × Seasons	n.s.	**	n.s

Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

10.3.3. Incidence of various diseases among the varieties/genotypes irrespective to cropping seasons

The results indicated that all the 9 mulberry varieties and 3 genotypes were affected by the three foliar diseases viz: powdery mildew, leaf spot and tukra. In summer season, the higher incidence of powdery mildew disease was 1.76% for the genotype of S-30. This incidence percentage was significantly ($P \leq 0.05$) differed with the incidence percentage of BM-7 variety in summer season. However, the incidence percentage of powdery mildew for other varieties or genotypes was not significantly

($P \geq 0.05$) differed. In case of leaf spot disease, the maximum incidence percentage was 1.73% in BM-6 variety. This incidence was significantly differed with the incidence % of Black (0.47%) genotype and BM-11 (0.67%) variety. However, the similar trend was found among the other varieties or genotypes. There were also the wide ranges of variation observed irrespective to tukra disease. The highest occurrence of tukra disease was 0.63% for the variety of BM-4 which was statistically differed with BM-10 (0.15%) and BM-11 (0.15%) varieties respectively. The similar trend was observed for rest of the varieties or genotypes (Table 10.2).

Similarly, in late autumn season the maximum occurrence of powdery mildew disease was 10.41% for the BM-7 variety. This incidence was statistically higher than the others varieties or genotypes. In case of leaf spot disease, the highest incidence% was 8.49 in S-13 genotype which was significantly differed with the others mulberry varieties or genotypes. The recorde higher incidence percentage of tukra disease was 3.10% for genotype of Black. This tukra incidence was significantly differed with the incidence% of BM-1 (1.49%) variety. But the similar trend was observed among rest of the varieties or genotype (Table 10.3).

Correspoindingly, in rainy season the recorded highest powdery mildew incidence was 3.88% in S-13 genotype. This incidence was significantly greater than the incidence percentage of other varieties or genotypes in rainy season. Conversely, in case of leaf spot disease the maximum occurrence percentage was 4.54% for BM-1 mulberry variety in rainy season. This incidence was comparatively higher than rests of the varieties or genotypes. In rainy season, the maximum incidence of tukra disease was 1.21% for BM-4 variety. But there was no significant difference was found among the varieties or genotypes irrespective to tukra incidence percentage (Table 10.4).

10.3.4. Incidence of different diseases among the mulberry varieties or genotypes

The results indicated that the highest incidence of powdery mildew was 4.48, 4.46 and 4.40% for the S-13 genotypes, and BM-5 and BM-4 varieties respectively. Conversely, the lowest incidence of powdery mildew was 1.99, 2.11 and 2.22 percent for the varieties of BM-11, BM-8 and Black genotype respectively (Table 10.6).

Table 10.6. Average two years different diseases incidences (%) among the mulberry varieties/genotypes

Name of the varieties/genotypes	Powdery mildew	Leaf spot	Tukra
Black	2.22	2.21	1.48
BM-1	2.93	3.71	3.14
BM-3	4.26	3.16	0.69
BM-4	4.40	1.47	0.84
BM-5	4.46	3.35	0.90
BM-6	3.17	3.07	0.71
BM-7	4.81	3.95	0.68
BM-8	2.11	2.33	0.60
BM-10	3.19	3.2	0.60
BM-11	1.99	1.59	0.62
S-13	4.48	3.76	0.71
S-30	3.3	3.3	0.63

Correspondingly, comparatively the maximum incidence percentage of leaf spot was 3.95, 3.76 and 3.71% for the BM-7 variety, S-13 genotype and BM-1 variety, respectively. On the contrary, the lowest incidence percentage of leaf spot was 1.47 and 1.56% for the BM-4 and BM-11 varieties, respectively (Table 10.6). In case of tukra disease (Mealy bug) comparatively the recorded higher incidence percentage was 3.14 and 1.48% for the BM-1 variety and Black genotype, respectively. But the lowest incidence percentage was 0.60 %, 0.60%, 0.62% and 0.63% for the varieties of BM-8, BM-10, BM-11 and S-30 genotype respectively (Table 10.6).

10.3.5. Climatic conditions during experimental study period

There was enormous variation was observed for the climatic conditions irrespective to cropping seasons during the study period. In summer season the maximum and minimum temperatures were 35.38°C and 24.76°C respectively, rainfall was 108.50 mm and relative humidity was 65.42%. In case of late autumn season the maximum and minimum temperatures were 27.52°C and 17.24°C respectively, rainfall was 66.00 mm and relative humidity was 77.56%. On the other hand in rainy season the maximum and minimum temperatures were 33.63°C and 26.60°C respectively, rainfall was 280.15 mm and relative humidity was 78.28% (Table 10.7).

Table 10.7. Average two year's temperature (min. and max.), rainfall and relative humidity during the disease observation seasons.

Weather parameters	Crop seasons		
	In summer	In late autumn	In rainy season
Temperature (°C)	Maximum: 35.38 Minimum: 24.76	Maximum: 27.52 Minimum: 17.24	Maximum: 33.63 Minimum: 26.60
Rainfall (mm)	108.50	66.00	280.15
Humidity (%)	65.42	77.56	78.28

10.4. DISCUSSIONS

10.4.1. Seasonal impact on occurrence of foliar diseases in mulberry

The occurrences of foliar diseases are one of the major limiting factors for production of healthy and nutritious mulberry leaves. The above results found that the foliar diseases like, powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra (*Maconellicocus hirsutus*, Green) occurred simultaneously more or less all the three crop seasons among the all mulberry varieties or genotypes. It was observed that among the three diseases the occurrence of powdery mildew disease was comparatively maximum among the all three crop seasons, which was 10.41% in late autumn season. The second highest incidence percentage was observed for the leaf spot disease that was 8.49% in also late autumn season. Though the incidence of tukra disease was too much limited but it was found more or less all the crop seasons. The highest incidence percentage of tukra was 3.14 also in late autumn season. The above findings represent that the occurrences of all three diseases more or less similar among the three cropping seasons. However, among the three diseases and three cropping seasons the incidence percentage was highest for powdery mildew disease in late autumn season. Previously in Bangladesh Pasha and Barman (1990) were conducted a general study on the incidence percentage of two diseases viz: powdery mildew and leaf spot. They found that among the two diseases the highest occurrence was 54.33% for powdery mildew and lowest incidence was 43.69% for leaf spot disease, which was more or less similar with this experimental finding.

However, in India, Biswas *et. al.,* (2002) were studied on the occurrence of five mulberry diseases like powdery mildew, anthracnose, leaf rust, red rust and bacterial blight in three cropping seasons viz, Spring (April-May), Rainy (June-July) and Autumn (September-October) with four mulberry cultivars, namely, Kosen, BC_2 59, Tr-10 and S_{146}. They found that among the five mulberry diseases powdery mildew was occurred in all the three seasons, while, anthracnose mainly in rainy and leaf rust in autumn season. Similarly, in another study was conducted by Illahi *et. al.,* (2011). They found that among the leaf spot and powdery mildew diseases the occurrence of powdery mildew was prevalent throughout the valley. Furthermore, these incidences started during August with disease incidence (DI) and percent disease index (PDI) of 3.47 and 1.04 respectively. In addition, the incidences of powdery mildew and leaf spot were reached more severe in the month of October with DI and PDI of 5.71 and 2.15, respectively which was also more or less similar with this study.

Though the incidence of tukra disease was found almost all the three crop seasons but it was lowest among the three diseases. The highest incidence percentage for tukra disease was found 3.10% also in late autumn season. Similarly, Benchamin *et. al.,* (1997) recorded the infestation of tukra disease (pest- mealy bug) in mulberry crop throughout the year which was 0.79 to 11.69 percent but maximum severity was found in July to August. The speculation was the seasonal environment or climatic factors (temperature, humidity and rainfall), agronomical conditions and cultural practices are highly responsible for the specific disease infection. Similarly, Seema *et. al.,* (2010) reported that the impact of local agronomical conditions, mulberry variety, cultural practices and cropping seasons were responsible for the incidence and severity of different diseases. It might be due to the more susceptibility of climatic factors in late autumn season (October-December) for powdery mildew disease infestation than the other two cropping seasons for the higher incidence percentage.

Srikantaswamy *et. al.,* (2000) observed that the average of 24°C temperature and relative humidity of not less than 60% are favorable for the development of leaf spot disease in mulberry plant. My finding was more or less closely related with this experimental result. It could be due to climatic susceptibility the infection percentage of leaf spot disease was also second highest in late autumn season than the other two cropping seasons. Likewise, in case of tukra disease due to the favorability of climatic conditions of late autumn season comparatively the other two cropping seasons the incidence percentage was also higher. Similarly, Mahimasanthi *et. al.,* (2015), found the non significant positively correlation of higher ranged of temperature from 32°C to 40°C but they found average relative humidity ranged from 60 to 89% and rainfall ranged from 9.7 to 99.2 mm were comparatively susceptible for tukra disease infestation and population respectively.

10.4.2. Varietal or Genotypic response for mulberry disease incidence

The similar trend was observed for the incidences of mulberry foliar diseases irrespective to varietal or genotypic performances except tukra disease. There was no significant variation for powdery mildew and leaf spot diseases incidences percentage was found among the mulberry varieties or genotypes. However, the tukra disease was significantly differed irrespective to mulberry varieties or genotypes and cropping seasons (Table 10.4). This study showed that the higher percentage of powdery mildew incidence was S-13 (4.48%), BM-5 (4.46%) and BM-4 (4.40%) respectively among the 9 varieties and 3 genotypes (Table 10.5).

Result also showed that among the total mulberry varieties and genotypes two varieties namely BM-11, BM-8 and one genotype viz: Black were comparatively more resistant to powdery mildew. Similarly, genotype S-13 and varieties of BM-5 and BM-4 were highly susceptible to the powdery mildew disease. Previously, Rabbel (1995) worked on four mulberry varieties, BM-1, BM-3, BM-4 and BM-5 and one genotype like Telia. Among them he also found that BM-3 variety and Telia genotype showed high powdery mildew severity which was 31.08% and 29.33% respectively. In contrast, BM-4 and BM-5 showed low severity which was 18.14% and 19.31% respectively. Similarly, Biswas *et. al,*. (1993), Gangwar and Thangavelu (1998) also identified some cultivars such as S-1, S-799 and *Morus australis* which were resistant to powdery mildew disease.

Further, out of the nine mulberry varieties and three mulberry genotypies the maximum incidence of leaf spot disease was 3.95%, 3.76% and 3.71% for BM-7 variety, S-13 genotype and BM-1 variety respectively. This finding also indicated that the varieties of BM-4 and BM-11 were comparatively more resistant to leaf spot disease. In contrast, varieties BM-7, genotype S-13 and BM-1 variety were more susceptible to leaf spot disease (Table 10.5). Earlierly, Rabbel (1995) worked on five mulberry varieties namely BM-1, BM-2, BM-3, BM-4, BM-5 and one genotype Telia. Among them he found that varieties BM-4 and BM-5 were comparatively resistant to leaf spot. On the other hand, genotypies Telia and varieties of BM-1, BM-2 and BM-3 were comparatively susceptible to leaf spot disease. Previously, another study was conducted by Nderitu *et. al.,* (2012). They found that the Embu accession was susceptible but Thika, S41 and Thailand accession were moderately susceptible, while Kanva-2 was resistant to leaf spot out of five mulberry accessions namely Embu, Thika, Thailand, Kanva-2 and S-41.

In addition, among the nine varieties and three genotypies the highest incidence of tukra (also known as mealy bug) disease was in BM-1 variety and Black genotypies, 3.14% and 1.48% respectively. In contrast, the low incidence was recorded 0.60, 0.62 and 0.63 percent for BM-10, BM-11 varieties and S-30 genotype respectively. This finding indicated that BM-1 and Black were comparatively more susceptible to tukra disease as compared to the other varieties or genotypes. In contrast, BM-10, BM-11 and S-30 were more resistant against tukra (also known as mealy bug) disease among the nine varieties and three genotypies. Similarly, in a previous study Sathyaprasad *et. al.,* (2000a) screened a mulberry genotypes Togowase (ACC No. 257) which was tolerant to the three sap suckers, namely, mealy bug (tukra disease), thrips and jassids. Besides, Sathyaprasad *et. al.,* (2000b) also screened certain ruling mulberry varieties, viz., S-36, S-34, S-13, K-2 and V1 for their tolerance to tukra disease through induction method. In this study, the overall rating among the nine varieties and three genotypies BM-11, BM-8 varieties and Black were comparatively resistant to the powdery mildew. Likewise, the varities BM- 4 and BM-11 were resistant to leaf spot disease.

Similarly, BM-8, BM-10, BM-11 and S-30 were resistant to tukra (also known as mealy bug) disease. This could be due to the reason that these genotypies were content some genetical (structural/anatomical) characteristics. That might be defending themselves against the pathogens by means of structural characteristics that act as physical barriers and block the passage of the pathogen into the host. Similarly, Juniper and Cox (1973) reported that certain features like thick cells wall, more number of Palisade layers, significantly higher thickness of epidermis cum cuticle, comparatively thinner spongy parenchyma and significantly higher palisade proportion makes comparatively defense mechanism and give them protection from the infection of pathogen for the specific diseases. Likewise, Kulkarni *et. al.,* (2006) stated that anatomical barriers, though passive, give required protection to the plant till the induction of chemical resistance which is more or less lines with my assumptions.

10.5. CONCLUSIONS

This study demonstrated that three common foliar diseases occurred in various cropping seasons in mulberry plant simultaniously. Among the powdery mildew, leaf spot and tukra diseases the maximum incidence was 10.41% for powdery mildew disease in late autumn season for variety of BM-7. The lowest incidence was 0.15% for tukra disease in summer season for the varieties of BM-10 and BM-11 respectively. The highest incidence of leaf spot was 8.49% for S-13 genotype in late autumn season. But the highest incidence of tukra (causes by mealy bug pest) was found 3.10% in Black genotype during the late autumn season. This study concluted that the incidence percentage and incidence period of different foliar diseases viz: powdery mildew, leaf spot and tukra were varied irrespective to cropping season, climatic condition and varietal as well as genotypes performance.

The mulberry varieties and genotypes as well as cropping season had a significant impact on incidence of mulberry foliar diseases were the major findings of this chapter. In this chapter the several diseases incidence was observed irrespective to mulberry varieties, genotypes and cropping seasons. But, the specific disease observation was not conducted in this study. However, this chapter also showed that among the three foliar diseases the greater incidence was obtained for powdery mildew disease in terms of varieties and genotypes as well as cropping seasons. Besides, in this chapter has not observed the impact of autum and spring seasons for the incidence of foliar diseases. That’s why, further study will be focused to evaluate the impact of mulberry varieties or genotypes and cropping seasons on incidence of specific powdery mildew disease (Chapter 11).

Chapter 11

Impact of mulberry varieties or genotypes and cropping seasons on incidence of powdery mildew disease in Bangladesh

Chapter 11

Impact of mulberry varieties or genotypes and cropping seasons on incidence of powdery mildew disease in Bangladesh

11.1. INTRODUCTION

Mulberry plant is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et. al*., 1990; Yashihiko, 1995). Among the different fungal diseases, powdery mildew is more economically important for mulberry plant production. Khan *et. al*., (2004) reported that among the mulberry diseases, leaf spot and powdery mildew are the major foliar diseases of mulberry in Kashmir valley, India which are the impediments in the production of quality leaf. The symptoms of this disease are white powdery patches on the lower surface of the leaf and as the disease advances the entire leaf turn to brownish black and fall off prematurely. It is more prevalent in tropics and temperate regions during the post rainy and winter seasons. The loss due to mildew is around 12% besides causing depletion in nutritive value (Teotia and Sen, 1994; Qadri *et. al*., 1998). A study reported that this pathogen infects mulberry leaves and reduces not only yield but also nutritional values, thus making the leaves unsuitable for silkworm feeding (Bakshi *et. al*., 1972). Likewise, moisture, ash, lipid, crude fiber, carbohydrate, vitamins and minerals contents were decreased significantly after infection of mulberry leaves with fungus, *Phyllactinia corylea* (Tang *et. al*., 2006).

Climate as well as cropping season is the important factors for infestation of powdery mildew disease. It is well established, that the clamitic condition is varies season to season that greatly influnce the incidence of respective pathogen for respective disease. Because, the requirements of temperature, rainfall and humidity for growth, reproduction and establishment of specific pathogen as well as disease incidence differ pathogen to pathogen or disease to disease due to seasonal climatic factors. Generally temperature, rainfall and humidity greatly influence the incidence of powdery mildew in mulberry plant. The climate of Bangladesh is characterized by high temperatures, heavy rainfall, and often excessive humidity with fairly marked seasonal variations (Anonymous, 1995). According to Fakir (2001) climate of Bangladesh harbors plant pathogens and provides luxuriant environment for the growth and reproduction of large number of plant pathogens. These cause hundreds of different diseases of crops.

Like, climate mulberry genotype as well as variety has a great impact on incidence or resistance of foliar diseases in mulberry plant. Gangwar *et. al.* (1998) identified some cultivars such as S-1, S-799 and *Morus australis* which were resistant to powdery mildew disease. Similarly, Rabbel (1995) found that BM-3 and Telia varieties were resistance to powdery mildew disease. The previous chapter showed that among the foliar diseases powdery mildew was major limiting factors for quality and quantity mulberry leaf production. In addition, mulberry genotype had a great impact on resistant to the incidence of powdery mildew disease. But, in previous chapter only the partial investigation of powdery mildew disease incidence was observed in terms of mulberry varieties as well as genotypes and cropping seasons. But the specific observation on powdery mildew disease incidence irrespective to cropping seasons, mulberry varieties, mulberry genotypes and climatic feature has not been study in previous chapter. Even, the earlier research found that mulberry genotype significantly influenced the incidence of powdery mildew. In addition the information especially on powdery mildew disease of mulberry plant was scarcely available in literature particularly in Bangladesh. Keeping in view of the above mentioned problems the present study was undertaken to find out the best mulberry variety or genotype which will be more resistant to powdery mildew in terms of cropping seasons and climatic factors. The hypothesis of this chapter was that the incidence of mulberry powdery mildew disease will be varied irrespective to mulberry varieties and cropping seasons.

11.2. MATERIALS AND METHODS

11.2.1. Experimental location

The present study was carried out in the experimental field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh (24° 22' 29" North and 88° 37' 3.84" East). The Agro Ecological Zones (AEZ), were Active Ganges Floodplain-10 and High Ganges River Floodplain-11.

11.2.2. Cropping seasons and sample material

This study was conducted between two cropping seasons viz: autumn (September to October) and spring (April to May) for the two conjugative years. Nine mulberry varieties viz: BM-1, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, BM-10 and BM-11 and three mulberry genotypes namely Black, S-13 and S-30 were used for this study as a sample testing materialas. All the 09 varieties were developed by Bangladesh. But, the used three genotypes were collected from India.

11.2.3. Powdery mildew disease

The recorded disease was powdery mildew. The causal organisms is *Phyllactinia corylea,* which belongs to the family Erysiphaceae, order Erysiphales of class Ascomycetes.

11.2.4. Experimental plot

The plot size was 5 m × 4 m. Plant-plant distance 0.92 m and line-line distance 0.92 m. each plot had total 20 numbers of plants.

11.2.5. Experimental design

The experiment was conducted in randomized complete block design (RCBD) under twelve testing plant materials × two cropping seasons × one foliar disease along with three replications.

11.2.6. Experimental procedure

For a period of two consecutive years, 10 numbers of plants were taken for each replication and each mulberry varieties or genotypes. The powdery mildew incidence were recorded both for the autumn and spring seasons. Data were collected at 70 days after pruning for each cropping season. The plantation system was high bush. Disease incidence was assessed as number of total mulberry leaves per plant and number of total powdery mildew infected leaves per plant of a disease or any visible symptom in that plant.

11.2.7. Soil of experimental plot

The soils of the experimental plots of BSRTI were mainly loam in nature, having normally alkaline characteristics with pH ranging from 7.2 to 8.8. As a consequence of this alkalinity, the soil is poor in potassium and available phosphorus. Both carbon and nitrogen levels are low in the uncultivated as well as in the cultivated plot. Nitrogen level is not in balance with carbon. This is more prominent in the farm area where mulberry is cultivated for years. Toxic metals are present in traces but they are well below the harmful levels (BSR, 1991). The basic soil physical and chemical properties were shown in Table 11.1.

Table 11.1. Physical and chemical properties of the experimental soil

Soil pH in H_2O	Nitrogen (%)	Phosphorus (ppm)	Potassium (Cmol/Kg)	Sulphur (ppm)	Zinc (ppm)	Organic matter (%)
8.4	0.06	16.80	0.27	7.1	0.96	1.10

11.2.8. Data collection

Data were collected in the months of April to May for spring and in the months of September to October for autumn seasons for each year. Assessment of the incidence of powdery mildew disease of mulberry leaf was calculated by using the formula of Rai and Mamatha (2005):

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

11.2.9. Collection of meteorological data

Moreover, monitoring disease environment relation to epidemiological aspects of powdery mildew disease in Bangladesh. The related meteorological data on temperature, relative humidity (RH) and rainfall were collected from weather stations of Shampur, Rajshahi throughout the study period for the respective seasons. The data were calculated for monthly mean of minimum and maximum temperature, mean of relative humidity and mean of rainfall of the respective locations.

11.2.10. Analysis of soil physical and chemical properties

The pH of the soil was determined in deionised water using a soil-to-solution ratio of 1:2.5 (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). 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 methyl red and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder *et. al.*, 2012).

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). 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). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

11.2.11. Statistical analysis

Some statistical analysis was conducted using Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK). Also, some analysis was conducted by Statistix 10 software. Treatment means were separated by the least significant difference (LSD) at a 0.05% level of significance (Steel and Torrie, 1984). Other parameters were statistically analyzed and mean values were evaluated by Duncan Multiple Range Test (DMRT).

11.3. RESULTS

11.3.1. Effect of climate and cropping seasons on incidence of mulberry powdery mildew disease

Effects of climate on the infestation of powdery mildew disease in different mulberry varieties and genotypes for two cropping seasons were studied for this study. In the study period the average temperature, relative humidity and rainfall were recorded, which are presented in Table 11.2. In autumn season, the maximum average temperature was 33.98°C in September and minimum 24°C in October month respectively. The average rainfall and humidity was 6.96 mm and 91.69% in September and 6.76 mm and 89.22% in October month, respectively (Table 11.2). Similearly, in spring season, the maximum average temperature was 36.93°C in April and minimum 22.85°C also in the month of April. In the month of May the average maximum temperature was 36.48°C and minimum 25.31°C. The average rainfall and humidity was 2.09 mm and 82.67% in April and 4.16 mm and 84.1% in May month respectively (Table 11. 2).

Table 11.2. Average temperature (minimum and maximum), rainfall and relative humidity during the observation seasons

Weather parameters	Seasons			
	Autumn		Spring	
	September	October	April	May
Temperature (^{0}C)	Max. 33.98 Min. 26.22	Max. 32 Mini. 24	Max. 36.93 Mini. 22.85	Max. 36.48 Mini. 25.31
Rainfall (mm)	6.96	6.76	2.09	4.16
Humidity (%)	91.69	89.22	82.67	84.1

The average incidence percentage of powdery mildew among the mulberry varieties or genotypes were significantly ($P \leq 0.01$) varied by the cropping seasons. Even the interactive effect between cropping seasons and mulberry varieties or genotypes were also significantly ($P \leq 0.01$) differed for the infestation of powdery mildew disease in mulberry plant (Table 11.3 and Figure 11.1).

Table 11.3. Level of significance for the main and interactive effect of varieties and seasons for the occurrence of powdery mildew in mulberry plant (*Morus* spp.)

Level of Significance	Powdery Mildew Disease
Season	**
Varieties or genotypes	**
Season ×Varieties or genotypes	**

Where "**" indicates $p \leq 0.01$ and values were means of three replicates.

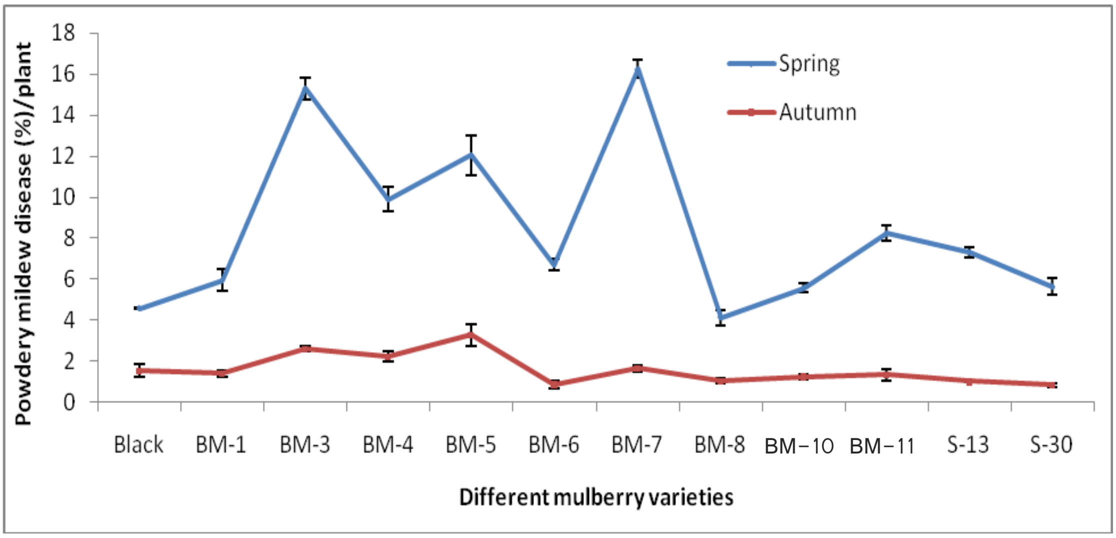

Figure 11.1: Seasonal variations of powdery mildew disease in different mulberry varieties and genotypes in two cropping seasons. Error bars represents S.E for n = ± 3.

11.3.2. Varietal or genotypic effect on the incidence of powdery mildew disease in mulberry plant

The powdery mildew incidence of mulberry plant was differed among the mulberry varieties. Among the nine mulberry varieties and three genotypes, the maximum average incidence percentage was 14.61 for the variety of BM-7. Conversely, the minimum average incidence percentage was 0.84 for S-30 genotype. The incidence of powdery mildew was comparatively less in autumn season for the different mulberry varieties or genotypes (Figure 11.1).

In autum season the maximum mildew incidence percentage was 3.28 for the variety of BM-5 followed by the varieties of BM-3, BM-4 and BM-7, Black genotype, varieties of BM-1, BM-10, BM-11, BM-8 and BM-6, S-13 and S-30 genotypes respectively. Convesrely, in spring season the maximum incidence percentage of mildew was 14.61 for BM-7 mulberry variety followed by the BM-3, BM-5, BM-4 and BM-11 varieties, S-13 genotypes, BM-6 variety, S-30 genotype, varieties of BM-1, BM-10, BM-8 and BM-7 and the genotype of Black respectively (Table 11.4).

Table 11.4. Mean **(%)** of powdery mildew infestation on different mulberry varieties or genotypes under two cropping seasons

Name of the varieties/genotypes	Mean **(%)** of powdery mildew infestation	
	Autumn Season	Spring Season
Black	1.51 (±0.32)*	3.07 (±0.05)*
BM-1	1.56 (±0.14)*	4.56 (±0.54)*
BM-3	2.69 (±0.10)*	12.69 (±0.55)*
BM-4	2.23 (±0.27)*	7.65 (±0.60)*
BM-5	3.28 (±0.54)*	8.75 (±0.98)*
BM-6	0.86 (±0.17)*	5.83 (±0.28)*
BM-7	1.63 (±0.14)*	14.61 (±0.45)*
BM-8	1.04 (±0.12)*	3.09 (±0.38)*
BM-10	1.24 (±0.13)*	4.32 (±0.21)*
BM-11	1.31 (±0.26)*	6.90 (±0.37)*
S-13	0.99 (±0.04)*	6.30 (±0.27)*
S-30	0.84 (±0.09)*	4.79 (±0.40)*

*Parenthesis indicates standard error of three replicates.

11.4. DISCUSSIONS

11.4.1. Climatic and seasonal effect on the incidence of powdery mildew in mulberry plant

The occurrence of powdery mildew (*Phyllactinia corylea*), is one of the major limiting factor for production of quality and quantity mulberry leaves. Cropping season significantly ($P \leq 0.01$) differed the incidence of powdery mildew disease in mulberry plant. The above result showed that the powdery mildew occurred simultaneously more or less both the spring and autumn seasons. However, between the two cropping seasons the occurrence of powdery mildew disease was comparatively maximum in spring seasons that was 14.61%. Similarly, in previous study, Khan *et. al*., (2015) found the similar trend. They found that the highest incidence and severity of powdery mildew was during the months of April 2011 at temperature, rainfall and relative humidity of 26.4°C, 80 mm and 77% respectively.

Furthermore, the number of disease incidence and severity was in the month of July 2010 at temperature, rainfall and relative humidity of 29.1°C, 458 mm and 85 % respectively. The mentioned finding was more or less lined with this experimental finding. Likewise, Munshi, *et. al*., (1999) observed that in Kashmir valley; India the peak period of powdery mildew incidence was August to November.

Likewise, Govindaiah *et. al.,* (2005) found that powdery mildew of mulberry, was most severe in the autumn season. Chowdhury (2009b) recorded the highest incidence and severity of powdery mildew was in month of April, which was also lined with this experimental findings. However, the speculation was due to the favorable temperature, rainfall and humidity in spring season the development and incidence of powdery mildew was comparatively higher in mulberry plant. The above speculation was strongly linked with the previous findings of Wolf *et. al.,* (2005). They indicated that meteorological factors had a predominate effect in the development of disease.

Similarly, Awasthi *et. al.,* (1994), reported that the intensity and duration of atmospheric precipitation plays a fundamental role in disease progress. Itoi *et. al.,* (1964) from Japan appearance reported that the powdery mildew disease was found almost in all the season. Likewise, Biswas, *et. al.,* (1996) reported that might be due to the favorable average maximum temperature and Etoi *et. al*., (1960) reported that the 30^0 C temperature and 80% percentage relative humidity were found to be most suitable for conidial germination of *Phyllactinia corylea*, pathogen of powdery mildew. The above all the findings or assumptions were more or less lined with my speculation.

11.4.2. Effect of mulberry varieties or genotypes on incidence of powdery mildew disease

The mulberry variety or genotype significantly ($P \geq 0.05$) influenced the incidence of powdery mildew disease. Among the nine mulberry varieties and three genotypes the lower incidence of powdery mildew was 0.84 and 0.86 % respectively for the variety of S-30 genotype and BM-6 variety respectively. This incidence was 94.25 and 94.11% respectively lower than the maximum powdery mildew incidence percentage of BM-7 mulberry variety. Similarly, in a previous study, Chattopadhyay *et. al*., (2010) found that out of the 147 mulberry germplasm sources 6.8% was useful resistance (two high and nine moderately resistant) to the powdery mildew pathogen on the basis of disease severity index (DSI). Likewise, Biswas *et. al*., (1993), Gangwar *et. al.,* (1998) were screen out of S-1, S-799 and *Morus australis* mulberry cultivars in their various screening programs which were resistant to powdery mildew. According to the Jindal *et. al.,* (2002) the difference of disease infection rate of different mulberry accessions can be attributed to varietal characteristics ascribed to genetic inheritance. This experimental result also showed that among the nine mulberry varieties and three genotypes, S-30 in autumn and Black in spring season was comparatively more resistance to powdery mildew followed by the others varieties or genotypes.

Furthermore, none of the variety or genotype was not completely free from the powdery mildew disease. The incidence of powdery mildew was comparatively low in S-30 and Black mulberry genotypes could be due to the genetical as well as structural characteristics of these two respective genotypes. That might be crated mechanical, physical, structural as well as anatomical barriers to protect the penetration against the pathogen of mulberry powdery mildew disease. This speculation was lined with the previous findings of Kulkarni *et. al.,* (2006). They reported that in generally the plants defend themselves against pathogens by means of structural characteristics. That act as physical barriers and block the passage of the pathogen into the host. In addition, anatomical barriers, though passive, give required protection to the plant till the induction of chemical resistance.

Similarly, Sonibare *et. al*., (2006) also reported that the anatomical barriers to pathogen penetration are very important in relation to the development of disease resistance. Because, they reduced the rate of infection progress. These include the amount and quality of wax and cuticle that cover the epidermal cells, the structure of epidermal cells walls, the size, location and shape of stomata and lenticels. Additionally the presence of tissues made up of thick walled cells also prevents the advance of the pathogen. Besides, anatomical characteristics (more number of palisade layers, significantly higher thickness of epidermis cum cuticle, nature of cuticle and palisade tissue, comparatively thinner spongy parenchyma significantly higher palisade protection) are thought to act as structural barriers against the penetration and invasion by different pathogens. The above concepts were possitively correlated with my above mentioned speculation.

11.5. CONCLUSIONS

This study concluded that powdery mildew disease caused by *Phyllactinia corylea* was recorded more or less in both the two cropping seasons. The incidence and severity of disease depends on the local climatic conditions, mulberry variety or genotype and crop seasons. Between the two cropping seasons in autumn, the incidence of powdery mildew was comparatively minimum and in spring season comparatively maximum. Among the 3 mulberry genotypes and 9 varieties, S-30 genotype was more resistance and BM-3 variety were more susceptible to powdery mildew in autum season. Conversely, Black mulberry genotype was more resistant and BM-7 variety more susceptible to powdery mildew disease in spring season.

This chapter showed that the incidence of powdery mildew disease was significantly ($P \geq 0.05$) differed by the mulberry varieties or genotypes and cropping seasons. The previous chapter only the incidence of powdery mildew disease irrespective to mulberry varieties and cropping seasons was partialy observed. Biseides, in my all previous chapters only the single effect of organic, organic plus recommended basal dose of NPK, liquid fertilizer and single effect of recommended basal of NPK fertilizers on growth, leaf yield, leaf quality and suppression of foliar diseases of mulberry plant was studied. But, the findings of earliear researcher was reported that the good quality leaf production in mulberry is highly dependent on the supply of various inputs especially nitrogen, phosphorus and potassium nutrients. However, no study was conducted previously on the single effect of elevated doses of nitrogen, phosphorus and potassium on the productivity, leaf quality, plant age variation and reduction of foliar diseases of mulberry plant. For this persepetive, the further study will be conducted to investigate the effect of eleavated doses of nitrogen with BSRTI recommended basal doses of phosphorus and potassium for mulberry plant production and decline of foliar diseases of mulberry plant in the next chapter (Chapter 12).

Chapter 12

Elevated nitrogen enhances productivity and amoliarates foliar diseases of mulberry plant

Chapter 12

Elevated nitrogen enhances productivity and amoliarates foliar diseases of mulberry plant

12.1. INTRODUCTION

Mulberry (*Morus spp*) is an economically and traditionally very important deciduous plant for the development of sericulture industry. This plant is mainly cultivated to harvest leaves for the rearing of silkworms (Jian *et. al*., 2012). The quality mulberry leaf fed to silkworms is the most important factor that influences the successful cocoon production by mulberry silkworm (Singheal, *et. al.,* 1999). Improvement of larvae and cocoon characters of the silkworms have been varied with the increase of mulberry leaf quality (Venkataramu 1986). Quality mulberry leaf is the basic requirements of sericulture that plays a key role for successful silkworm cocoon crop (Guttierrez *et. al*., 1997). Quality leaf production in mulberry is highly dependent on the supply of various inputs especially nitrogen fertilizers (Nasreen *et. al.,* 1999). Among the NPK, nitrogen is the main plant nutrient that has a key role in the growth, metabolism and development of plants (Gallegos-Cedillo *et. al.,* 2016). Application of N significantly influenced the mulberry leaf yield, quality and cocoon characters of silkworm race (Shankar *et. al*., 1999). Mulberry responds to nitrogen since it is a constituent of plant proteins, nucleic acids and vitamins (Shankar *et. al.,* 1999). The digested N used for moth and eggs was more effective at early spring silkworm rearing (Tzenov *et. al.,* 1994).

Mulberry plant is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et. al.,* 1990; Yashihiko 1995). Among the major foliar diseases of mulberry plant powdery mildew, leaf spot, leaf rust and tukra are the economically important which reduce the leaf production as well as depletion of leaf quality feed to silkworm (Khan *et. al.,* 2004; Rabbel 1995). Nitrogen fertilization has an additional potentiality to suppress of fungal pathogens (Veresoglou *et. al.,* 2013). But the nitrogen disease hypothesis states that plant growth at high nitrogen (N) availability may result in increased plant susceptibility to pathogens as a result of increased foliar nitrogen concentrations (Mitchell *et. al.,* 2003). Like, fertilizer management plant age is also an important factor for mulberry plant production. Because, the ages of plant dirrectly related with the nutreient uptake form the soil, utilization of nutrients by the plant, enhances the photosysthesis rate, other phosiological fuctions of the plant as well as plant productivity.

However, in my previous several chapters only the combined effect of organic fertilizer with recommended basal dose on NPK has been observed for mulberry plant production and reduction of foliar diseases. But, the findings of earlier researcher reported that inorganic fertilizer is the essential element for plant growth and development. Even among the nitrogen, phosphorus and potassium, nitrogen is the major key element for plant production. Beside, the finding on the single effect of nitrogen on mulberry plant production was hardly available. So, it was the core researchable issue to investigate the single effect of nitrogen on mulberry plant production and incidence of foliar diseases in mulberry plant. Therefore, this study was carried out to quantify the optimum level of N along with BSRTI, recommended basal dose of P and K for getting best quality and quantity mulberry plant production as well as amelioration of common foliar diseases. It was hypothesized that the application of different levels of N with recommended basal doses of P and K will be varied the mulberry plant production as well as suppress the infestation rate of common foliar diseases irrespective to plant ages.

12.2. MATERIALS AND METHODS

12.2.1. Experimental site

This experiment was conducted in the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh which is located at the 24°22′29″ N and 88°37′84″ E.

12.2.2. Experimental plant

Mulberry (*Morus spp*) plant, variety BM-11 (BM = Bangladesh Mulberry) was used for this study. The plantation system was high-bush. Mulberry plant (*Morus* sp) is small to medium sized shrubs or trees with a thick tan-gray ridged trunk which is perennial, deep rooted and hardy in nature. Due to its perennial, deep rooted and hardy habit, mulberry is grown in wide range of soil and agro-climatic conditions in Bangladesh.

12.2.3. Experimental condition

In Bangladesh the silkworm is reared in four commercially rearing seasons for each year. Depending upon the silkworm rearing season for this experiment the mulberry garden was pruned four times each year after three months of interval. Two ages of mulberry plant viz: (0-5) and (6-10) years were used for this study. The nitrogen treatments were applied 20 DAPr (Days after Pruning) when the sprouting of mulberry plant was started. The other cultural practices like irrigation, digging cum weeding, insect-pest management practices etc. were done as per requirement.

12.2.4. Plot size

Each plot size was 5 m × 4 m. Plant to plant distance was 0.92 m and line to line distance was 0.92 m. The numbers of plant was 20 for each plot.

12.2.5. Experimental design

This experiment was conducted in split plot design with three replications. The respective nitrogen treatments were applied in the assign split plots.

12.2.6. Treatments

The following N treatments were applied in the experimental plots:

T_0: Only the BSRTI recommended basal dose of P and K were applied. No N was applied (0 kg N, 150 kg P and 100 kg K/ha/yr).

T_1: 80 kg N/ha/yr+ BSRTI recommended basal dose of P and K per hectare per year.

T_2: 160 kg N/ha/yr+ BSRTI recommended basal dose of P and K per hectare per year.

T_3: 240 kg N/ha/yr+ BSRTI recommended basal dose of P and K per hectare per year.

T_4: 320 kg N/ha/yr+ BSRTI recommended basal dose of P and K per hectare per year.

T_5: 400 kg N/ha/yr+ BSRTI recommended basal dose of P and K per hectare per year.

12.2.7. Measurement of soil physical and chemical properties

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). Soil organic C was determined by chromic acid digestion and spectrophotometric analysis (Heanes, 1984). 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). 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). 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). 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). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979). Calcium and magnesium content were determined following the method of Tandon (1993. Manganese was estimated by spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991).

12.2.8. Recorded growth and yield parameters

Growth attributes namely, total branches number per plant, total branches height per plant (cm), total shoots weight per plant (g), nodes per meter, 10 leaves area per plant (cm^2), 10 leaves weight per plant (g), total leaves weight (g) per plant and total leaf yield/ha/year (MT) were recorded for this study. Data were collected at 90 DAPr (Days after pruning) for each cropping seasons. Total four times data was collected in a year. The annual yield was computed by pooling the two years data. The following formula was used for determined the total green leaf yield per hectare per year:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2\text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

12.2.9. Analysis of leaf quality

The mulberry leaf samples at different heights of the plant (top, middle and bottom) were collected in paper bags at 75 days after pruning and composite leaf samples were made. Then the leaves sample were shade dried for three days and again then dried in hot air oven at 700°C for one hour and were ground into powder for chemo-assay. The moisture (%) was determined by followed the Vijayan *et. al*., (1996), total mineral (%) followed the AOAC (1980), protein (%) followed by the Kjeldahl's method (Wong 1923), total sugar followed by the Miller (1972) and Loomis *et. al.,* (1937) procedure and methods and soluble carbohydrate (%) followed by Dubois *et. al*., (1956) method.

12.2.10. Analysis of diseases data

For a period of two consecutive years in each replication 10 mulberry plants were taken. Data were collected at 60 days after pruning. Disease incidence (%) was assessed as number of total mulberry leaves per plant and number of infected leaves per plant by powdery mildew, leaf spot and tukra diseases with any visible symptom for respective disease. The percentage of disease incidence (PDI) was calculated using the formula of Rai and Mamatha (2005) which was following:

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

12.2.11. 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 Duncan Multiple Range Test (DMRT) through using the Statistic-10 software. In case of soil the mean values of post harvest soil properties were recorded for this study.

12.3. RESULTS

12.3.1. Effect of nitrogen on post harvest soil properties of the experimental soil

The average physicochemical properties of the post harvest experimental soil are presented in (Table 12.1). The average soil pH, OM, N, P, K, Zn, Ca and Mg for (0-5) year's plant were 6.67 to 8.1, 1.46 to 1.68%, 0.06 to 0.10%, 6.3 to 8.9 micro g/g, 0.15 to 0.18 meq/100 g soil, 0.63 to 0.76 micro g/g, 17.51 to 17.92 meq/100 g soil and 2.29 to 2.79 meq/100 g soil respectively. On the other hand, the average soil pH, OM, N, P, K, Zn, Ca and Mg for (6-10) year's plant were 6.6 to 8.3, 1.47 to 1.67%, 0.08 to 0.11%, 6.4 to 8.8 micro g/g, 0.16 to 0.18 meq/100 g soil, 0.64 to 0.77 micro g/g, 17.49 to 17.95 meq/100 g soil and 2.31 to 2.82 meq/100 g soil respectively.

Table 12.1. Effect of nitrogen levels on physicochemical properties of the post harvest experimental soil

Treatments	Soil pH		OM (%)		N (%)		P (micro g/g)		K (meq/100 g soil)		Zn (micro g/g)		Ca (meq/100 g soil)		Mg (meq/100 g soil)	
	Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	8.1	8.3	1.57	1.59	0.09	0.10	6.3	6.4	0.18	0.17	0.76	0.77	17.51	17.49	2.29	2.31
T_1	7.9	8.0	1.68	1.67	0.07	0.08	8.9	8.8	0.18	0.18	0.68	0.67	17.83	17.85	2.33	2.34
T_2	7.5	7.4	1.46	1.47	0.08	0.09	8.7	8.6	0.16	0.17	0.65	0.66	17.86	17.87	2.39	2.41
T_3	7.3	7.2	1.48	1.5	0.07	0.08	8.8	8.7	0.15	0.17	0.63	0.64	17.78	17.83	2.46	2.47
T_4	6.9	6.7	1.55	1.53	0.09	0.08	8.6	8.8	0.17	0.16	0.66	0.67	17.73	17.72	2.56	2.59
T_5	6.7	6.6	1.65	1.67	0.10	0.11	8.4	8.8	0.18	0.17	0.67	0.65	17.92	17.95	2.79	2.82

Here, $T_0 = N_0P_{150}K_{100}$ kg/ha/yr, $T_1 = N_{80}\ P_{150}\ K_{100}$ kg/ha/yr, $T_2 = N_{160}P_{150}K_{100}$ kg/ha/yr, $T_3 = N_{240}P_{150}K_{100}$ kg/ha/yr, $T_4 = N_{320}P_{150}K_{100}$ kg/ha/yr and $T_5 = N_{400}\ P_{150}\ K_{100}$ kg/ha/yr.

12.3.2. Growth response of mulberry plant due to nitrogen levels and ages of plant

Total number of branches per plant

The total branches number per plant of mulberry was highly significant (*$P \leq 0.001$*) by the fertilizer treatments. The more marked increasing trend was found for the T_5 (N_{400} P_{150} K_{100} kg/ha/yr) treatment and (6-10 years) ages of older mulberry plant. However, between the two types of mulberry plant in case of (0-5) year's ages of mulberry plant total branches number were 9.7, 12.27, 12.33, 13.85, 14.91 and 15.87 for the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, total branches number for (6-10) year's ages of older mulberry plant were 10.53, 12.43, 12.56, 14.89, 15.83 and 16.49 respectively for the same treatments (Figure 12.1; Table 12.2).

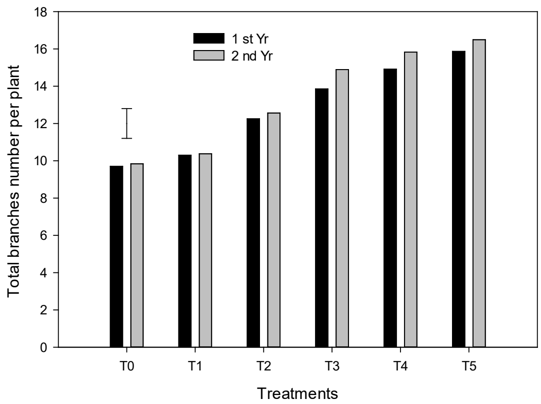

Figure 12.1: Total number of branches per plant of mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (*P* = 0.05) different levels of nitrogen and mulberry plant age interactions.

Total branches height per plant (cm)

The highly significant (*$P \leq 0.001$*) difference was observed both for the nitrogen levels and the ages of mulberry plant irrespective to total branches height of mulberry. The T_5 treatment and (6-10) year's ages of mulberry plant showed the remarkable increasing trend. However, in case of (0-5) year's ages of mulberry plant the recorded total branches height were 741.50, 1021.14, 1182.41, 1232.33, 1256.04 and 1339.05 cm for the T_0, T_1, T_2, T_3, T_4 and T_5 treatments, respectively. On the contrary, total branches height were 784.70, 1029.52, 1192.23, 1241.26, 1264.21 and 1349.61 cm respectively in (6-10) year's ages of mulberry plant for the similar treatments (Figure 12.2; Table 12.2).

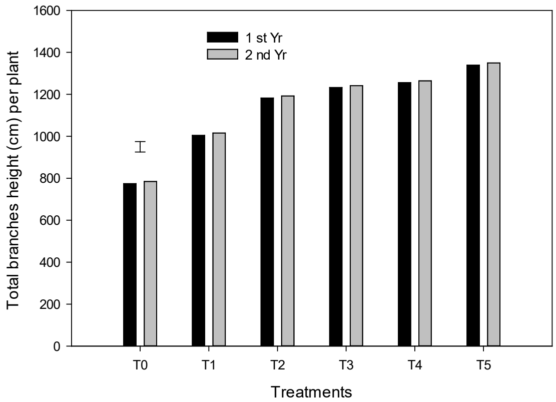

Figure 12.2: Total branches height per plant of mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (*P* = 0.05) different levels of nitrogen and mulberry plant age interactions.

Nodes per meter

The nodes per meter of mulberry plant was highly significant ($P \leq 0.001$) among the nitrogen treatments. The more marked increasing trend was found for the T_5 treatment. The ages of mulberry plant showed the similar trend irrespective to nodes per meter of mulberry plant. However, the nodes per meters were 16.70, 19.53, 21.57, 22.66, 22.69 and 23.88 for T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively in (0-5) year's ages of mulberry plant. In contrast, nodes per meter were 17.66, 20.35, 21.84, 22.80, 23.32 and 24.91 respectively in (6-10) year's ages of mulberry plant for the same treatments (Figure 12.3; Table 12.2).

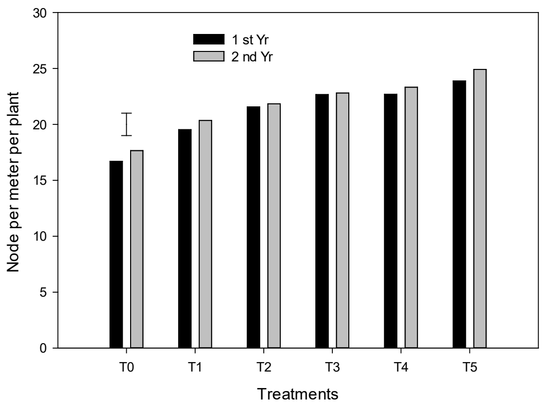

Figure 12.3: Nodes per meter of mulberry plants as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (*P* = 0.05) different levels of nitrogen and mulberry plant age interactions.

Table 12.2. Effect of different levels of nitrogen on mulberry plant production

Factors	Total branches number/plant	Total branches height/plant (cm)	Nodes/meter/plant	Total shoots weight /plant (g)	10 leaves area/plant (cm^2)	10 leaves weight /plant (g)	Total leaves weight/ plant (g)	Total leaf yield/ha /yr (MT)
Treatments	***	***	***	***	***	***	****	***
Plant age	n.s.	***	n.s.	***	***	***	***	***
Plant age × Treatment	n.s.	*	n.s.	*	**	n.s.	*	n.s.

Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

Total shoots weight per plant (g)

Statistically highly significant ($P \leq 0.001$) trend was found both for the treatments and the ages of mulberry plant irrespective to total shoots weight of mulberry plant. The more remarkable changed was observed between the (6-10 years) ages of plant for the treatment of T_5. Nevertheless of that the recorded total shoots weight per plant were 346.44, 467.05, 518.70, 557.29, 574.29 and 592.52 g due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively for (0-5) year's ages of mulberry plant. Conversely, the total shoots weight for the (6-10) year's ages of mulberry plant were 352.04, 476.14, 527.78, 567.47, 583.3 and 603.93 g respectively for the same fertilizers management (Figure 12.4; Table 12.2).

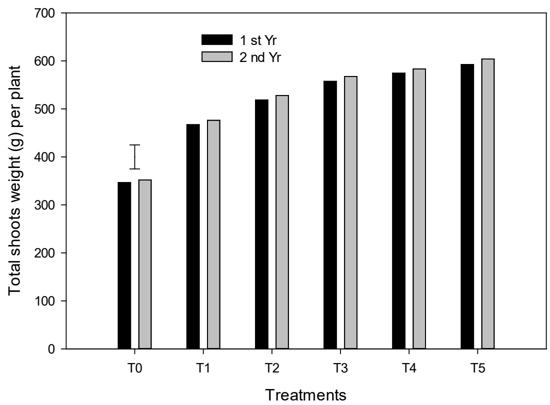

Figure 12.4: Total shoots weight per plant of mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P = 0.05) different levels of nitrogen and mulberry plant age interactions.

10 leaves area per plant (cm^2)

The 10 leaves area of mulberry plant was highly significant ($P \leq 0.001$) both for the treatments and ages of mulberry plant. The more marked increasing trend was noted in (6-10 years) ages of plant for the T_5 treatment. Between the two types of plant the 10 leaves area were 428.95, 530.27, 537.30, 586.81, 597.69 and 600.86 cm^2 in (0-5) year's ages of plant for the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, in case of (6-10) year's ages of plant the 10 leaves area were 433.38, 537.96, 542.80, 594.84, 601.87 and 608.35 cm^2 due to the similar treatments (Figure 12.5; Table 12.2).

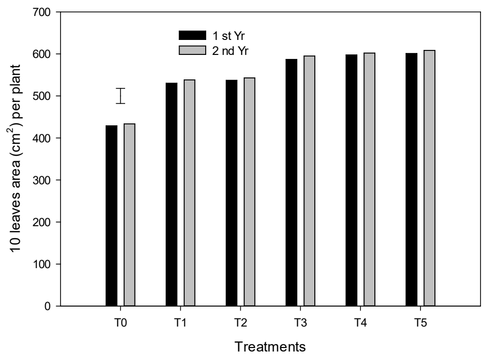

Figure 12.5: 10 leaves area per plant of mulberry as influenced by various levels of N management practices. Where, T_0= 0 kg N/ha/yr, T_1= 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4= 320 kg N/ha/yr and T_5= 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

10 leaves weight (g) per plant

The 10 leaves weight of mulberry plant was significantly ($P \leq 0.001$) differed both for the treatments and ages of mulberry plant. The T_5 treatment and (6-10) years ages of mulberry plant presented the more increasing trend. However, the recorded 10 leaves weight were 20.13, 23.43, 25.67, 35.97, 41.28 and 45.67 g for T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively in the (0-5) year's ages of plant. Consequently, 10 leaves weight were 22.67, 26.17, 28.66, 38.10, 43.07 and 47.95 g in (6-10) year's ages of plant due to same fertilizers management (Figure 12.6; Table 12.2).

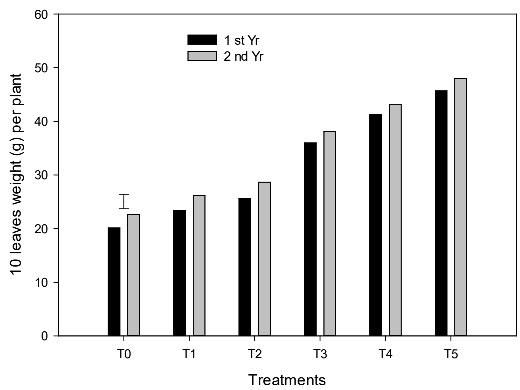

Figure 12.6: 10 leaves weight per plant of mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1= 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3= 240 kg N/ha/yr, T_4= 320 kg N/ha/yr and T_5= 400 kg N/ha/yr. Vertical bar represent LSD (P=0.05) different levels of nitrogen and mulberry plant age interactions.

Total leaves weight (g) per plant

The highly significant ($P \leq 0.001$) variation was observed both for the treatments and ages of mulberry plant. The more remarkable increasing trend was recorded in (6-10) years ages of plant for the T_5 treatment. Nevertheless of that in case of (0-5) years ages of plant the total leaves weights were 482.15, 592.23, 693.40, 804.23, 870.07 and 947.09 g due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. On the other hand, the recorded total leaves weights were 509.45, 634.30, 739.1, 854.93, 925.70 and 1014.65 g respectively in (6-10) year's ages of plant for the similar treatments (Figure 12.7; Table 12.2).

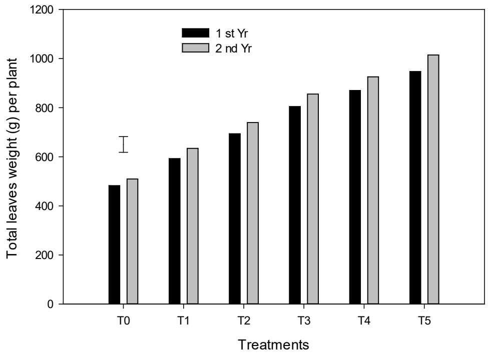

Figure 12.7: Total leaves weight per plant of mulberry as influenced by various levels of N management practices. Where, T_0= 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2= 160 kg N/ha/yr, T_3= 240 kg N/ha/yr, T_4= 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P = 0.05) different levels of nitrogen and mulberry plant age interactions.

Total leaf yield/ha/year (MT)

The total leaf yield of mulberry plant was significantly ($P \leq 0.001$) increased both for the treatments and ages of mulberry plant. The more marked increasing trend was found in (6-10) years ages of plant due to application of T_5 treatment. However, the total leaf yield was 25.14, 26.42, 33.28, 38.60, 41.76 and 45.46 MT/ha/year in (0-5) year's ages of plant for the treatments of T_0, T_1, T_2, T_3, T_4 and T_5 respectively. However, in case of (6-10) years ages of mulberry plant total leaf yield was 26.77, 27.79, 35.48, 41.04, 44.43 and 48.93 MT/ha/year respectively for the same fertilizers management (Figure 12.8; Table 12.2).

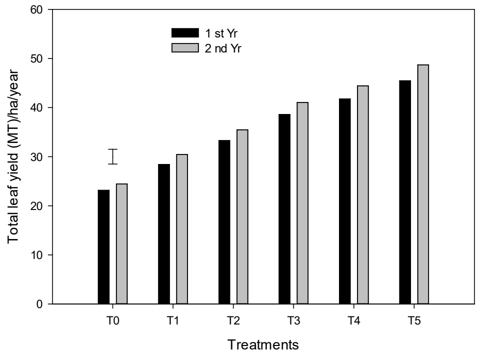

Figure 12.8: Total leaf yield/ha/year of mulberry as influenced by various levels of N management practices. Where, T_0= 0 kg N/ha/yr, T_1= 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4= 320 kg N/ha/yr and T_5= 400 kg N/ha/yr. Vertical bar represent LSD (P = 0.105) different levels of nitrogen and mulberry plant age interactions.

12.3.3. Effect of nitrogen levels and ages of plant on leaf quality of mulberry

Several leaf quality parameters viz: moisture percentage, total mineral percentage, crude protein percentage, soluble carbohydrate percentage and total sugar percentage affected for the nitrogen fertilization level and mulberry plant age.

Moisture percentage

The moisture percentage of mulberry leaf was statistically differed due to the nitrogen levels. Among the six levels of nitrogen the maximum moisture was 78.59% in (6-10) year's plant for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr). This moisture percentage was significantly ($P \geq 0.05$) differed with the moisture percentage of (0-5) year's plant. However, the minimum moisture was 67.78 in (0-5) year's mulberry plant for the treatment of T_0 (Table 12.3).

Table 12. 3. Effect of different level of nitrogen and ages of mulberry plant on Bio-chemical constitutions of mulberry leaf

Treatments	Moisture (%)		Total Mineral (%)		Crude Protein (%)		Soluble Carbohydrate (%)		Total Sugar (%)	
	Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	67.78d	68.96cd	8.33d	8.96cd	15.41b	15.87b	7.37b	7.66b	3.89d	3.97d
T_1	69.22cd	69.77c	8.63cd	8.99cd	15.63b	16.09b	7.57b	7.97b	3.99d	4.11cd
T_2	69.82c	69.97c	8.97cd	9.1cd	15.77b	16.43b	7.75b	8.13b	4.19bcd	4.44bcd
T_3	69.97c	70.15c	9.53bcd	10.13bc	15.97b	16.77b	7.81b	8.23	4.39bcd	4.83abcd
T_4	72.84b	73.18b	10.11bc	12.72a	16.67b	18.68a	8.13b	8.99ab	5.11abcd	5.87ab
T_5	73.19b	75.59a	10.87b	11.13ab	18.81a	20.17a	8.92ab	10.44a	5.73abc	6.19a

Means with the same letter are not significantly different at 5% level by DMRT. Here, $T_0 = N_0P_{150}K_{100}$ kg/ha/yr, $T_1 = N_{80}$ P_{150} K_{100} kg/ha/yr, $T_2 = N_{160}P_{150}K_{100}$ kg/ha/yr, $T_3 = N_{240}P_{150}K_{100}$ kg/ha/yr, $T_4 = N_{320}P_{150}K_{100}$ kg/ha/yr and $T_5 = N_{400}$ P_{150} K_{100} kg/ha/yr. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

Total mineral percentage

The total mineral contains of mulberry leaf was significantly ($P \geq 0.05$) differed among the nitrogen treatments. But the similar trend was found both for the (0-5) and (6-10) year's ages of mulberry plant. However, between the two types of mulberry plant the maximum total mineral was 12.72 % in the leaf of (6-10) year's plant for the treatment of T_4. Conversely, the minimum total mineral was 8.33 % recorded in (0-5) year plant for the treatment of T_0 (Table 12.3).

Crude protein percentage

Statistically significant trend was observed among the nitrogen treatments but the similar trend was recorded between the ages of plant. However, the recorded maximum crude protein was 20.17% for the T_5 treatment and the leaf of (6-10) year's ages of plant. The recorded minimum crude protein was 15.41 % in the leaf of (0-5) year's ages of plant due to application of T_0 treatment (Table 12.3).

Soluble carbohydrate percentage

The soluble carbohydrate content in mulberry leaves was significantly influenced by the nitrogen treatments but the similar trend was found both the (0-5) and (6-10) year's ages of mulberry plant. However, the maximum soluble carbohydrate was 10.44% in the leaf of (6-10) years ages of plant for the treatment of T_5 that was statistically similar with the treatments of T_4. Conversely, the minimum soluble carbohydrate was 7.37% in (0-5) year's ages of plant for the treatment of T_0 (Table 12.3).

Total sugar percentage

The total sugar content in mulberry leaves were significantly differed among the treatments but no difference was found between the ages of mulberry plant. However, between the two types of mulberry plant the maximum total sugar was 6.19% in the leaf of (6-10) year's plant for the treatment of T_5. Conversely the minimum total sugar was 3.89% in (0-5) year's plant for the treatment of T_0 (Table 12.3).

12.3.4. Effect of nitrogen levels and ages of plant on suppression of foliar diseases in mulberry

The incidence of foliar diseases in mulberry plant was significantly ($P \geq 0.05$) differed among the levels of nitrogen. But the similar trend was found between the (0-5) and (6-10) year's age of mulberry plant. However, in case of powdery mildew disease the lower incidence percentage was 6.83 in (6-10) year's ages of mulberry plant due to application of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) treatment. Conversely, the maximum incidence of powdery mildew disease was 11.13 % in (0-5) year's ages of mulberry plant for the T_0 treatment (Table 12.4).

Similarly, the incidence of leaf spot disease was statistically differed by the graded doses of nitrogen. But the plant ages have no significant impact on incidence of leaf spot disease of mulberry. However, the lower incidence of leaf spot disease was 7.53% in (6-10) year's ages of mulberry plant for the T_5 treatment. Conversely, the higher incidence of leaf spot was 10.79% in (0-5) year's ages of mulberry plant due to application of T_5 treatment (Table 12.4).

Correspondingly, the tukra disease incidence of mulberry plant was significantly differed among the treatments but the similar trend was observed between the ages of mulberry plant. However, the recorded minimum incidence of tukra was 6.79% in (6-10) year's ages of mulberry plant for the T_5 (N_{400} P_{150} K_{100} kg/ha/yr) treatment. Conversely, the maximum incidence of tukra was 9.67% in (0-5) year's ages of mulberry plant for the treatment of T_5 (Table 12.4).

Table 12.4. Effect of different levels of nitrogen and ages of mulberry plant on means diseases incidence (%) in mulberry plant

N application rate (kg/ha/yr)	Powdery mildew (%) Plant age (0-5)	Powdery mildew (%) Plant age (6-10)	Leaf spot (%) Plant age (0-5)	Leaf spot (%) Plant age (6-10)	Tukra (%) Plant age (0-5)	Tukra (%) Plant age (6-10)
T_0 (0)	11.13a	10.77abc	10.79a	9.87abc	9.67a	9.29ab
T_1 (80)	10.97ab	9.58abcd	10.30ab	9.53abcd	9.43ab	8.79abc
T_2 (160)	9.35bcde	8.67def	9.77abcd	8.86bcde	8.87abc	7.93bcd
T_3 (240)	9.13cdef	8.41defg	9.57abcd	8.43cde	8.13abcd	7.89bcd
T_4 (320)	8.78def	7.67efg	9.17abcde	8.10de	7.97bcd	6.93d
T_5 (400)	7.56fg	6.83g	8.79bcde	7.53e	7.33cd	6.79d

Means with the same letter are not significantly different at 5% level by DMRT. Where, $T_0 = N_0P_{150}K_{100}$ kg/ha/yr, $T_1 = N_{80}\ P_{150}\ K_{100}$ kg/ha/yr, $T_2 = N_{160}P_{150}K_{100}$ kg/ha/yr, $T_3 = N_{240}P_{150}K_{100}$ kg/ha/yr, $T_4 = N_{320}P_{150}K_{100}$ kg/ha/yr and $T_5 = N_{400}\ P_{150}\ K_{100}$ kg/ha/yr. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

12.4. DISCUSSIONS

12.4.1. Effect of nitrogen on mulberry leaf yield and quality

The elevated doses of N significantly increased the leaf yield and quality of mulberry plant. Findings showed that among the six levels of nitrogen viz: 0 kg, 80 kg, 160 kg, 240 kg, 320 kg and 400 kg N/ha/yr with BSRTI recommended P and K @ 150 kg P and 100 kg K/ha/yr in four splits doses, the better performance was 400 kg N/ha/year in respect of growth and yield of mulberry plant. The more marked increasing trend for yield contributing characters of mulberry plant viz: nodes per meter, total branches number, total branches height, total shoots weight, 10 leaves area, 10 leaves weight and total leaves weight per plant were found for the treatment of T_5 ($N_{400}\ P_{150}\ K_{100}$ kg/ha/yr) as compared to the other treatments (Table 12.2).

The recorded highest mulberry leaf yield was 48.70 MT/ha/year for the treatment of T_5. This leaf yield was 81.92% greater than the maximum leaf yield of T_0 ($N_0\ P_{150}\ K_{100}$ kg/ha/yr) treatment. Similarly, the leaf quality of mulberry plant was significantly differed by the different doses of nitrogen. The remarkable improving trend was recorded for the same (T_5) fertilizer management. However, the recorded maximum moisture, crude protein, soluble carbohydrate and total sugar were 75.59, 20.17, 10.44 and 6.19% respectively for the T_5 treatment except total mineral. These percentages were 9.61, 27.10, 41.65 and 55.92% respectively higher over the maximum moisture, crude protein, soluble carbohydrate and total sugar of T_0 treated mulberry plant. These findings were similar with the previous findings of Paul *et. al.,* (2009). They were applied 0 kg, 200 kg, 300 kg and 400 kg N/ha/yr with different doses of P and K along with one and two irrigation respectively. Among the different doses of N the application of 400 kg N/ha/yr with two irrigations showed the significantly highest yield components viz: plant height, number of branches per plant, number of leaves per branches and leaf yield per plant. Similarly, the maximum leaf qualities viz: leaf moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral were recorded also for the application of 400 kg N/ha/yr with two irrigations.

This experimental result was also similar with the earlier findings of Miah (1989). He found that the application of 400 kg N with 200 kg P and 150 kg K the mulberry leaf yield was increased 77.92% over the control treatment. He also found that the leaf constituents viz: moisture percentage, chlorophyll-a, chlorophyll-b, total sugar percentage, soluble carbohydrate percentage, reducing sugar and crude protein percentage except total mineral contents increased gradually due to progressive increase of NPK fertilizers. Ray (1978) also applied the N @ of 0, 150, 300, 600 and 900 kg/ha/yr and found that the leaf yield was increased by 88% in the highest dose (900 kg/ha/yr) compared to the control (T_0) treatment. The leaf yield per plant of T_1 (150 kg N), T_2 (300 kg N) and T_3 (600 kg N) were increased by 25.96, 41.60 and 49.29% respectively.

However, they did not explain their speculation about their experimental findings. But in this experiment my speculation was the applied 400 kg N/ha/yr with recommended P and K @ (N_{400} P_{150} K_{100} kg/ha/yr) could be comparatively balanced and available form than the others treatments. As a results, the N as well as the other related nutrients especially P, K uptake form the soil, assimilation and utilization through the proliferated mulberry roots was comparatively maximum. That directly improved the several key functions, including energy transfer, photosynthesis rate, transformation of sugars and nutrient movement within the plant cell. In addition, it might be also improved many structural, genetics, metabolic components, various physiological process, chlorophyll and protein contents. Consequences, the growth, development, leaf area production, leaf area duration as well as net assimilation rate of mulberry plant were increased in T_5 treatment. Resulting, the growth parameters, leaf yield as well as the leaf quality viz; moisture, total sugar, soluble carbohydrate, reducing sugar and crude protein except total mineral, were greater for the T_5 treatment.

The above assumption was lined with the previous findings of Rafiq *et. al.,* (2010). They reported that maximum leaf area and total leaf biomass of plants are a determinant of higher crop yield. Because, nitrogen is the essential constituent of protein, nucleic acids, chlorophyll and growth hormones (Barker *et. al.,* 1974). Besides, proper growth and development of plants require optimum supply of nitrogen. Because, too little application of N directly reduces crop yield while excess supply of N also causes negative effects on plant and this issue getting focus continuously in crop production (Magistad *et. al.,* 1945).

12.4.2. Elevated doses of nitrogen suppresses of foliar diseases of mulberry plant

Elevated doses of soil applied nitrogen with BSRTI recommended basal dose of phosphorus and potassium significantly reduced the severity of foliar diseases of mulberry plant. Findings showed that the incidence of foliar diseases viz: powdery mildew, leaf spot and tukra were 38.63, 30.21 and 29.78% respectively reduced for the T_5 (N_{400} P_{150} K_{100} kg/ha/yr) treatment followed by the maximum incidence percentage of T_0 (N_0 P_{150} K_{100} kg/ha/yr) treatment. Thus optimum level of N application suppresses the common foliar diseases of mulberry plant. This could be due to the reason that the higher rate of N might be improved metabolic and enzymatic functions of the mulberry plant. Furthermore, T_5 treated mulberry plant was also ensured the nutritious and healthier growth compared to the other treatments treated plant. In terms, this positive benefit could be developed defense system against the pathogen. Thus the incidences of foliar diseases were comparatively reduction in T_5 treatments followed by the other treatments.

12.4.3. Impact of ages of plant on productivity and foliar diseases of mulberry

The older (6-10 years) mulberry plant significantly ($P \geq 0.05$) increased the growth and yield parameter of mulberry plant compared to the younger (0-5 years) mulberry plant. Results showed that the older mulberry plant gave the maximum nodes per meter, total branches number, total branch height, total shoot weight, 10 leaf areas, 10-leaf weights and total leaf weights per plant followed by the younger mulberry plant. Even the maximum leaf yield of older and younger mulberry plant was 48.70 and 45.46 MT/ha/yr, respectively. The leaf yield was 7.13% greater in older mulberry plant than the younger mulberry plant. Similarly, the improving trend was found for leaf qualities of mulberry irrespective to ages of mulberry plant. The better leaf qualities viz: moisture, crude protein, soluble carbohydrate, total mineral and total sugar were recorded in older mulberry plant than the younger mulberry plant. Even the leaf qualities viz: moisture, crude protein, soluble carbohydrate, total mineral and total sugar of older mulberry plant was 3.28, 7.23, 17.04, 17.02 and 8.03 percent respectively higher than the younger mulberry plant. Such type finding was totally new in mulberry crop. Correspondingly, the incidences of powdery mildew, leaf spot and tukra diseases were 9.66, 14.33 and 7.37 percent respectively reduced in older mulberry plant than the younger mulberry plant.

The speculation was the nitrogen absorption rate by the older mulberry plant was comparatively higher than the younger mulberry plant due to the well developed, larger, deeper root system and larger leaves of older plant. That might be contributed the rapid and maximum photosynthesis as well as enhanced the physiological activity and N use efficiency of the plant. In addition, it also might be better improved the metabolic and enzymatic activities of older mulberry plant compared to the younger mulberry plant. As a result the growth and development of the (6-10) years ages of older mulberry plant was better compared to (0-5) years ages of younger mulberry plant. In terms, the leaf yield as well as moisture, crude protein, soluble carbohydrate, total mineral and total sugar were comparatively greater in the older mulberry plant followed by the younger mulberry plant. Furthermore, better metabolic and enzymatic functions of older mulberry plant might be created more resistance system against the pathogen. That could be reduction the incidences of foliar diseases in older mulberry plant. Similarly, Deborah *et. al.,* (1990) found that the N absorption rate was increased with plant age of marigold seedlings. They were treated the seedlings of 30, 35, 40, 45 and 50 days old marigold (*Tagetes erecta* Big. Inca Gold) in 500 ml plastic pots containing a 1 peat: 1 per liter (v/v) with several nitrogen levels (N at 20, 50, 80 and 100 mg /Liter); solution nutrient levels in the medium. They found N absorption rate was increased by the older plants than the younger plants even the older plants (> 40 days) absorbed at least 88% of the N solution regardless of N treatment. Likewise, Leghari *et. al.,* (2016) reported that when the plants roots completely developed and leaves also become wider in size then the utilization of N was increased. Besides, they also reported that the deeper root system enhances the up take of N, while larger leaves contribute rapid and maximum photosynthesis process that stimulates physiological activity of plant resulting help in N use efficiency by the plant.

12.5. CONCLUSIONS

The present study demonstrated that the elevated dose of nitrogen with BSRTI recommended doses of phosphorus and potassium increased the leaf yield of mulberry by 81.92% over the basal dose. It also improved the leaf quality parameters viz: moisture, crude protein, total mineral, total sugar and soluble carbohydrate percentage respectively due to elevated doses of nitrogen. In addition, increasing doses of nitrogen significantly reduction of foliar diseases of mulberry plant. Furthermore, older mulberry plant radically influenced the leaf yield, leaf qualities as well as reduction of foliar diseases as compared to the younger mulberry plant. This chapter concluded that irrespective to plant ages the application of elevated 400 kg N/ha/yr with BSRTI recommended basal dose of P and K is a proactive fertilizer management practice, in terms of leaf yield and leaf quality as well as suppression of foliar diseases than the existing 300 kg N/ha/yr for mulberry plant production in Bangladesh.

The performance of elevated nitrogen was better in terms of leaf yield, leaf quality as well as reduction of foliar diseases. However, next to nitrogen, phosphorus is the major key element for successful plant growth, establishment as well as productivity. Furthermore, the information on impact of elevated phosphorus for mulberry cultivation was scarcely available. That's why further study will be conducted to determine the best possible level of phosphorus for mulberry cultivation and suppression of foliar diseases in the following chapter (Chapter 13).

Chapter 13

Elevated phosphorus enhances productivity and reduces foliar diseases of mulberry plant

Chapter 13

Elevated phosphorus enhances productivity and reduces foliar diseases of mulberry plant

13.1. INTRODUCTION

Mulberry is a deep rooted perennial plant mainly cultivated to harvest leaves for rearing of silkworms (Jian *et. al*., 2012). Improvement in larval and cocoon characters of the silkworms has been witnessed with the increase in the nutritional status of mulberry leaf (Venkataramu, 1986). The better growth and development of silkworm larvae as well as good quality cocoons when fed on nutritionally enriched mulberry leaves (Seki *et. al*., 1959). Hence, quality of mulberry leaf is one of the basic prerequisite of sericulture and plays a pivotal role for successful silkworm cocoon production (Guttierrez *et. al*., 1997).

Phosphorus (P) has a positive response on mulberry crops under irrigated condition (Ray *et. al*., 1973). The P influences the yield and leaf quality of mulberry plant (Bose *et. al*., 2009). The P is also the most important plant nutrient that has a key role in the growth, metabolism and development of mulberry plants (Gallegos-Cedillo *et. al.,* 2016). Mulberry plant is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et. al.,* 1990; Yashihiko 1995). Likewise, Khan *et. al.,* (2004) reported that in Kashmir valley among the mulberry diseases like leaf spot and powdery mildew are the major foliar diseases of mulberry which are the impediments in the production of quality leaf feed. Powdery mildew, leaf spot and tukra are the major foliar diseases which reduces the leaf production as well as depletion of leaf quality of mulberry plant (Rabbel, 1995). So, it is needed to control the mulberry foliar diseases for successful mulberry leaf production.

Previous chapter showed that the graded dose of nitrogen (N) significantly enhanced the growth and leaf yield of mulberry plant. Similarly, the leaf quality was also improved by the increasing dose of nitrogen. Further, the elevated dose of N had a passive effect on the reduction of foliar diseases in mulberry plant (Chapter 12). But, the earlier researcher reported that inorganic fertilizer is the essential nutrient for plant growth and development. Among the major key elements NPK, next to nitrogen, phosphorus is more essential for better growth and development of mulberry plant. In my previous study, the single effect of different levels of nitrogen has been evaluated in terms of leaf yield and quality as well as reduction of foliar diseases of mulberry plant. But, the single effect of elevated phosphorus was not estimated previously. Even, the information on elevated phosphorus application for mulberry plant cultivation was scarcely available. So, it was very much essential to evaluate the impact of graded doses of phosphorus for sustainable mulberry plant production. In this aspect, the present study was undertaken to estimate the impact of elevated phosphorus on soil properties, leaf yield, leaf quality and reduction of foliar diseases in mulberry plant. It was hypothesized that graded doses of different levels of phosphorus will be varied the mulberry plant production as well as suppresses the foliar diseases incidences.

13.2. MATERIALS AND METHODS

13.2.1. Experimental site

This experiment was conducted in the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh. This location is located at the 24°22′29″ N and 88°37′84″ E.

13.2.2. Experimental plant

Mulberry plant was used as sample planting material. Mulberry plant (*Morus* sp) is small to medium sized shrubs or trees with a thick tan-gray ridged trunk which is perennial, deep rooted and hardy in nature. Due to its perennial, deep rooted and hardy habit, mulberry is grown in wide range of soil and agro-climatic conditions in Bangladesh. Mulberry (*Morus spp*) variety BM-11 (BM = Bangladesh Mulberry) was used for this study. The cultivation system was high-bush.

13.2.3. 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. Two types of mulberry plant viz: (0-5) and (6-10) year's mulberry plants were used for this study. The phosphorus fertilizer treatments were applied 20 DAPr (Days after Pruning) when the sprouting was started after pruning. The necessary cultural practices like irrigation, digging cum weeding, insect-pest management practices etc. were done as per requirement.

13.2.4. Plot size

The each plot size was 5 m × 4 m. The number of plant for each plot was 20.

13.2.5. Experimental design and treatments

The experiment was conducted in split plot design with three replications. The respective treatments were applied in the allocated split plots. The following six phosphorus treatments were applied in the experimental plots:

T_0: Only the BSRTI recommended basal dose of N and K were applied no P was applied (N = 300 kg and K = 100 kg/ha/yr).

T_1: 40 kg P + BSRTI recommended basal dose of N and K per hectare per year.

T_2: 80 kg P + BSRTI recommended basal dose of N and K per hectare per year.

T_3: 120 kg P + BSRTI recommended basal dose of N and K per hectare per year.

T_4: 160 kg P + BSRTI recommended basal dose of N and K per hectare per year.

T_5: 200 kg P + BSRTI recommended basal dose of N and K per hectare per year.

13.2.6. Recorded growth attributes

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 (g) and total leaf yield/ha/year (MT) were recorded for this study. Data were collected at 90 DAPr for each cropping seasons. Total four times data was collected in a year and the annual yield was computed by pooling the two years data. The total green leaf yield per hectare per year was calculated by the following formula:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2 \text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

13.2.7. Analysis of leaf quality

The mulberry leaf samples at different heights of the plant (top, middle and bottom) were collected in paper bags at 75 days after pruning and composite leaf samples were made. Then the leaves sample were shade dried for three days and again then dried in hot air oven at 700°C for one hour and were ground into powder for chemo-assay. The moisture (%) was determined by followed the Vijayan *et. al*., (1996), total mineral (%) followed the AOAC (1980), protein (%) followed by the Kjeldahl's method (Wong 1923), total sugar and reducing sugar (%) followed by the Miller (1972) and Loomis *et. al,*. (1937) procedure and methods and soluble carbohydrate (%) followed by Dubois *et. al*., (1956) method.

13.2.8. Measurement of soil physical and chemical properties

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). Soil organic C was determined by chromic acid digestion and spectrophotometric analysis (Heanes, 1984). 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). 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).

The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et. al.,* 2012). 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). Calcium and magnesium content were determined following the method of Tandon (1993). Manganese was estimated by Spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979).

13.2.9. Analysis of diseases data

For a period of two consecutive years in each replication, 10 mulberry plants were taken into observation to study the incidence of diseases. The diseases data were collected at 60 days after pruning. Disease incidence percentage was assessed as number of total mulberry leaves per plant was infected by powdery mildew, leaf spot and tukra 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 as follows:

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

13.2.10. **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 Duncan Multiple Range Test (DMRT) through using the Statistic-10 software. In case of soil the mean values of post harvest soil properties were recorded for this study.

13.3. RESULTS

13.3.1. Effect of phosphorus on post harvest soil properties of mulberry garden

The average physicochemical properties of the post harvest experimental soil are presented in the Table 13.1. The average post-harvest soil pH, OM, N, P, K, Zn, Ca and Mg for (0-5) year's plant were 7.4 to 8.1, 1.21 to 1.61%, 0.06 to 0.09%, 10.3 to 18.8 micro g/g, 0.16 to 0.19 meq/100 g soil, 0.54 to 0.66 micro g/g, 17.33 to 17.53 meq/100 g soil and 2.31 to 2.56 meq/100 g soil respectively. Conversely, the average soil pH, OM, N, P, K, Zn, Ca and Mg for (6-10) year's plant were 7.3 to 8.2, 1.23 to 1.63%, 0.07 to 0.09%, 10.3 to 18.9 micro g/g, 0.18 to 0.20 meq/100 g soil, 0.55 to 0.66 micro g/g, 17.35 to 17.55 meq/100 g soil and 2.29 to 2.57 meq/100 g soil respectively.

Table 13.1. Effect of different phosphorus levels on physicochemical properties of the post harvest soil

Treatments	Soil pH		OM (%)		N (%)		P (micro g/g)		K (meq/100 g soil)		Zn (micro g/g)		Ca (meq/100 g soil)		Mg (meq/100 g soil)	
	Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	7.4	7.3	1.21	1.23	0.06	0.07	10.3	9.3	0.16	0.18	0.54	0.55	17.33	17.35	2.31	2.29
T_1	7.4	7.4	1.25	1.27	0.07	0.07	13.7	13.9	0.17	0.18	0.56	0.57	17.41	17.43	2.35	2.37
T_2	7.7	7.8	1.37	1.41	0.08	0.09	14.9	14.9	0.18	0.17	0.59	0.61	17.45	17.46	2.34	2.35
T_3	7.9	7.9	1.42	1.44	0.08	0.09	18.4	18.5	0.19	0.18	0.63	0.65	17.47	17.45	2.47	2.47
T_4	8.1	7.9	1.52	1.51	0.08	0.09	18.6	18.5	0.19	0.20	0.64	0.66	17.51	17.5	2.53	2.54
T_5	8.1	8.2	1.61	1.63	0.09	0.09	18.8	18.9	0.19	0.20	0.66	0.65	17.53	17.55	2.56	2.57

Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr.

13.3.2. Effect of Phosphorus and ages of plant on growth and yield of mulberry

Total branches number per plant

The total branches number per plant was highly significant ($P \geq 0.001$) by the phosphorus treatments. But there were no significant difference was found between the ages of mulberry plant. The more marked increasing trend was observed for the T_4 (300 Kg N/ha/yr + 160 Kg P/ha/yr/ + 100 K/ha/yr) treatment. However, between the two aged types of mulberry plant the total branches number was 10.23, 10.67, 11.77, 12.67, 15.53 and 13.67 in younger (0-5 year's ages) plant for the treatments of T_0, T_1, T_2, T_3, T_4 and T_5 respectively. Conversely, the total branches number per plant was 10.53, 10.99, 12.21, 12.99, 16.13 and 14.21 respectively in older (6-10 year's ages) mulberry plant due to same fertilizers management (Figure 13.1; Table 13.2).

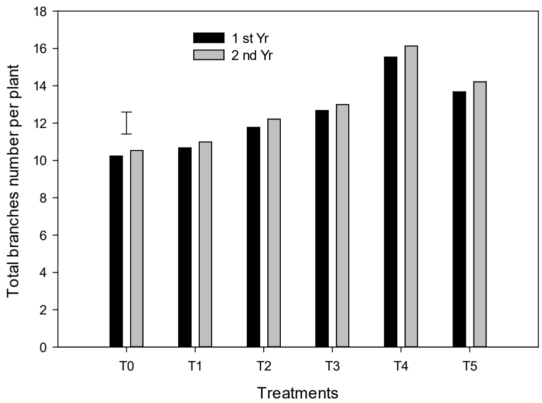

Figure 13.1: Total branches number per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total branches height per plant (cm)

The highly significant ($P \geq 0.001$) trend was observed among the treatments, ages of plant and their interactive effect in respect of total branches height per plant of mulberry. The remarkable increasing trend was found for the T_4 treatment and the older mulberry plant. However, the recorded total branches height was 998.89, 1009.78, 1167.77, 1191.67, 1327.89 and 1227.09cm in younger (0-5 year's ages) plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. In case of older (6-10 year's ages) mulberry plant total branches height was 1051.77, 1023.57, 1178.98, 1199.89, 1336.79 and 1236.77 cm respectively for the similar treatments (Figure 13.2; Table 13.2).

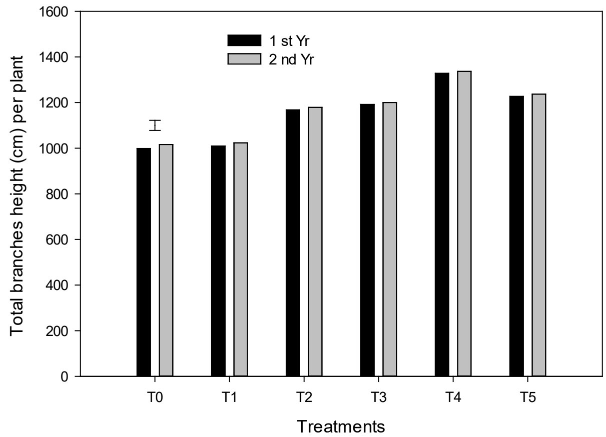

Figure 13.2: Total branches height per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Node per meter per plant

The node per meter of mulberry was significant ($P \geq 0.01$) differed both for the elevated doses of P and ages of mulberry plant. The more increasing trend was found for the T_4 treatment and the older (6-10 year's ages) mulberry plant. However, the noted nodes per meter were 20.67, 20.99, 21.01, 21.07, 22.57 and 21.1 in younger mulberry plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, the nodes per meter were 21.79, 22.01, 22.02, 22.16, 23.57 and 22.18 respectively in older (6-10 year's ages) mulberry plant for the same fertilizers management (Figure 13.3; Table 13.2).

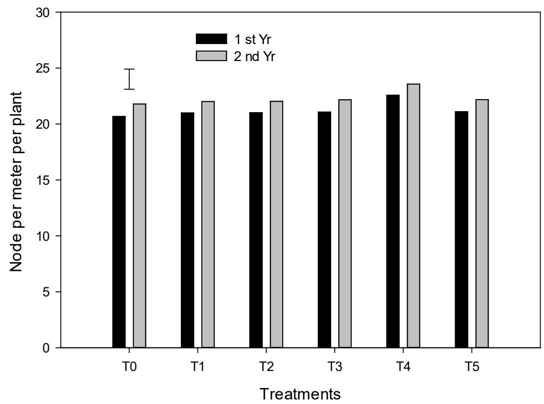

Figure 13.3: Node per meter in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total shoots weight per plant (g)
Statistically, highly significant ($P \geq 0.001$) trend was observed among the fertilizer treatments, ages of mulberry plant and their interactive effect irrespective to total shoots weight per plant of mulberry. The more marked increasing rate was found for the T_4 treatment and the older (6-10 year's ages) mulberry plant. However, the recorded total shoots weight was 483.53, 487.67, 511.43, 523.57, 586.56 and 558.87 g in younger (0-5 year's ages) mulberry plant for the treatments of T_0, T_1, T_2, T_3, T_4 and T_5 respectively. Conversely, in case of older mulberry plant total shoots weight was 498.79, 503.37, 521.31, 536.79, 596.79 and 565.67g respectively due to the similar treatments (Figure 13.4; Table 13.2).

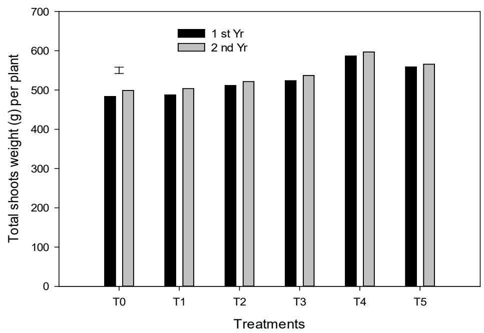

Figure 13.4: Total shoots weight per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

10 leaves area (cm^2) per plant
The 10 leaves area of mulberry was highly significant ($P \geq 0.001$) by the treatments, mulberry plant ages and their interactive effect. The remarkable increasing trend was recorded for T_4 treatment and the older (6-10 year's ages) mulberry plant. However, the recorded 10 leaf areas were 530.47, 533.77, 537.67, 557.87, 597.87 and 581.57 cm^2 in younger (0-5 year's ages) mulberry due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, the 10 leaves area for older mulberry plant was 536.67, 541.67, 549.86, 569.79 and 569.79 cm^2 respectively for the same fertilizers management (Figure 13.5; Table 13.2).

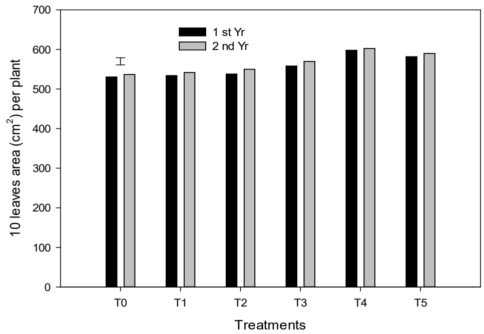

Figure 13.5: 10 leaves area per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Table 13.2. Effect of different levels of Phosphorus on mulberry plant production

Factors	Node/Meter	Total branches number/ plant	Total branches height/ plant (cm)	Total shoots weight/ pant (g)	10 leaves area/plant (cm^2)	10 leaves weight/ plant (g)	Total Leaf Yield/ ha/yr (MT)
Age	**	***	***	***	***	***	***
Treatments	*	n.s	***	***	***	***	***
Age × Treatment	n.s.	n.s.	***	***	***	n.s.	n.s.

Where, n.s., * ** and *** represent not significant, probability of >0.05, ≤0.05, ≤0.01 and ≤0.001. Values were means of three replicates.

10 leaves weight per plant (g)

The highly significant ($P \geq 0.001$) difference was found among the fertilizer treatments and the ages of mulberry plant irrespective to 10 leaves weight per plant of mulberry. The more increasing trend was marked for the application of T_4 treatment and the older mulberry plant. However, the recorded 10 leaves weight was 30.33, 32.34, 33.57, 35.47, 45.67 and 35.97g in younger (0-5 year's ages) mulberry for the treatment of T_0, T_1, T_2, T_3, T_4 and T_5 respectively. On the other hand, in case of older mulberry plant (6-10 year's ages) 10 leaves weight was 32.67, 34.67, 34.97, 37.77, 46.57 and 38.71g respectively for the similar treatments (Figure 13.6; Table 13.2).

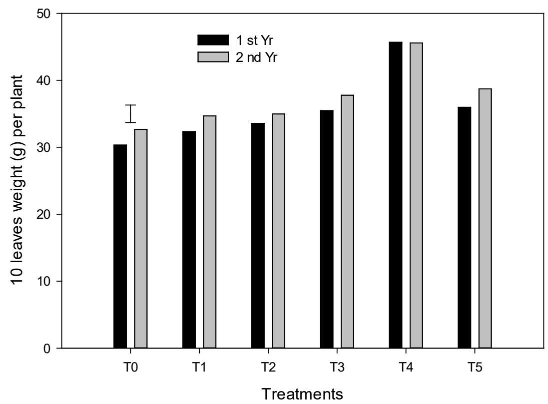

Figure 13.6: 10 leaves weight per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total leaves weight (g) per plant

The total leaves weight per plant of mulberry was significantly ($P \geq 0.001$) differed among the fertilizer treatments and ages of mulberry plant. The remarkable increasing rate was recorded in T_4 treatment and the older (6-10 year's ages) mulberry plant. However, in case of older mulberry plant the recorded total leaves weight was 574.79, 596.25, 620.21, 694.38, 935.21 and 786.88g in younger (0-5 year's ages) mulberry plant for the treatment of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Conversely, the total leaves weight for older mulberry plant (6-10 year's ages) was 622.71, 680.21, 731.25, 749.79, 1016.04 and 872.92g respectively for the similar treatments (Figure 13.7; Table 13.2).

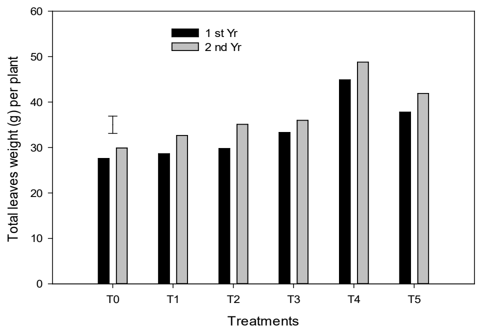

Figure 13.7: Total leaves weight per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total leaf yield/ha/year (MT)

The highly significant ($P \geq 0.001$) difference was found both for the fertilizer treatments and the ages of mulberry plant. The more marked increasing trend was found for T_4 treatment and older mulberry plant. However, the recorded total leaf yields were 27.59, 28.62, 29.77, 33.33, 44.89 and 37.77 MT/ha/yr in younger (0-5 year's ages) mulberry plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, the total leaf yields for older mulberry plant (6-10 year's ages) were 29.89, 32.65, 35.1, 35.99, 48.77 and 41.9 MT/ha/yr respectively for the same fertilizers management (Figure 13.8; Table 13.2).

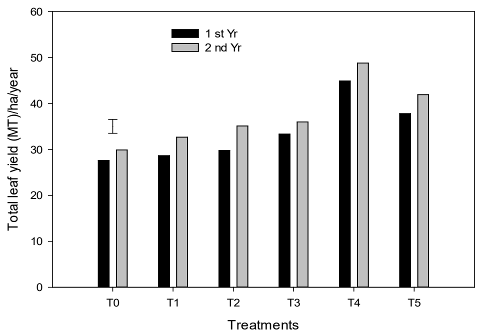

Figure 13.8: Total leaf yield/ha/year in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/year, T_1 = 40 kg P/ha/year, T_2 = 80 kg P/ha/year, T_3 = 120 kg P/ha/year, T_4 = 160 kg P/ha/year and T_5 = 200 kg P/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

13.3.3. Effect of phosphorus and ages of plant on leaf quality of mulberry

The similar trend was observed among the treatments and the ages of mulberry plant in respect of moisture percentage of mulberry leaf except T_4 treatment. However, among the six levels of P treatments, the maximum moisture percentage was 74.59 in the leaf of older (6-10 year's ages) plant for the treatment of T_4 (300 kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr). Conversely, the minimum moisture percentage was 65.93 for the T_0 treated mulberry leaf of younger (0-5 year's ages) plant (Table 13.3).The total mineral content in mulberry leaves was statistically differed among the treatments but the similar trend was found between the two types of mulberry plant. However, the maximum total mineral was 12.33 % in the leaves of older (6-10 year's ages) mulberry plant for the treatment of T_4. On the other hand, the minimum total mineral was 8.41 % in the leaves of younger (0-5 year's ages) mulberry plant due to application of T_0 treatment (Table 13.3). The similar trend was observed among the phosphorus treatments and ages of mulberry plant with respect of crude protein contain of mulberry leaf except T_4 treatment.

Among the two types of mulberry plant the maximum crude protein was found 20.13 % for the T_4 treated older (6-10 year's ages) plant mulberry plant. Conversely, the minimum crude protein was 15.63 % in the leaf of younger (0-5 year's ages) mulberry plant for the T_0 treatment (Table 13.3). The soluble carbohydrate contain of mulberry leaf was not significantly differed by the P treatments and the ages of mulberry plant except T_4 treatment. However, the maximum soluble carbohydrate was found 10.17 % in T_4 treated older mulberry plant. On the contrary, the minimum soluble carbohydrate was 7.39 % in the leaf of younger plant due to application of T_0 treatment (Table 13.3). The total sugar contain of mulberry leaf was significantly ($P \geq 0.05$) differed by the P treatments. But the similar trend was found between the two types of mulberry plant. However, the maximum total sugar was 6.10 % in the leaves of older (6-10 year's ages) mulberry plant for the T_4 treatment. Conversely, the minimum total sugar was 3.97 % in the leaf of younger (0-5 year's ages) mulberry plant for T_0 treatment (Table 13.3).

Table 13.3. Effect of different level of phosphorus and ages of mulberry plant on Bio-chemical constitutions of mulberry leaf

Treatments	Moisture (%)		Total Mineral (%)		Crude Protein (%)		Soluble Carbohydrate (%)		Total Sugar (%)	
	Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	69.31c	69.54c	8.41c	8.63c	15.63b	16.11b	7.39b	7.89b	3.97c	4.1bc
T_1	69.57c	69.77c	8.71c	8.87c	15.71b	16.27b	7.66b	8.05b	4.05bc	4.18bc
T_2	69.75c	69.87c	8.89c	9.08bc	15.75b	16.33b	7.69b	8.06b	4.11bc	4.37bc
T_3	69.89c	69.98c	9.05bc	9.16bc	15.89b	16.69b	7.79b	8.19b	4.27bc	4.53abc
T_4	72.84b	74.97a	10.73ab	12.33a	18.78a	20.13a	8.89ab	10.17a	5.69ab	6.1a
T_5	69.94c	70.11c	9.43bc	10.02bc	15.77b	16.71b	7.8b	8.21b	4.31bc	4.77abc

Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Means with the same letter are not significantly different at 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

13.3.4. Effect of elevated phosphorus on common diseases infestation in mulberry plant

The incidences of common foliar diseases of mulberry plant were significantly ($P \geq 0.05$) reduced due to the application of elevated phosphorus in soil. The similar trend was observed between the two types of mulberry plant. However, in case of powdery mildew disease the minimum incidence was 6.31 % in older (6-10 year's ages) mulberry plant for the T_4 treatment. Conversely, the maximum incidence of powdery mildew was 11.19 % in younger (0-5 year's ages) mulberry plant for the T_0 treatment (Table 13.4).

Similarly, the incidence of leaf spot disease was significantly ($P \geq 0.05$) differed among the phosphorus treatments. But, the similar trend was found between the two types of mulberry plant. However, the lower incidence of leaf spot disease was 7.10 % in older mulberry plant due to the application of T_4 treatment. On the contrary, the higher incidence of leaf spot disease was 10.91 % in younger mulberry plant due to treated by the T_0 treatment (Table 13.4).

Correspondingly, tukra incidence was statistically differed among the treatments but no difference was found between the two types of mulberry plant. However, between the two types of mulberry plant the minimum incidence of tukra disease was 6.37 % in older (6-10 year's ages) mulberry plant for the T_4 treatment. Conversely, the maximum incidence of tukra disease was 9.77 % recorded in younger mulberry plant due to application of T_0 (0-5 year's ages) treatment (Table 13.4).

Table 13.4. Effect of different phosphorus levels on means diseases infestation (%) in mulberry plant

P application rate (kg/ha/yr)	Powdery mildew (%) Plant age		Leaf spot (%) Plant age		Tukra (%) Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0 (0)	11.19a	10.89ab	10.91a	9.97ab	9.77a	9.43ab
T_1 (80)	10.81ab	9.49bc	10.09ab	9.19bc	9.33abc	8.57abcd
T_2 (160)	9.1c	8.34cd	9.67abc	8.71bcd	8.71abcd	7.77bcde
T_3 (240)	8.97c	8.23cd	9.31abc	8.21cd	8.55abcd	7.67cde
T_4 (320)	7.12de	6.31e	8.53bcd	7.10d	7.09de	6.37e
T_5 (400)	8.47cd	8.12cd	9.10bc	8.09cd	8.43abcd	7.59de

Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Means with the same letter are not significantly different at 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

13.4. DISCUSSIONS

13.4.1. Elevated phosphorus enhances mulberry plant productivity

Elevated doses of P significantly ($P \geq 0.05$) increased the growth, leaf yield and leaf quality of mulberry plant. The six levels of P viz: 0 kg P, 40 kg P, 80 kg P, 120 kg P, 160 kg P and 200 kg P/ha/yr respectively were applied with BSRTI recommended N and K @ 300 kg N and 100 kg K/ha/yr in four splits doses for mulberry plant production. The above results showed that the growth and yield contributing characters of mulberry plant viz: total branch number, total branches height, nodes per meter, total shoot weight, 10 leaf areas, 10 leaf weights and total leaf weights per plant were significantly ($P \leq 0.001$) increased due to the application of 160 Kg P/ha/yr with recommended 300 Kg N and 100 K/ha/yr as compared to the other treatments (Table 13.2). Even the interactive effect of P treatments × ages of plant was also significantly differed for the growth and yield contributing characters viz: total branch height, total shoot weight and 10 leaf areas of mulberry plant (Table 13.2).

However, the maximum leaf yield was 48.77 MT/ha/year for the treatment of T_4 (300 kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr). This leaf yield was 63.16 % higher than the maximum leaf yield of T_0 treatment. Similarly, the nutritional properties of mulberry leaf viz: moisture (%), crude protein (%), total sugar (%), soluble carbohydrate (%) and total mineral (%) were also significantly increased by the T_4 (300 kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr) treated mulberry plant compared to the other treatments. These nutritional values were 7.81, 24.95, 48.78, 28.90 and 42.87 % respectively greater than the maximum nutritional values of T_0 treatment. The above findings were more or less similar with the previous findings of Paul *et. al.,* (2009). They were applied four levels of P in four split doses viz; 0 kg, 100 kg, 150 kg and 200 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr.

Among the four levels of P the maximum yield components viz: plant height, number of branches per plant, number of leaves per branches and leaf yield per plant were obtained for the application of 200 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr. Similarly, they also obtained the maximum leaf qualities viz: leaf moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral for the same fertilizer management. Likewise, Bose *et. al.,* (2009) found the significant impact of elevated P on mulberry leaf yield and quality. They were applied five levels of P_2O_5 as basal doses @ 0, 15, 30, 45 and 60 kg/ha/yr respectively. Their result showed that the plant height, leaf area and leaf yield with moisture contents were significantly increased due to P application from 30 kg to 60 kg P_2O_5/ha/yr over the control, the maximum being with 60 P_2O_5/ha/yr. The speculation was the applied 160 kg P/ha/yr with recommended 300 kg N and 100 kg K/ha/yr was optimum and available than the others doses of phosphorus. As a results, the P as well as the other associated nutrients especially N, K and others micronutrients uptake form the soil and utilization by the deeper mulberry roots of older plant was comparatively maximum. In terms, it's improved the several key functions, including energy transport, photosynthesis rate, conversion of sugars and nutrient movement within the mulberry plant. In addition, it could be also improved the metabolic components, diverse physiological process, chlorophyll and protein contents. Resulting, the growth and development as well as net assimilation rate of mulberry plant were improved in T_4 treated mulberry plant.

Thus, the growth and leaf yield as well as the leaf quality viz; moisture, total sugar, soluble carbohydrate, reducing sugar, crude protein and total mineral, were comparatively optimum in 160 kg P/ha/yr (T_4) treated mulberry plant. The above speculation was lined with the previous assumption of Singh *et. al*., (2016). They reported that next to nitrogen, phosphorus is very important essential nutrients for plant growth and is found in every living plant cell. This element is involved in several key functions of plant, including energy transfer, photosynthesis rate, transformation of sugars and starches, nutrient movement within the plant and others related parameters. That are positively enhanced the growth, leaf yield and leaf quality of mulberry plant.

13.4.2. Elevated phosphorous suppresses foliar diseases of mulberry plant

The 160 kg/ha/yr phosphorus with BSRTI recommended basal doses of 300 kg N and 100 kg K/ha/yr suppressed the foliar diseases incidences in mulberry plant. Findings showed that the foliar diseases of mulberry viz: powdery mildew, leaf spot and tukra were drastically reduced due application of 160 kg P/ha/yr. The minimum incidence of powdery mildew was 6.31% in T_4 treatment. This incidence was 42.06% lower than the minimum incidence of T_0 treatment. Similarly, the application of 160 kg P/ha/yr reduced the leaf spot disease incidence was 28.79% over the minimum incidence percentage of T_0 treatment. Correspondingly, the minimum incidence of tukra was 6.37% for the same (T_4) treatment. This incidence was 32.50% lower compared to the T_0 treatment.

Likewise, Nwogbaga *et. al.,* (2015) found that the downy mildew and other fungal diseases of Cucumber (*Cucumis sativus* L.) were significantly reduced due to the foliar application of NPK at the rate of 19.181 kg/ha. Further, Huber *et. al*., (1999) also found that P is most effective when it is applied to control the fungal disease of seedlings due to the faster root development allows to the plant to escape disease. The speculation was the applied 160 kg P/ha/yr could be best compared to the other doses of P for suppression of foliar diseases of mulberry. Because, P is the essential element of the building blocks of life, the ribonucleic acids (RNA) as well as being required for many additional biochemical and physiological processes including energy transfer, protein metabolism and other related functions of the plant. That might be creating the defense mechanism against the fungal diseases of mulberry plant. Resulting, the infestation of powdery mildew, leaf spot and tukra diseases were comparatively low in T_4 treatment followed by the other treatments.

13.4.3. Impacts on age variation for leaf yield, quality and suppression of foliar diseases of mulberry plant

The ages of mulberry plant had a positive impact on leaf yield, quality and suppression of foliar diseases. Findings showed that the (6-10) year's ages of older mulberry plant gave the highest leaf yield with superior leaf quality than the (0-5) year's ages of younger mulberry plant. In this study, six levels of phosphorus viz: 0 kg, 40 kg, 80 kg, 120 kg, 160 kg and 200 kg P/ha/yr respectively were applied on two types of mulberry plant viz: (0-5) and (6-10) year's with BSRTI recommended basal dose of 300 kg N and 100 kg K/ha/yr in four splits doses for mulberry production. Between the two types of mulberry plant the highest growth and yield contributing parameters viz: total branch number, total branch heights, nodes per meter, total shoot weights, 10 leaf areas, 10 leaf weights and total leaf weights per plant were recorded for the older mulberry plant compared to the younger mulberry plant.

The recorded highest leaf yield was 48.77 MT/ha/yr also for the older mulberry plant. This leaf yield was 8.64 % higher than the maximum leaf yield of younger mulberry plant. Similar, the better leaf qualities viz: moisture, crude protein, soluble carbohydrate, total mineral and total sugar were found for the (6-10) year's ages of older mulberry plant. These leaf qualities were 2.92, 7.19, 14.40, 14.91 and 7.21 % respectively greater in older plant over the maximum leaf qualities of younger mulberry plant. Correspondingly, the incidences of foliar diseases viz: powdery mildew, leaf spot and tukra were comparatively lower in older mulberry plant than the younger mulberry plant. Even, the incidences of powdery mildew, leaf spot and tukra diseases were 11.38, 16.76 and 10.16 % respectively reduction in older mulberry plant compared to the younger mulberry plant.

The higher leaf yield, superior leaf quality and more suppression of foliar diseases in older mulberry plant could be due to the greater nutrients demand and absorption rate of (6-10) years ages of older mulberry plants compared to the younger mulberry plant. Because, well developed larger root system and bigger canopy closer of the older mulberry plant may be attributed the more nutrients as well as P uptake or accessing from a greater volume of the soil. In terms, the energy transfer, photosynthesis rate, revolution of sugars and starches, biochemical, physiological, structural, metabolic and mechanical processes of older mulberry plant was comparatively better than the younger mulberry plant. Resulting, the leaf yield, leaf quality and reduction of foliar diseases in older mulberry plant were comparatively higher than the younger plant. Similar, Deborah *et. al.,* (1990) found that the P absorption was increased by the older marigold seedlings than the younger the seedlings. They found that the marigold (*Tagetes erecta* Big. Inca Gold) seedlings of 30, 35, 40, 45 and 50 days old P absorption rate was 0.38, 0.41, 0.92, 1.70 and 2.30 mg respectively. This result implies that the P absorption by the older seedlings was higher than the younger seedlings of marigold which was more or less similar with my thought.

13.5. CONCLUSIONS

This study demonstrated that the application of elevated phosphorus in soil with BSRTI recommended basal dose of N and K is a progressive fertilizer management approach for mulberry cultivation. The elevated phosphorus application in soil enhanced the growth, leaf yield as well as improved the leaf quality of mulberry plant. Furthermore, foliar diseases of mulberry plant were considerably reduced due to application of phosphorus at elevated doses. In addition, older mulberry plant has a great impact on increasing the leaf yield, leaf qualities as well as suppression of foliar diseases as compared to the younger mulberry plant. Therefore, this chapter concluded that the application of 160 kg phosphorus per hectare per year in combination with BSRTI recommended basal dose of N and K is a suitable phosphorus management practices than the existing 150 kg P/ha/yr for obtaining higher leaf yield, superior nutritive value with maximum suppression of foliar diseases in terms of ages of mulberry plant.

The elevated dose of phosphorus showed the better perfomances irrespective to leaf yield, leaf quality as well as supression of foliar diseases in mulberry plant. But the previous findings repoted that potassium is also the essential plant nutreint next to phosphorus. Besides, earlier findings also reported that potassium had a significant effect on the resistanc of plant diseases. However, the literature on the single effect of potassium for mulberry plant production was barely avaliable. For this perspective, the present study will be executed to evaluate the optimum dose of potassium for quality and quaintity mulberry leaf production as well as reduction of foliar diseases in the following chapter (Chapter 14).

Chapter 14

Impact of elevated potassium on productivity and suppression on foliar diseases of mulberry plant

Chapter 14

Impact of elevated potassium on productivity and suppression on foliar diseases of mulberry plant

14.1. INTRODUCTION

Mulberry belongs to the genus *Morus* comprising of about 68 species (Datta, 2000). It is a perennial crops and once it is properly raised during the first year, it can come to full yielding capacity during the second year and last for over 15 years without any significant deterioration in leaf yield (Begum *et. al.,* 2018). Mulberry (*Morus spp.*) leaves have been the traditional feed for the silk worm (*Bombyx mori*) which is rich source of proteins, carbohydrates, chlorophyll and total carotenoids, ascorbic acid and various mineral elements. Deficiency of certain nutrients or an imbalance of nutrients in leaves cause changes in the composition or metabolic activity of silkworm larval body (Ito, 1972). The quality of mulberry silk is directly dependent on the nutrition of leaf which influences healthy growth of silkworm larvae and thereby the good cocoon production (Bongale *et. al.,* 1996). Hence, quality of mulberry leaf is one of the basic prerequisite of sericulture and plays a pivotal role for successful silkworm cocoon production (Guttierrez *et. al.*, 1997).

Potassium (K) is essential for normal growth and development of mulberry plants (Yadav 1983). Shortage of K results in soft branches and poor quality leaves in mulberry (Anonymous, 1988). The K markedly increased fresh leaf yield of mulberry plant and promoted the growth of mulberry plants (Jianrong *et. al.,* 1995). The K is also the most important plant nutrient that has a significant role in the growth, metabolism and development of plant after N and P (Gallegos-Cedillo *et. al.,* 2016). Like, K management in soil diseases is also a limiting factor for successful mulberry cultivation. Because, like other crops/plant mulberry is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et. al.,* 1990). The most common diseases of mulberry are powdery mildew, leaf spot, leaf rust and tukra (Reddy *et. al.,* 2009). Among the various diseases of mulberry plant, powdery mildew, leaf spot and tukra are the major foliar diseases which losses the leaf production as well as depletion of leaf quality (Rabbel 1995). Feeding of the diseased leaves affects the health of the silkworm adversely and cocoon yield in terms of quality and quantity (Datta, 2010). Nutrients are important for growth and development of plants and also microorganisms and they are important factors in disease control (Agrios, 2005). All the essential nutrients can affect disease severity (Huber, *et. al.,* 1999). However, there is no general rule, as a particular nutrient can decrease the severity of a disease but can also increase the severity of the disease incidence of other diseases or have a completely opposite effect in a different environment (Graham and Webb 1991). In addition, the balanced application of NPK fertilizer decreased disease severity to 6-8% (Ghosh *et. al*., 2012). Plant age is an important factor for management of diseases. Kuruppu *et. al*., (2004) found that 1 week old plants were more susceptible to red crown rot of soybean caused by *Calonectria illicicola* than older plants. Similarly, the Diaporthe stem canker of soybean plants became less susceptible when the plant age increased (Smith *et. al*., 1989).

The findings of the previous chapter reported that increasing dose of phosphorus had a significant effect on the growth and leaf yield of mulberry plant. Furthermore, the elevated dose of phosphorus improved the leaf quality as well as reduced the incidences of foliar diseases in mulberry plant. But the previous study suggest that inorganic nutrients especially NPK is the major key elements for proper growth and establishment of the plant. On the basis of plant requirements next to phosphorus, potassium is the essential plant nutrients. But, the information on the single effect of potassium for mulberry plant production was hardly available. In the previous chapters (chapter 12 and chapter 13) the single impact of elevated nitrogen and phosphorous on mulberry plant production as well as suppression of foliar diseases were observed. But, the single effect of elevated potassium was not observed earlier. So, it was time needed demand to determinant the appropriate dose of K for successful mulberry plant production as well as estimate the impact of potassium on incidence of mulberry foliar diseases. That's why, the present study was undertaken to estimate the effect of graded doses of potassium on soil properties, leaf yield, leaf quality and suppress of foliar diseases of mulberry plant. The hypothesis was the elevated potassium will be enhanced the mulberry leaf yield, quality as well as reduces the infestation rate of foliar diseases both for the (0-5) and (6-10) years ages of mulberry plant.

14.2. MATERIALS AND METHODS

14.2.1. Experimental site

The experiment was conducted in the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh that located at the 24°22′29″ N and 88°37′84″ E.

14.2.2. Experimental plant

The mulberry variety BM-11 (BM = Bangladesh Mulberry) was used for this study. The used plantation system was high-bush. Mulberry plant (*Morus* sp) is small to medium sized shrubs or trees with a thick tan-gray ridged trunk. It is a perennial, deep rooted and hardy in nature. Due to its perennial, deep rooted and hardy habit, mulberry is grown in wide range of soil and agro-climatic conditions in Bangladesh.

14.2.3. Experimental condition

The four commercially rearing seasons is followed for silkworm rearing in Bangladesh. On the basis of silkworm rearing season the mulberry garden was pruned four times in a year each after three months interval. Two types of mulberry plant viz: (0-5) and (6-10) year's ages of plant were used for this study. The potassium treatments were applied 20 DAP (Days after Pruning) when the sprouting of mulberry plant was started. The other cultural practices like irrigation, digging cum weeding, insect-pest management practices etc. were done as per requirement.

14.2.4. Experimental design and treatments

This experiment was conducted in a split plot design with three replications. The respective fertilizer treatments were applied in the assign experimental sub plot. The each sub plot was 5 m × 4 m. The number of plants per plot was 20. The following potassium treatments were applied:

T_0: Only the BSRTI recommended basal dose of N and P were applied (N = 300 kg, P = 150 K= 0 kg/ha/yr).

T_1: 30 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T_2: 60 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T_3: 90 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T_4: 120 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T_5: 150 kg K + BSRTI recommended basal dose of N and P per hectare per year.

14.2. 5. Recorded growth attributes

Growth attributes namely, node per meter, length of longest shoot per plant (cm), total branch number per plant, total branch heights per plant (cm), total shoot weights per plant (g), 10 leaf areas per plant (cm^2), 10 leaf weights per plant (g) and total leaf yield/ha/year (MT) were recorded. Data were collected at 90 DAP for each cropping seasons. Total four times data was collected for each year. The annual yield was computed by pooling the two years data. The following formula was used for calculate the green leaf yield per hectare per year:

$$\text{Leaf yield (MT/hectare/year)} = \frac{\text{Leaf weight (g) of per m}^2\text{ plant} \times \text{number of crop season per year} \times 10000\text{m}^2}{1000\text{g} \times 1000\text{kg}}$$

14.2.6. Analysis of leaf quality parameters

The mulberry leaf samples at different heights of the plant (top, middle and bottom) were collected in paper bags at 75 days after pruning and composite leaf samples were made. Then the leaves sample were shade dried for three days and again then dried in hot air oven at 700°C for one hour and were ground into powder for chemo-assay. The moisture (%) was determined followed by the Vijayan *et. al*., (1996), total mineral (%) followed the AOAC (1980), protein (%) followed by the Kjeldahl's method (Wong 1923), total sugar and reducing sugar (%) followed by the Miller (1972) and Loomis *et. al.,* (1937) procedure and methods and soluble carbohydrate (%) followed by Dubois *et. al*., (1956) method.

14.2.7. Measurement of soil physical and chemical properties

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). Soil organic C was determined by chromic acid digestion and spectrophotometric analysis (Heanes, 1984). 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). 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). 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). 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). The soil calcium and magnesium content were determined following the method of Tandon (1993). Manganese was estimated by spectrometrically (Jackson, 1973; Chopra *et. al.,* 1991). The Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979).

14.2.8. Analysis of diseases data

For a period of two consecutive years in each replication 10 mulberry plants were taken into consideration for the respective diseases. The 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 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:

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

14.2.9. Statistical analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK). 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, nutrient uptake and diseases data were statistically analyzed and mean values were evaluated by Duncan Multiple Range Test (DMRT) through using the Statistic-10 software. In case of soil the mean values of post harvest soil properties were recorded for this study.

14.3. RESULTS

14.3.1 Effect of potassium on post harvest soil properties of mulberry garden

The average physicochemical properties of the post harvest experimental soil are presented in the Table 14.1. The average soil pH, OM, N, P, K, Zn, Ca and Mg for (0-5) year's plant were 7.6 to 8.1, 1.23 to 1.63%, 0.06 to 0.09%, 9.9 to 13.3 micro g/g, 0.13 to 0.22 meq/100 g soil, 0.49 to 0.57 micro g/g, 17.18 to 17.28 meq/100 g soil and 227 to 2.53 meq/100 g soil, respectively. On the other hand, the average soil pH, OM, N, P, K, Zn, Ca and Mg for (6-10) year's plant were 7.5 to 8.1, 1.25 to 1.65%, 0.06 to 0.10%, 9.9 to 13.5 micro g/g, 0.13 to 0.22 meq/100 g soil, 0.50 to 0.59 micro g/g, 17.17 to 17.29 meq/100 g soil and 2.29 to 2.51 meq/100 g soil respectively.

Table 14.1. Effect of different potassium levels on physicochemical properties of the post harvest soil

Treatments	Soil pH		OM (%)		N (%)		P (micro g/g)		K (meq/100 g soil)		Zn (micro g/g)		Ca (meq/100 g soil)		Mg (meq/100 g soil)	
	Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	7.6	7.5	1.23	1.25	0.06	0.07	9.9	10.1	0.13	0.13	0.49	0.5	17.18	17.17	2.27	2.29
T_1	7.7	7.8	1.33	1.36	0.07	0.06	10.9	11.1	0.14	0.15	0.51	0.53	17.19	17.2	2.37	2.39
T_2	7.6	7.7	1.44	1.45	0.07	0.07	11.1	11.3	0.16	0.16	0.49	0.5	17.19	17.21	2.41	2.42
T_3	7.9	7.9	1.53	1.55	0.07	0.08	12.7	12.9	0.19	0.20	0.53	0.54	17.23	17.23	2.43	2.43
T_4	8.0	7.9	1.63	1.65	0.09	0.10	13.3	13.5	0.22	0,23	0.57	0.59	17.26	17.29	2.45	2.47
T_5	8.1	8.1	1.45	1.47	0.08	0.09	13.1	13.2	0.21	0.22	0.56	0.58	17.28	17.29	2.53	2.51

Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year.

14.3.2 Growth response of mulberry plant due to ages of plant and elevated potassium levels

Total branches number per plant of mulberry was highly significant ($P \leq 0.001$) by the levels of potassium. But the similar trend was observed between the younger (0-5 year's ages) and older (6-10 year's ages) mulberry plant. The more marked increasing trend was found for the T_5 treatment and older mulberry plant. However, the recorded total branches number was 10.33, 10.56, 10.61, 10.83, 13.43 and 15.43 in younger mulberry plant for the treatments of T_0, T_1, T_2, T_3, T_4 and T_5 respectively. Conversely, in case of older mulberry plant total branches number was 10.48, 10.67, 10.77, 10.87, 13.89 and 15.89 respectively for the same treatments (Figure 14.1; Table 14.2).

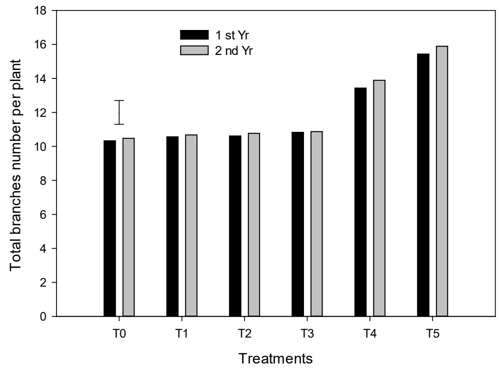

Figure 14.1: Total branches number per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

The highly significant ($P \leq 0.001$) trend was found among the potassium treatments, ages of mulberry plant and their interactive effect irrespective to total branches height per plant. The T_5 treatment and older mulberry plant showed the more remarkable increasing trendy. However, the total branches height was 819.79, 891.67, 933.77, 987.87, 1211.57 and 1313.63 cm in younger mulberry plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, in older mulberry plant total branch heights were 877.98, 943.37, 949.91, 1013.43, 1216.67 and 1332.57 cm respectively for the similar treatments (Figure 14.2; Table 14.2).

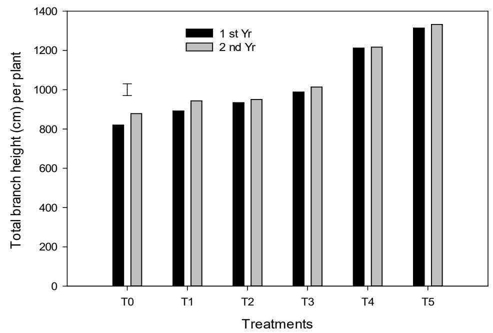

Figure 14.2. Total branch heights per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

The node per meter was significantly ($P \leq 0.01$) differed among the treatments. The more marked increasing trend was recorded for the T_5 treatment. However, between the two types of mulberry plant recorded node per meter were 20.41, 20.57, 20.61, 20.66, 21.07 and 22.35 for the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively in younger mulberry plant. On the other hand, in case of older mulberry plant node per meter were 20.47, 20.59, 20.64, 20.67, 21.89 and 23.31 respectively for the same treatments (Figure 14.3; Table 14.2).

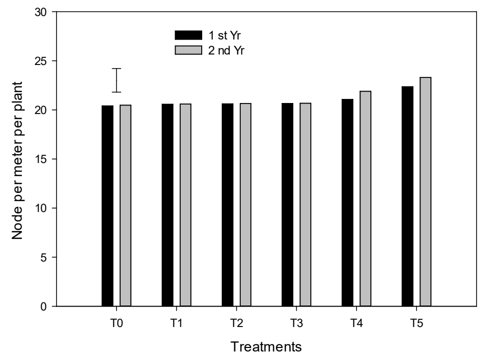

Figure 14.3. Node per meter in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Table 14.2. Effect of different levels of nitrogen on mulberry plant production

Factors	Total branch numbers/plant	Total branch heights/ plant (cm)	Node /meter/ plant	Total shoot weights/plant (g)	10 leaf areas/ plant (cm^2)	10 leaf weights/plant (g)	Toal leaf weights /plant (g)	Total leaf yield/ ha/yr (MT)
Treatments	***	***	**	***	***	***	****	***
Plant age	n.s.	***	n.s.	***	***	n.s.	***	***
Plant age × Treatment	n.s.	***	n.s.	***	***	n.s.	***	**

Where, n.s., * ** and *** represent not significant, probability of >0.05, ≤0.05, ≤0.01 and ≤0.001. Values were means of three replicates.

The highly significant ($P \leq 0.001$) trend was found among the treatments, ages of plant and their interactive effect. The older mulberry plant and the T_5 treatment showed the more remarkable increasing trendy. However, between the two types of mulberry plant the recorded total shoot weights were 387.98, 447.67, 453.76, 479.89, 551.77 and 584.37 g in younger mulberry plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments, respectively. Conversely, in case of older mulberry plant total shoot weights were 415.75, 468.97, 477.73, 481.67, 563.67 and 590.63 g respectively for the similar treatments (Figure 14.4; Table 14.2).

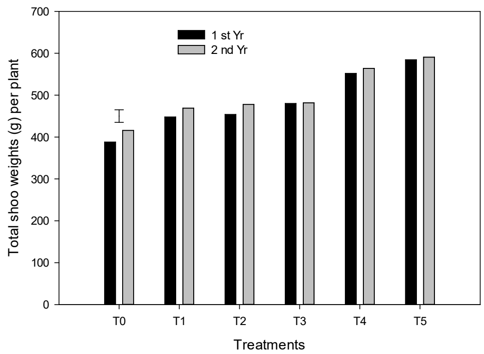

Figure 14.4. Total shoots weights per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

The 10 leaf areas of older mulberry plant was highly significantly ($P \leq 0.001$) by the treatments and their interactive effect. However, the recorded 10 leaf areas were 457.79, 513.37, 519.67, 527.63, 577.63 and 591.47 cm^2 for younger mulberry plant due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Correspondingly, the 10 leaf areas for older mulberry plant were 489.79, 527.79, 531.61, 537.77, 583.64 and 597.89 cm^2 for the same treatments (Figure 14.5; Table 14.2).

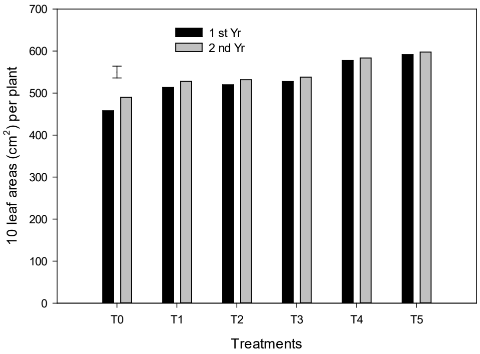

Figure 14.5. 10 leaf areas per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

The highly significant ($P \leq 0.001$) trend was observed among the treatments. The more marked increasing trend was found in older mulberry plant for the T_5 treatment. The recorded 10 leaf weights were 22.89, 23.31, 23.53, 24.33, 35.63 and 45.13 gm in younger mulberry plant for the T_0, T_1, T_2, T_3, T_4 and T_5 treatments, respectively. Conversely, the 10 leaf weights for older mulberry plant were 22.97, 23.67, 23.87, 24.39, 38.18 and 45.37 gm respectively for the similar treatments (Figure 14.6; Table 14.2).

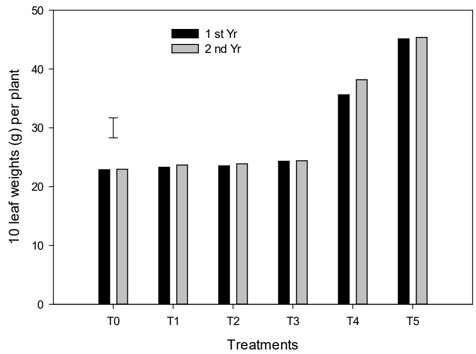

Figure 14.6. 10 leaf weights per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

The total leaf weights per plant was highly significant ($P \leq 0.001$) by the treatments, ages of mulberry plant and their interactive effect. The older mulberry plant and the T_5 treatment showed the more increasing trendy. However, the total leaf weights for younger mulberry plant were 518.54, 538.13, 553.96, 566.46, 773.54 and 919.38 g due to application of T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. On the hand, in case of older mulberry plant total leaf weights were 524.38, 560.21, 562.08, 570.21, 852.71 and 981.25 g respectively for the same treatments application (Figure 14.7; Table 14.2).

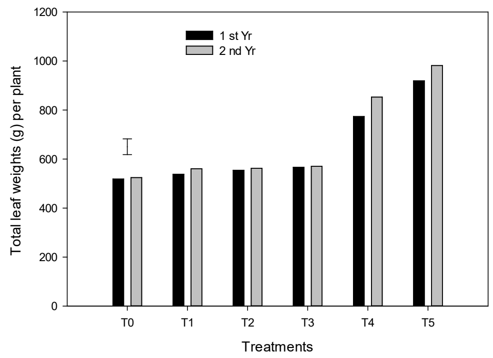

Figure 14.7. Total leaf weights per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

The highly significant ($P \leq 0.001$) trend was found among the treatments and the older mulberry plant. The more increasing trend was observed in older mulberry plant due to application of T_5 treatment. However, the recorded total leaf yields for younger mulberry plant were 24.89, 25.83, 26.59, 27.19, 37.13 and 44.13 MT/ha/yr for the treatments of T_0, T_1, T_2, T_3, T_4 and T_5 treatments, respectively. Conversely, in case of older mulberry plant total leaf yields were 25.17, 26.89, 26.98, 27.37, 40.93 and 47.10 MT/ha/yr respectively for the similar treatments (Figure 14.8; Table 14.2).

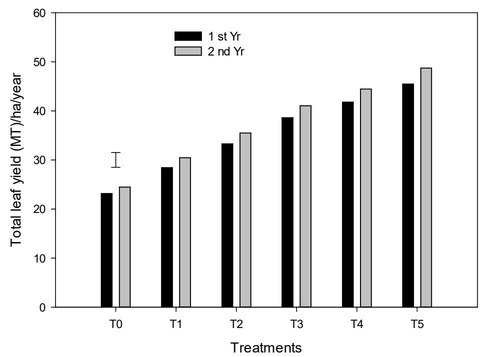

Figure 14.8. Total leaf yield per hectare per year in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/year, T_1 = 30 kg K/ha/year, T_2 = 60 kg K/ha/year, T_3 = 90 kg K/ha/year, T_4 = 120 kg K/ha/year and T_5 = 150 kg K/ha/year. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

14.3.3 Effect of ages and potassium fertilizer on leaf quality of mulberry plant

The similar trend was found among the treatments and ages of mulberry plant for the moisture (%) of mulberry plant except T_5 and T_4 treatments. However, between the younger (0-5 year's ages) and older (6-10 year's ages) mulberry plant the maximum moisture percentage was 73.97 in the leaf of older plant due to application of T_5 ($N_{300}P_{150}K_{150}$ kg ha^{-1} $year^{-1}$) treatment. Conversely, the minimum moisture percentage was 69.77 recorded in the leaf of younger mulberry plant for the treatment of T_0 ($N_{300}P_{150}K_0$kg ha^{-1}year^{-1}) (Table 14.3).

Table 14.3. Effect of different level of potassium and ages of mulberry plant on Bio-chemical constitutions of mulberry leaf

Treatments	Moisture (%)		Total Mineral (%)		Crude Protein (%)		Soluble Carbohydrate (%)		Total Sugar (%)	
	Plant age		Plant age		Plant age		Plant age		Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	69.77b	69.86b	7.97d	8.09d	15.62d	15.67d	7.31b	7.37b	3.76c	3.85bc
T_1	69.93b	69.99b	8.15d	8.39cd	15.72d	15.97d	7.46b	7.67b	3.91bc	3.99bc
T_2	69.96b	70.03b	8.29cd	8.47cd	15.89d	16.04d	7.53b	7.73b	3.96bc	4.07bc
T_3	70.11b	70.17b	8.89bcd	8.97bcd	16.09d	16.15cd	7.99b	8.09b	4.27abc	4.47abc
T_4	72.55a	72.89a	9.37bcd	9.97bc	17.79bc	18.53ab	8.16b	8.77ab	5.29abc	5.49ab
T_5	72.77a	73.97a	10.57ab	11.87a	18.77ab	19.99a	8.77ab	9.97a	5.53ab	5.93a

Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Means with the same letter are not significantly different at 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The total mineral contains of mulberry leaf was statistically differed among the treatments. But the similar trend was found between the two types of mulberry plant. However, the maximum total mineral was 11.87% in the leaf of older mulberry plant due to application of T_5 treatment. On the contrary, the minimum total mineral was 7.97% in the leaf of younger mulberry plant for the T_0 treatment (Table 14.3).

The crude protein contains of mulberry leaf was significantly differed by the K treatments. But, there was no significant difference was found between the two types of mulberry plant. However, the maximum crude protein was 19.99% in the leaf of 6-10 year's ages of older mulberry plant for the treatment of T_5 ($N_{300}P_{150}K_{150}$ kg ha^{-1} year^{-1}). Conversely, the minimum crude protein 15.62 % in the leaf of (5-10) year's ages of younger mulberry plant due to application of T_0 ($N_{300}P_{150}$kg ha^{-1}year^{-1}) treatment (Table 14.3).

The similar trend was found both for the treatments and the two types of mulberry plant in respect of soluble carbohydrate content in mulberry leaf. However, between the two types of mulberry plant the maximum soluble carbohydrate was 9.97% in the leaf of older mulberry plant also for the same (T_5) treatment. Correspondingly, the minimum soluble carbohydrate was 7.31% in the leaf of younger mulberry plant for the T_0 ($N_{300}P_{150}$kg ha^{-1}year^{-1}) treatment (Table 14.3).

The total sugar contains of mulberry leaf was statistically differed among the K fertilizer treatments. But the similar trend was observed between the two types of mulberry plant. However, the recorded maximum total sugar was 5.93% in the leaf of (6-10) year's ages of older mulberry plant due to application of T_5 ($N_{300}P_{150}K_{150}$ kg ha^{-1} year^{-1}) treatment. Conversely, the minimum total sugar was 3.76% in the leaf of

(0-5) year's ages of younger mulberry plant for the treatment of T_0 ($N_{300}P_{150}$kg ha^{-1} $year^{-1}$) (Table 14.3).

14.3.4 Effect of potassium and ages of plant on diseases incidence of mulberry

The incidence of foliar diseases in mulberry plant was significantly differed by the different levels of potassium treatments. But the similar trend was observed between the older and younger mulberry plant. However, in case of powdery mildew disease the lower incidence percentage was 6.10 in leaf of older mulberry plant due to application of T_5 treatment. On the contrary, the higher incidence of powdery mildew was 11.22 % in the leaf of younger mulberry plant for the T_0 treatment (Table 14.4).

Similarly, the lower incidence of leaf spot disease was 6.83 % in the leaf of older (6-10 year's ages) mulberry plant for the T_5 treatment. Conversely, the higher incidence of leaf spot disease was 10.95% in the leaf of younger plant due to application of T_0 treatment (Table 14.4).

Correspondingly, the minimum incidence percentage of tukra disease was 6.21% in the leaf of older mulberry plant due to application of T_5 treatment. On the contrary, the maximum incidence percentage of tukra disease was 9.83% in the leaf of younger plant for the treatment of T_0 (Table 14.4).

Table 14.4. Effect of different phosphorus levels on means diseases infestation (%) in mulberry plant

Treatments	Powdery mildew (%) Plant age		Leaf spot (%) Plant age		Tukra (%) Plant age	
	(0-5)	(6-10)	(0-5)	(6-10)	(0-5)	(6-10)
T_0	11.22a	10.97a	10.95a	10.87a	9.83a	9.57a
T_1	10.83a	10.77a	10.83a	10.79a	9.75a	9.47a
T_2	10.76a	10.67a	10.71a	10.65a	9.35a	9.27a
T_3	10.58a	10.51a	10.59ab	10.49abc	9.23a	9.17a
T_4	8.31b	7.77bc	8.91bc	8.85c	8.33ab	7.31bc
T_5	6.99bc	6.1c	6.89d	6.83d	6.93bc	6.21c

Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Means with the same letter are not significantly different at 5% level by DMRT. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

14.4. DISCUSSIONS

14.4.1. Impact of elevated potassium on mulberry leaf yield and quality

The elevated potassium had a significant effect on the leaf yield and leaf quality of mulberry plant. Findings showed that among the six levels of K, the application of 150 K/ha/yr with BSRTI recommended basal dose of 300 kg N/ha/yr and 150 kg P/ha/yr gave the maximum total branches number, total branch heights, nodes per meter, total shoot weights, 10 leaf areas, 10 leaf weights and total leaf weights per plant. The maximum leaf yield was 47.10 MT/ha/yr also for the T_5 ($N_{300}P_{150}K_{150}$ kg ha^{-1} $year^{-1}$) treatment. This leaf yield was 87.13 % greater than the maximum leaf yield of control (T_0) treatment. The elevated doses of K also improved the leaves quality of mulberry plant. The leaf qualities of mulberry plant viz: moisture, total mineral, crude protein, soluble carbohydrate and total sugar % were maximum for the same (T_5) treatment. These leaf qualities were 5.88, 46.72, 27.57, 35.28 and 54.03 percentage respectively superior over the maximum leaf qualities of control (T_0) treatment. These finding was similar with the previous findings of Miah (1989). He found that the application of 150 kg K/ha/yr with 400 kg N/ha/yr and 200 kg P/ha/yr in four split doses increased the mulberry leaf yield by 77.92% over the control treatment with the progressive increase of NPK fertilizers.

Furthermore, the leaf constituents viz: moisture, crude protein, total sugar, reducing sugar, starch and soluble carbohydrate contains were also tended to be increased under same condition. Similarly, Paul *et. al.,* (2009) found that the application of 125 kg K/ha/yr with 400 kg N/ha/yr and 200 kg P/ha/yr in four split doses gave the higher mulberry leaf yield with maximum moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral. Likewise, Jianrong *et. al*., (1995) found that among the three levels of K viz: 45, 90 and 135 kg K_2O /ha/yr the maximum number of branches per plant, height of branches, leaf area and dry weight of leaves were for the application of 135 kg K_2O /ha/yr as well as the total fresh leaf weight increased by 13.1 and 33.4% respectively for 45 and 135 kg K_2O /ha/yr compared to the unfertilized check plot. They found that 135 kg K_2O/ha may not be high enough and additional rates should be tested to determine the maximum economic yield for mulberry leaves. They also found that in the K_{90} and K_{135} treatments, leaf protein content was 2.7 and 3.0 percent higher compared to the K_0 treatment.

Shankar *et. al.,* (1999) found the significant effect of K on mulberry leaf yield and quality. They were applied three levels of K at 120, 160 and 200 kg K_2O/ha/yr with two levels of N at 300 and 400 kg K_2O/ha/yr in five split doses. They get the higher leaf yield with total chlorophyll and moister added to overall leaf quality for the treatment of N and K at 400-200 kg N-k_2O/ha/yr in five splits doses. This finding was also more or less similar with this experimental finding. The speculation was that soil applied 150 kg K/ha/yr with BSRTI recommended 300 kg N/ha/yr and 150 kg P/ha/yr in four split doses was comparatively optimum and available. As a result the K uptake by the mulberry plant was higher that could be improved the metabolic functions related to N and P uptake, enzyme activities, water relations, energy transfer, protein, starch and other related inputs synthesis. Resulting, the growth, leaf yield and leaf quality was comparatively higher than the other treatments. This speculation was lined with the previous findings of Subbaswamy *et. al*., (2001). They speculated that the growth and yield of mulberry plant might be increased due to the involvement of potassium in metabolic functions related to enzyme activation, water relations, energy transformations, translocation of a assimilates, nitrogen metabolism, protein and starch synthesis.

14.4.2. Mulberry plant age variation irrespective to leaf yield and quality

The ages variation had a positive impact on the leaf yield and quality of mulberry plant. Six levels of K viz: 0 kg K/ha/yr, 30 kg K/ha/yr, 60 kg K/ha/yr, 90 kg K/ha/yr, 120 kg K/ha/yr and 150 kg K/ha/yr respectively were applied in soil with BSRTI recommended 300 kg N/ha/yr and 150 kg P/ha/yr in four split doses on (0-5) and (6-10) year's ages of mulberry plant. Between the (0-5) and (6-10) year's ages of mulberry plant, the growth and yield contributing characters viz:, total branches number, total branch height, nodes per meter, total shoot weight, 10 leaf areas, 10 leaf weights and total leaf weights per plant were grater in (6-10) year's mulberry plant than the (0-5) year's plant. The maximum leaf yield was 47.10 MT/ha/yr for the (6-10) year's ages of older mulberry plant. The leaf yield was 6.73% higher in (6-10) year's aged older plant than the maximum leaf yield of (0-5) year's aged plant. The average maximum moisture, total mineral, crude protein, total sugar, soluble carbohydrate and crude protein percentage were 73.97, 11.87, 19.99, 5.93 and 9.97 percentage respectively for the older (6-10 year's ages) plant. The leaf qualities of older mulberry plant viz: moisture, total mineral, crude protein, total sugar, soluble carbohydrate and crude protein percentage were 6.02, 48.93, 27.98, 57.71 and 36.39 percentage respectively higher than the minimum leaf qualities of younger mulberry plant.

The impact of ages of mulberry plant on growth, leaf yield and leaf quality was a totally new idea, there were no such type study was conducted for the mulberry plant previously. But, a study marigold (*Tagetes erecta* Big. Inca Gold) that was conducted by Deborah *et. al.,* (1990). They were treated the marigold seedlings of 30, 35, 40, 45 and 50 days old in 500 ml plastic pots containing a 1 peat: 1 per liter (v/v) with K solution. They found that the K absorbed by the 30, 35, 40, 45 and 50 days old seedlings were 0.61, 3.20, 3.60, 10.00 and 12.80 mg respectively. However, they did not express their speculation for maximum K uptake by the older seedlings than the younger seedlings. This could be due to the higher ages of (6-10) year's mulberry plant, the root development and establishment was good as well as the root system was deeper, larger, high values of root length density and root diameter. That conversely might be helps to engross the maximum K uptake from the soil as well as contributed the rapid and maximum photosynthesis. In terms, it enhanced the physiological activity, N and P use efficiency by the (6-10) year's ages of older mulberry plant. As a result, the total branches number, total branch heights, nodes per meter, 10 leaf areas, 10 leaf weights and total leaf weights per plant as well as leaf yield per hectare per year were comparatively improved in older (6-10 year's) mulberry plant than the younger (0-5 year's) mulberry plant.

Similarly, the leaf qualities were also improved in older mulberry plant as compared to the younger mulberry plant due to better growth and establishment might be maximum K uptake by the deeper and larger root system of older mulberry plant. This speculation was more or less lined with the previous findings of Almeida *et. al.,* (2016). They found that in case of rice the highest root length density, root diameter, dry matter and shoot dry matter increased linearly with the increasing K rates. Similarly, in case of maize (*Zea mays* L.), Du *et. al.,* (2017) found that the total root length, root surface area, the root diameter and root volume of root system were significantly decreased by K deficiency. Correspondingly, Sattelmacher *et. al,.* (1993) also reported that root system is the main organ for nutrient uptake. In addition, ideal root morphology and activity has a great significance to nutrient absorption from soil. That plays an important role in the growth and development of crops which was strongly supports my speculation.

14.4.3. Interactive effect of elevated potassium and ages on diseases incidences of mulberry plant

The interactive effect of elevated potassium and ages of mulberry plant had a great impact on reduced the foliar diseases of mulberry plant. Findings showed that among the six levels of potassium and two aged types of mulberry plant, the lower incidence of powdery mildew was 6.10% in older (6-10 year's ages) mulberry plant due to application of T_5 treatment. On the other hand the higher incidence of powdery mildew was 11.22% in younger (0-5 year's ages) plant for the T_0 treatment. However, the powdery mildew incidence percentage of older mulberry plant was 45.63% reduced compared to the younger plant for the T_5 treatment over the T_0 treatment. Similar type of study was not available for interactive effect of elevated potassium and plant ages suppress on foliar disease of mulberry plant. But, a study was conducted by Reuveni *et. al.,* (1996). They found that the application of K in the form of mono potassium phosphate (MKP) successfully control the powdery mildew of apples, vineyards, peaches, nectarines, greenhouse cucumbers, roses, melons and mangoes. This finding was more of less similar with this experimental finding. Similarly, the minimum incidence of leaf spot disease was 6.83% in older (6-10 year's ages) mulberry plant also for the T_5 treated mulberry plant.

Conversely, the maximum incidence of leaf spot was 10.95% in younger (0-5 year's ages) plant due to application of T_0 treatment. However, the leaf spot incidence of younger mulberry plant was 37.63% higher than the older mulberry plant due to the T_5 treatment followed by the T_0 treatment. Such type of finding in mulberry crop was not available. But, a study was conducted by Glen Harris (1997) in cotton crop which was lined with this experimental finding. They found that the leaf spot of cotton which creates small brown lesions caused by the fungal organisms *Cercospora* and *Alternaria* in addition to *Stemphylium* was actually secondary to the primary problem of K deficiency. Correspondingly, the lower incidence of tukra disease was 6.21% in older mulberry plant for the same (T_5) treatment. Conversely, the higher incidence of tukra was 9.83% for younger plant due to T_0 treatment. The tukra incidence was 36.83 % lower in older plant as compared to the younger plant due to T_5 treatment followed by the T_0 treatment. Though, the similar trend was observed for the foliar diseases incidences percentage between the older and younger mulberry plant. But, the overall incidences percentages of all the three diseases were comparatively lower in (6-10 year's) ages of older mulberry plant than the (0-5 year's) ages of younger plant. This study was mostly new idea for mulberry crop. But earlier a study was conducted by the Gao *et. al*., (2016), which was more or less similar with this experimental finding. They investigated the impact of different growth stages of potato for infestation of Zebra Chip diseases caused by *B. cockerelli.* They were also exposed separately at different growth stages (4, 5 and 7 weeks after germination) of potato to four different *B. cockerelli* densities (0, 5, 20 and 40 psyllids per cage) in field cages and monitored the Zebra chip symptoms. Their observation was the *B. cockerelli* infestation and Zebra Chip expression was more susceptible in younger plants at 4-week growth stage after germination than the older plants.

However, the potassium absorbed by the T_5 treated 6-10 year's ages of older mulberry plant might be adequate followed by the other treatments and 0-5 year's ages of younger mulberry plant due to the maximum K levels of T_5 treatment and well developed larger as well as deeper root system of older plant. In terms, the phenols contained of T_5 treated older mulberry plant was increased than the younger plants. That beneficial role of older plant could be played resistance against the fungal pathogen of mulberry. In addition, the higher potassium contains of T_5 treated older mulberry plant might be affected plant morphology, hardening the tissues with resulting improvement in resistance to disease penetration. Furthermore, K may have a direct antifungal impact for break up and defect of conidia and mycelium of fungal diseases. Thus, the incidence of powdery mildew and leaf spot caused by fungus as well as tukra disease caused by mealy bug pest was comparatively reduction in T_5 treated 6-10 year's ages older mulberry plant followed by the other K treatments treated 0-5 year's ages of younger plant. The above speculation was lined with the previous assumptions of Pervez *et. al,.* (2007). They mentioned that the adequate potassium nutrition enhanced the phenols contain by the plant. In addition, potassium affects plant morphology and physiology. That can play a beneficial role in plant resistance to disease penetration as well as K reduced the incidence of fungal diseases.

14.5. CONCLUSIONS

This study demonstrated that the application of 150 kg K ha $^{-1}$ year $^{-1}$ in soil with BSRTI recommended basal dose of N and P is a practical fertilizer management strategy for mulberry cultivation. This approach improves efficient, balanced and available uptake of essential macro and micro nutrients as well as K by the mulberry plant. Resulting, its improved nutrients uptake, plant growth and development of mulberry plant in respect of leaf yield, leaf quality and suppression of foliar diseases.

This study concluded that both the (0-5) and (6-10) year's mulberry plant responded to the application of 150 kg ha $^{-1}$ year $^{-1}$ of potassium fertilizer (MoP) showed better performances in respect of yield contributing characters, leaf yield and leaf quality compared to other potassium levels. However, among the six levels of potassium the 150 kg K/ha/yr showed better performances for reducing the infestation of powdery mildew, leaf spot and tukra diseases respectively. In addition, (0-5) year's mulberry plant was more susceptible to powdery mildew, leaf spot and tukra diseases compared to the (6-10) year's mulberry plant. Finally, this study revealted that 150 kg K per hectare per year in combination with BSRTI recommended basal dose of nitrogen and phosphorus can be recommended to the sericulture farmers in Bangladesh to obtain a quality and quantity mulberry leaf yield with optimum reduction of foliar diseases.

Chapter 15

General Discussion

Chapter 15

General Discussion

15.1 GENERAL DISCUSSION

The focus of this thesis has been to quantify advanced fertilizer management practices for mulberry leaf yield and quality as well as suppression of foliar diseases of mulberry plant. The key findings have been presented in earlier experimental chapters (Chapter 4 to Chapter 14). Among them control, basal, liquid fertilizer, rice husk biochar, mineral enrich biochar, Seri-waste compost, cow dung compost, vermi-compost and farm yard manure were used most of the experimental chapters (Chapter 4 to Chapter 9). The foliar diseases incidences irrespective to mulberry genotypes and cropping seasons were observed only in several experimental chapters (Chapter 10 to Chapter 11). The elevated doses of nitrogen, phosphorus and potassium fertilizers were used in rest of the chapters (Chapter 12 to Chapter 14). The number of additional issues relating to these experiments will be discussed in this chapter.

15.2 SINGLE EFFECT OF VARIOUS FERTILIZER MANAGEMENT ON GROWTH AND LEAF YIELD OF MULBERRY PLANT

Control, liquid fertilizer, rice husk biochar, mineral enrich biochar, Seri-waste compost, cow dung compost, vermi-compost, farm yard manure, were used only in several experimental chapters (Chapter 4 to Chapter 9). Impact of single use only these fertilizer managements on mulberry plant productivity were discussed as below:

Total branch number per plant of mulberry was highly significant ($P \geq 0.001$) by the fertilizers treatments of mulberry plant. The more marked increasing trend was found for the Seri waste Compost (SW) treatment followed by the other fertilizer managements. However, the recorded total branch number was 15.88, 14.51, 14.23, 13.25, 12.69, 12.68, 12.66 and 10.69 for the Seri waste Compost (SW), Cow dung Compost (CD), Vermi-compost (VC), Mineral enriched Biochar (MB), Farm Yard Manure (FM), Rice husk Biochar (RB), Liquid Fertilizer (LF) and Control (C) treatments respectively (Figure 15.1; Table 15.1).

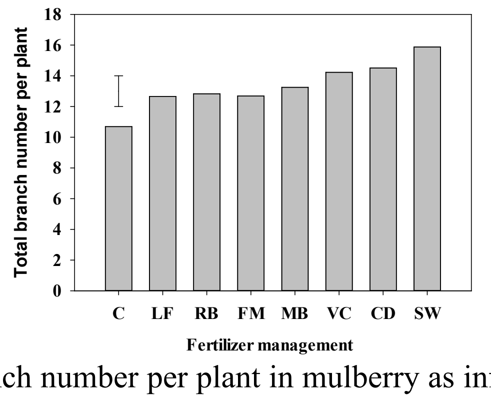

Figure 15.1. Total branch number per plant in mulberry as influenced by the fertilizer treatments. Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri-waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi-compost/ha/year and FM= 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

The highly significant ($P \geq 0.001$) trend was found among the fertilizer treatments in respect of node per meter of mulberry. The more remarkable increasing trendy was observed for the SW treatment. However, the obtained node per meter was 24.47, 22.18, 21.92, 21.83, 21.82, 21.76, 20.60 and 17.62 due to application of SW, CD, VC, MB, FM, RB, LF and C treatments respectively (Figure 15.2; Table 15.1).

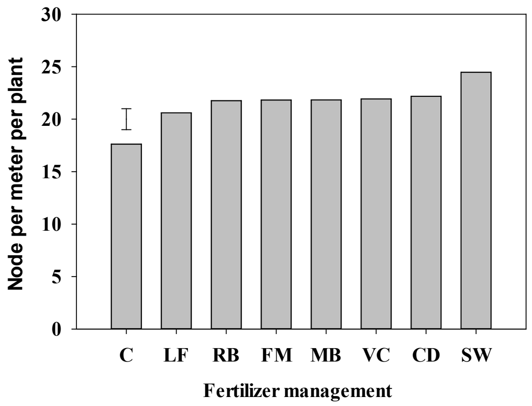

Figure 15.2. Node per meter per plant in mulberry as influenced by the fertilizer treatments. Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri-waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi-compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD ($P = 0.05$) different fertilizer treatments.

Table 15.1. Level of significance for the main effect on fertilizer treatments

Source of variation	Total branch number per plant	Node per meter per plant	10 leaf areas (cm) per plant	10 leaf weights (g) per plant	Total leaf yield/ ha/yr (MT)
Treatments	***	***	***	***	***

Note. Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

The average 10 leaf areas of mulberry plant was highly significant ($P \geq 0.001$) by the various fertilizers management. However, the recorded 10 leaf areas were 595.93, 591.77, 575.97, 562.60, 557.77, 539.95, 538.29 and 431.43 cm^2 for the treatments of SW, CD, VC, MB, FM, RB, LF and C treatments respectively (Figure 15.3; Table 15.1).

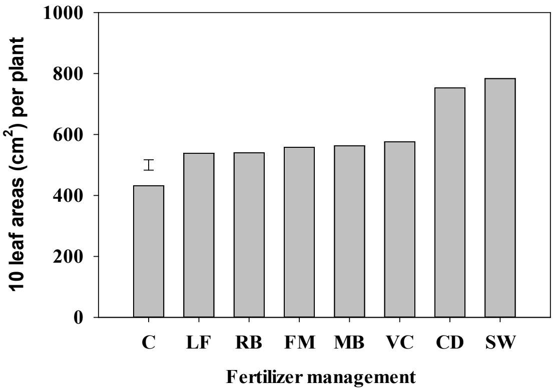

Figure 15.3. 10 leaf areas per plant in mulberry as influenced by the fertilizer treatments. Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri-waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi-compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

The average 10 leaf weights of mulberry plant was highly significant ($P \geq 0.001$) due to the various fertilizer management. The more marked increasing trendy was recorded for the SW treatment. The noted 10 leaf weights were 40.80, 38.84, 31.22, 29.61, 28.25, 27.61, 26.47 and 20.16 g due to treated of SW, CD, VC, MB, FM, RB, LF and C treatments respectively (Figure 15.4; Table 15.1).

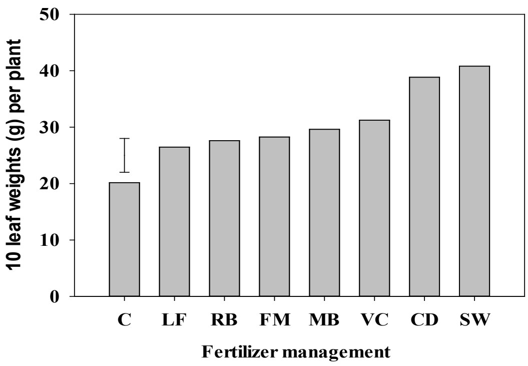

Figure 15.4. 10 leaf weight per plant in mulberry as influenced by the fertilizer treatments. Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri-waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi-compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

The leaf yield of mulberry plant was highly significant ($P \geq 0.001$) among the fertilizer treatments. The more significant increasing trend was found for the SW treatment. However, the recorded average leaf yield was 42.19, 40.38, 31.26, 30.95, 30.5, 29.71, 28.77 and 24.03 MT for the SW, CD, VC, MB, FM, RB, LF and C treatments respectively (Figure 15.5; Table 15.1).

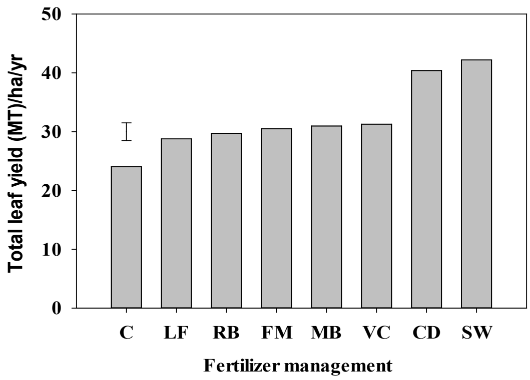

Figure 15.5. Total leaf yield per hectare per year in mulberry as influenced by the fertilizer treatments. Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri-waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi-compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

The above findings showed that the growth and yield parameters of mulberry plant viz: total branch number, node per meter, 10 leaf areas, 10 leaf weight per plant and total leaf yield per hectare per year were maximum for the application of 10 MT Seri-waste compost/ha/year (SW) followed by the Cow dung Compost (CD), Vermi-compost (VC), Mineral enriched Biochar (MB), Farm Yard Manure (FM), Rice husk Biochar (RB), Liquid Fertilizer (LF) and Control (C) treatments respectively. The total branch number, node per meter, 10 leaf areas and 10 leaf weight per plant were 48.55, 38.88, 81.56 and 102.38 percent respectively greater in SW treated mulberry plant over the control treated plot. The recorded maximum leaf yield was 42.19 MT and the 2nd highest leaf yield was 40.38 MT for the application of 10 MT Cow dung compost /ha/year followed by the VC (31.26 MT), MB (30.95 MT), FM (30.51 MT), RB (29.71 MT), LF (28.77 MT) and C (24.03 MT) treatments respectively.

The total leaf yield of SW compost treated mulberry plot was 4.48% and 34.96% respectively greater than the application of 10 MT/ha/year CD and 5 MT/ha/year vermi-compost treated mulberry plot respectively. However, the leaf yield of SW treated mulberry plant was 75.57 % grater over the control treatment. No any study was found on utilization of seri-waste for mulberry plant production. But, Sangeetha *et. al.,* (2012) found that the utilization of silk-worm litter-pupal waste as compost after 60 days of pruning of mulberry garden the average maximum plant height was 153.8 cm and average leaves number / plant was 140. Similarly, Samuthiravelu *et. al.,* (2012) found that the foliar application of 0.2 % Seriboost prepared by the sericulture wastes increased the number of shoots, total length of shoot, number of leaves per plant, biomas kg/ha/crop and leaf yield/kg/ha/crop of mulberry plant was greater over the control treatment.

In this study the maximum total branch number, node per meter, 10 leaf areas, 10 leaf weight per plant and total leaf yield per hectare per year were recorded for the Seri-waste Compost treated mulberry plant could be due to the superior nutrient status of applied Seri waste Compost compared to the other fertilizer treatments. Because, the applied Seri waste compost generated by the silkworm pupae, excreta, liter, mulberry leafs, twigs etc contain maximum amount of protein, fat, nitrogen, phosphorus, potassium, sodium, carbon and other micronutrients which may improved the soil nutrient status in term the balanced growth and development of mulberry plant was ensured as well as the above mentioned parameters were increased in SW treated mulberry plant compared to the other treatments. This concept was similar with the previous findings of Krishnaswamy *et. al.,* (1973) who reported that silkworm pupae are very rich in protein and fat.

Likewise, Ramakrishna (2001) also reported that the silkworm excreta and silkworm litter revealed the higher composition of nitrogen, phosphorus, potassium, sodium and carbon when compared to cow dung or FYM that why, it is used as an organic fertilizer. Similarly, Das *et. al.,* (1997) reported that has a tremendous manorial value and 12-15 million tons of Seri-waste compost contain of nitrogen (280-300 kg), phosphorus (90-100 kg) and potassium (150-200 kg) as well as micronutrients like iron, zinc, copper etc which is lined with the above mentioned assumption.

15.3 COMBINED EFFECT OF VARIOUS FERTILIZER MANAGEMENT WITH BSRTI RECOMMENDED BASAL DOSE OF NPK ON GROWTH AND LEAF YIELD OF MULBERRY PLANT

Basal along with liquid fertilizer, rice husk biochar, mineral enrich biochar, seri-waste compost, cow dung compost, vermi-compost and farm yard manure were used in several experimental chapters (Chapter 4 to Chapter 9). Combined impact of these fertilizers managements with basal on mulberry plant productivity were discussed as below:

The total branch number per plant was highly significant ($P \geq 0.001$) by the combined fertilizer management. The more marked increasing trend was found for the combined application of B+SW treatment. However, the recorded total branch number was 12.11, 13.96, 14.46, 14.52, 14.78, 15.78, 17.17 and 18.12 due to application of B, B+LF, B+RB, B+FM, B+MB, B+VC, B+CD and B+SW treatments respectively (Figure 15.6; Table 15.2).

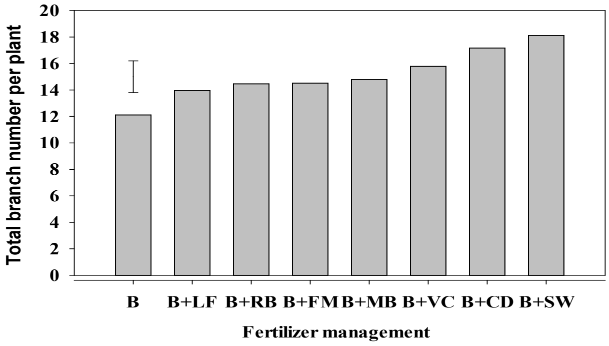

Figure 15.6. Total branch number per plant in mulberry as influenced by the fertilizer treatments. Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

Table 15.2. Level of significance for the main and interaction effect on fertilizer treatments and cropping years

Source of variation	Total branch number per plant	Node per meter per plant	10 leaf areas (cm^2) per plant	10 leaf weights (g) per plant	Total leaf yield/ ha/yr (MT)
Treatments	***	***	***	***	***

Note. Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

The highly significant ($P \geq 0.001$) trend was observed among the fertilizer treatments in respect of average node per meter of mulberry. However, the noted node per meter was 20.45, 22.10, 22.25, 23.24, 23.97, 24.25, 24.83 and 26.57 for the treatments of B, B+LF, B+RB, B+FM, B+MB, B+VC, B+CD and B+SW respectively (Figure 15.7; Table 15.2).

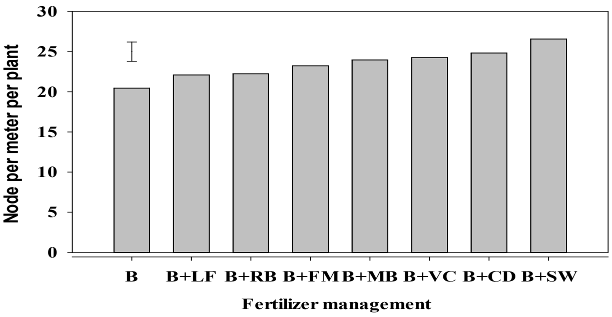

Figure 15.7. Node per meter per plant in mulberry as influenced by the fertilizer treatments. Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments.

The average 10 leaf areas per plant of mulberry was highly significant ($P \geq 0.001$) for the fertilizers management. The more remarkable increasing trendy was found for B+SW treatment. However, the recorded 10 leaf areas were 529.57, 546.50, 587.10, 600.46, 601.80, 607.76, 621.77 and 637.37 cm^2 due to combined application of B, B+LF, B+RB, B+FM, B+MB, B+VC, B+CD and B+SW treatments respectively (Figure 15.8; Table 15.2).

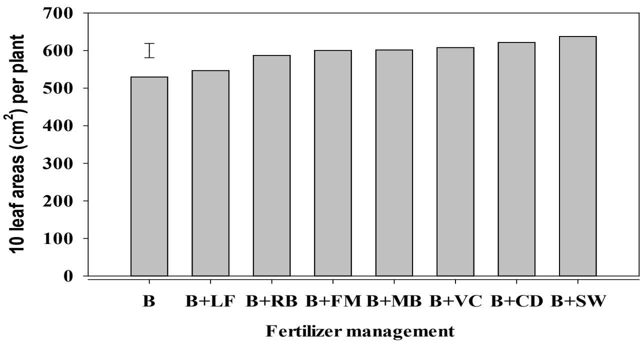

Figure 15.8. 10 leaf area per plant in mulberry as influenced by the fertilizer treatments. Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD ($P = 0.05$) different fertilizer treatments.

The highly significant ($P \geq 0.001$) trend was observed among the fertilizer treatments in respect of 10 leaf weights per plant of mulberry. The B+SW treatment was showed the more remarkable increasing trendy among the treatments. However, the noted 10 leaf weights were 24.31, 33.07, 34.59, 35.16, 39.80, 42.86, 46.60 and 49.09 g for the treatments of B, B+LF, B+RB, B+FM, B+MB, B+VC, B+CD and B+SW respectively (Figure 15.9; Table 15.2).

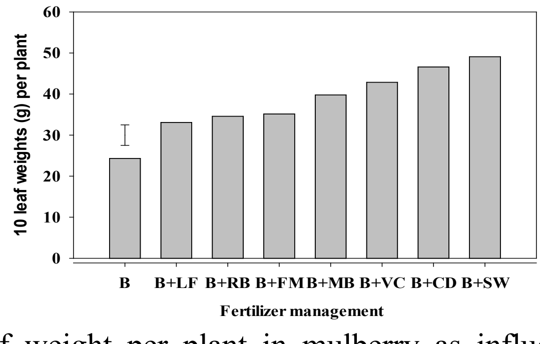

Figure 15.9. 10 leaf weight per plant in mulberry as influenced by the fertilizer treatments. Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD ($P = 0.05$) different fertilizer treatments.

The total leaf yield per hectare per year was highly significant ($P \geq 0.001$) by the fertilizer treatments. The more marked increasing trend was found for the B+SW treatment. However, the recorded total leaf yield was 27.92, 36.77, 38.65, 42.62, 49.19, 49.65, 50.14 and 52.23 MT per hectare per year due to combined application of B, B+LF, B+RB, B+FM, B+MB, B+VC, B+CD and B+SW treatments respectively (Figure 15.10; Table 15.2).

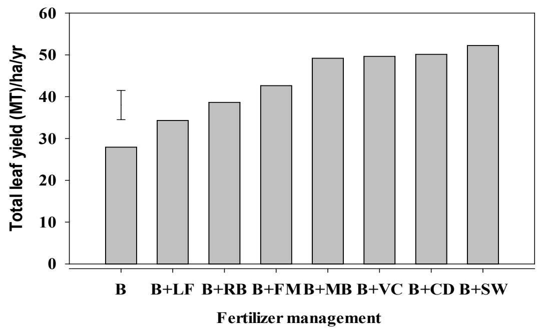

Figure 15.10. Total leaf yield per hectare per year in mulberry as influenced by the fertilizer treatments. Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD ($P = 0.05$) different fertilizer treatments.

The above findings revealed that the combined application of BSRTI recommended basal of $N_{300}P_{150}K_{100}$ kg/ha/year with 10 MT/ha/year Seri-waste compost (B+SW) gives the maximum growth and leaf yield of mulberry plant. The application of 10 MT/ha/year Seri-waste compost + BSRTI recommended basal of $N_{300}P_{150}K_{100}$ kg/ha/year results in maximum increased the total branch number, node per meter, 10 leaf areas, 10 leaf weights per plant and total leaf yield per hectare per year in mulberry plant. Even the combined application of 10 MT/ha/year Seri-waste compost with $N_{300}P_{150}K_{100}$ kg/ha/year increased the total branch number per plant, node per meter, 10 leaf area per plant, 10 leaf weight per plant and total leaf yield per hectare per year were 49.63, 29.93, 71.21, 101.93 and 87.07 percent respectively followed by the only BSRTI recommended basal dose of NPK. However, the 2nd highest performance was recorded for the combined application of 10 MT Cow dung compost with BSRTI recommended basal of $N_{300}P_{150}K_{100}$ kg/ha/year.

The application of 10 MT cow dung compost and 5 MT Vermi-compost respectively with BSRTI recommended basal of $N_{300}P_{150}K_{100}$ kg/ha/year increase the mulberry leaf yield was 79.58 and 77.83 percent respectively compared to the only BSRTI recommended basal dose of NPK. Similar, type of study was conducted by the Sudhakar *et. al.,* (2018) and they found that application of 5 MT Vermi-compost prepared from the Seri rearing residue with $N_{350}P_{140}K_{140}$ kg/ha/year gave the maximum mulberry plant height (151 cm), number of branch per plant (8.13), number of leaves per plant (199.4), leaf area (172.2 cm^2) and leaf yield (10877.9 kg/ha/crop).

Likewise, Bhogesha *et. al.,* (1997) reported that the application of compost manure produced out of sericulture waste including silkworm liter is highly beneficial for mulberry cultivation and it much effective than the conventional farm yard manure. It might be due to the maximum nutrients (macro and micro) availability through combined application of Seri waste compost plus NPK which mineralization of N during the decomposition of seri-waste compost would have enhanced the N availability, improving water holding capacity, micronutrients and nutritional properties of soil resulting increased the N and other nutrients uptake by the mulberry plant in turn would have promote higher yield attributes and leaf yield of mulberry, because seri waste compost contains maximum amount of NPK and other micro nutrients which is lined with the findings of Ramakrishna (2001).

He reported that the silkworm excreta and silkworm litter exposed the higher composition of nitrogen, phosphorus, potassium, sodium and carbon when compared to cow dung or FYM that why, it is used as an organic fertilizer. Similarly, Heenkende *et. al.,* (2010) reported that the combined application of 50% N recommended dose of fertilizer + 50% N Seri-compost increased the nitrogen, phosphorus and potassium contents in soil compared to the application of 100% N through Seri-compost. Similarly, Das *et. al.,* (1997) reported that Seri-waste has a tremendous manorial value of nitrogen, phosphorus, and potassium as well as micronutrients like iron, zinc, copper etc.

15.4 SINGLE EFFECT OF VARIOUS FERTILIZERS MANAGEMENT ON LEAF QUALITY OF MULBERRY PLANT

Control, basal, liquid fertilizer, rice husk biochar, mineral enrich biochar, seri-waste compost, cow dung compost, vermi compost and farm yard manure were used only in several experimental chapters (Chapter 4 to Chapter 9). Impact of single use only these fertilizer managements on leaf quality of mulberry plant were discussed as below:

Leaf quality is the key essential factor for successful mulberry silk cocoon production. Leaf quality differed significantly ($P \geq 0.05$) for the various fertilizer management. Five bio-chemical constituents of mulberry leaf quality were analyzed in several experimental chapters (Chapter 4 to Chapter 9). All the bio-chemical parameter viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar percentage were differed by the various fertilizer treatments. However, the maximum moisture was found 74.53% for the SW treatment. Similar, moisture percentage was found for the CD treated mulberry plant. Lowest moisture percentage was found 68.19% for the control treatment. Crude protein is another vital factor for mulberry silkworm quality. Findings showed that crude protein was tended to be highest in the Seri-waste treated mulberry plant which was statistically similar with the CD, VC, FM and MB treatments respectively. (Table 15.3). However, the maximum crude protein was 18.47% for SW treatment. Conversely, the minimum crude protein was 15.32 % for control treatment.

The maximum soluble carbohydrate was 10.28% which was statistically similar with CD, VC and MB treatments respectively. The minimum soluble carbohydrate was 7.28% for control which was statistically similar with LF treatment. The maximum mineral percentage was 13.22 for the treatment of SW. This value was statistically similar with the treatments of CD and VC treatments respectively followed by the other treatments. Interestingly, the total sugar percentage was statistically similar among the fertilizer treatments except control. However, among the eight types of fertilizer treatments the maximum total sugar percentage was 5.89 for SW treatment followed by the CD, VC, MB, FM, RH, LF and control treatments respectively (Table 15.3).

Table 15.3. Leaf quality status under various fertilizers management

Treatments	Moisture (%)	Crude protein (%)	Soluble Carbohydrate (%)	Mineral (%)	Total sugar (%)
C	68.19e	15.32c	7.28d	7.72d	3.63b
LF	70.61d	15.98bc	8.01cd	10.02c	5.04ab
FM	71.59bcd	17.37ab	8.23bcd	10.39bc	5.16ab
VC	72.68bc	17.65ab	9.63abc	11.84ab	5.25ab
RB	71.24cd	16.48bc	8.20bcd	10.39bc	5.02ab
MB	71.59bcd	17.14ab	8.60abcd	11.01bc	5.13ab
CD	73.19ab	18.45a	9.77ab	12.75a	5.77a
SW	74.53a	18.47a	10.28a	13.22a	5.89a

Where, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar/ha/year, SW = 10 MT Seri waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (*P* = 0.05) different fertilizer treatments. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

Leaf quality results revealed that the moisture, crude protein, soluble carbohydrate and mineral percentage were considerably increased by the application of 10 MT Seri waste compost/ha/year (SW) followed by the Cow dung Compost (CD), Vermi-compost (VC), Mineral enriched Biochar (MB), Farm Yard Manure (FM), Rice husk Biochar (RB), Liquid Fertilizer (LF) and Control (C) treatments respectively. The average moisture, crude protein, soluble carbohydrate and mineral percentage were 6.69, 20.86, 41.21 and 34.08% respectively greater in SW treated mulberry plant over the control. The 2nd highest leaf quality was found for the application of 5 MT Cow dung compost/ha/year followed by the VC, MB, FM, RB, LF and C treatments respectively. In mulberry crop similar type study was limited. But in a previous study Sudhakar *et. al.,* (2018) used the 5 MT Seri rearing residue/ha/year as a vermi compost for mulberry cultivation. They found that the leaf moisture %, Chlorophyll-a (mg/g), Chlorophyll-b (mg/g), total chlorophyll (mg/g) and leaf protein % were 76.50, 2.49, 0.71, 3.20 and 18.05 respectively.

Conversely, the application of 20 MT FYM/ha/year as a control treatment the leaf moisture %, Chlorophyll-a (mg/g), Chlorophyll-b (mg/g), total chlorophyll (mg/g) and leaf protein % were 75.27, 2.46, 0.64, 3.10 and 17.45 respectively. They speculated that the leaf quality of mulberry was improved in application of 5 MT Seri rearing residue/ha/year as a Vermi-compost compared to control may due to the superior nutrient status of Vermi-compost generated through incorporation of Seri rearing residue. In this study the leaf quality of mulberry viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar were increased in SW compost treated mulberry plant compared to the other treatments might be due to the maximum nutrients availability of SW compost enhanced the nutrients uptake by the mulberry plant. Resulting, it was ensured the balanced and optimum growth and establishment of mulberry plant. In terms, the leaf quality was improved. Because Seri-wastes compost contains the higher quantity of macro and micro nutrients which was lined with the finding of Ramakrishna (2001). He reported that the silkworm excreta and silkworm litter exposed the higher alignment of nitrogen, phosphorus, potassium, sodium and carbon when compared to cow dung or FYM. Das *et. al.,* (1997) also reported that Seri-waste compost contain of NPK as well as micronutrients like iron, zinc, copper etc.

15.5 COMBINED EFFECT OF VARIOUS FERTILIZER MANAGEMENT WITH BSRTI RECOMMENDED BASAL DOSE OF NPK ON LEAF QUALITY OF MULBERRY PLANT

Basal along with liquid fertilizer, rice husk biochar, mineral enrich biochar, Seri-waste compost, cow dung compost, Vermi-compost and farm yard manure were used in several experimental chapters (Chapter 4 to Chapter 9). Combined impact of these fertilizers managements with basal on leaf quality of mulberry plant were discussed as below:

Quality mulberry leaf is the basic requirements for successful silk cocoon production which was significantly influenced by the fertilizer treatments. Biochemical analysis showed that the combined application of 10 MT Seri-waste compost/ha/year (B+SW) with BSRTI recommended basal dose of NPK increased the bio-chemical constituents of mulberry leaf viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar percentage compared to the other treatments. However, the maximum moisture percentage was 76.63 for the B+SW treatment which was statistically similar with B+CD treatment but statistically greater than the other treatments. Conversely, the minimum moisture percentage was 70.23 for only the basal treatment. The maximum crude protein was 20.54 for the treatment of B+SW which was statistically similar with the treatments of B+CD and B+VC respectively. The 2nd highest crude protein was 20.23 % for B+CD treatment. However, the lowest crude protein percentage was 15.50% for B treatment. The soluble carbohydrate contains in mulberry leaves were differed significantly among the fertilizer treatments. The recorded maximum soluble carbohydrate was 10.81% for the B+SW treated mulberry plant which was statistically similar with B+CD, B+VC and B+MB treatments respectively. On the other hand, the minimum of soluble carbohydrate was 7.72% for B treatment. The maximum mineral percentage was 13.78 for the treatment of B+SW which was more or less similar with the all treatments except greater than the B+LF and B treatments respectively. Conversely, the minimum mineral percentage was 9.98% for basal treatment which was statistically similar with B+LF (10.39) treatment. Interestingly, the similar trendy was observed among the fertilizer treatments in respect of total sugar contain by the mulberry leaf. However, the maximum total sugar percentage was 6.29 for B+SW treatment followed by the B+CD (6.11%), B+VC (6.07%), B+MB (5.99), B+FM (5.35%), B+RH (5.25%), B+LF (5.13%) and B (4.99%) treatments respectively (15.4).

Table 15.4. Leaf quality status under various fertilizers management

Treatments	Moisture (%)	Crude protein (%)	Soluble Carbohydrate (%)	Mineral (%)	Total sugar (%)
B	70.23c	15.50d	7.72d	9.98b	4.99a
B+LF	71.44bc	17.15cd	8.23cd	10.39b	5.13a
B+FM	71.80bc	17.85bc	8.6bcd	12.78a	5.35a
B+VC	73.01b	19.02ab	10.28ab	13.02a	6.07a
B+RH	71.59bc	17.26c	8.34cd	12.32a	5.25a
B+MB	72.56b	17.96bc	9.83abc	12.97a	5.99a
B+CD	75.97a	20.23a	10.51a	13.66a	6.11a
B+SW	76.63a	20.54a	10.81a	13.78a	6.29a

Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD (*P* = 0.05) different fertilizer treatments. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above findings revealed that the combined application of BSRTI recommended basal dose of NPK with 10 MT Seri waste compost/ha/year (B+SW) was the better fertilizer management practice for improvement of mulberry leaf quality. Among the eight types of fertilizers management the B+SW treatment was increased the leaf quality viz: moisture, crude protein, soluble carbohydrate, mineral and total sugar were 9.11, 32.52, 40.03, 38.08 and 26.05% respectively over the single application of BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year (B).

The performance of combined application of BSRTI recommended basal dose of NPK with 10 MT Cow dung compost/ha/year (B+CD) was not bad. The B+CD treatment was also increased the leaf quality viz: moisture, crude protein, soluble carbohydrate mineral and total sugar was 8.17, 30.52, 36.14, 36.87 and 22.44 percent respectively compared to the B treatment. This finding was similarly with the previous findings of Chakraborty *et. al.*, (2015). They were applied five types of fertilizer treatments viz: 10 MT/ha/yr FYM + (150 kg N+50 kg P_2O_5+ 50 kg K_2O) /ha /yr), 10 MT/ha/ha weed composts + (Azotobacter 20kg + 75kg N + 20 kg P_2O_5 and 50kg K_2O) /ha /yr, 10 MT/ha/yr silkworm rearing waste composts + (Azotobacter 20kg + 75kg N + 20kg P_2O_5 and 50K_2O) /ha /yr, 7 MT/ha/yr poultry-manure + (Azotobacter 20kg + 75kg N + 20kg P_2O_5 and 50kgK_2O) /ha /yr and 8 MT/ha/yr pig manure + (Azotobacter 20kg + 75kg N + 20kg P_2O_5 and 50kg K_2O) /ha /yr for mulberry cultivation. Their experimental findings showed that the maximum leaf moisture content (72.31%), leaf moisture retention capacity (88.83%) and leaf protein % (17.96 mg/g fresh weight) were for the silkworm rearing waste + AZB + 50% N + 40% P + 100% K treated mulberry plot which was comparatively higher than the (FYM + NPK) and weed compost + AZB + 50% N + 40% P + 100% K) treated plot respectively. They speculated that this could be due to the beneficial combined effect of silkworm rearing waste + AZB + 50% N + 40% P + 100% K to the soil fertility status, overall plant growth and biochemical constituents of mulberry leaf. Resulting, the leaf quality was comparatively higher than the other treatments.

Similarly, in another study Kerenhap *et. al.,* (2007) found that the leaf quality of mulberry viz: moisture, total protein, total carbohydrate, reducing sugar and total sugar contains were, (73.80%), (210.80 mg/g), (38.02mg/g), (1.87mg/g) and (14.16 mg/g) respectively due to application of cow dung compost. These leaf qualities were comparatively greater than the compost prepared from the piggery manure and control treatment. However, in this study the leaf quality of mulberry viz: moisture, total protein, total carbohydrate, reducing sugar and total sugar contains were comparatively superior in combined application of B+SW treated mulberry plant might be due to the additional applied of NPK with superior nutrients enriched Seri waste compost. That increased the decomposition rate of Seri waste compost and released of macro as well as micronutrients which is essential for plant. In terms, it could be increased the availability of essential nutrients in the soil. Resulting, the nutrients uptake by the (B+SW) treated mulberry plant was optimum. That was influenced the balanced, sufficient and nutritious growth of mulberry plant as well as improved the leaf quality. Because, it was evident that Seri waste compost contains approximately 2.00-2.24% N, 0.93-1.00% P and 1.5-1.8% K besides Zn, Fe, Mn and Cu as micronutrient as found by Ravi Kumar *et. al.,* (2014). Besides, the deficiency of essential nutrients to cause nutritional, anatomical and histological disorders in mulberry. In addition, the unbalanced nutrient management have adverse effect on crop productivity and nutrients availability (Krishna *et. al.,* 2001).

15.6 SINGLE EFFECT OF VARIOUS FERTILIZERS MANAGEMENT ON COMMON FOLIAR DISEASES OF MULBERRY PLANT

Control, liquid fertilizer, rice husk biochar, mineral enrich biochar, Seri-waste compost, cow dung compost, vermi-compost, farm yard manure, were used only in several experimental chapters (Chapter 4 to Chapter 9). Impact of single use only these fertilizer managements on incidences of common mulberry foliar diseases were discussed as below:

The incidences of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra were statistically differed by the various fertilizer managements. The SW and CD treatments more marked significantly reduced the incidences of foliar diseases followed by the other treatments. However, among the eight types of fertilizer treatments the minimum incidence of powdery mildew, leaf spot and tukra were 3.11, 2.36 and 1.07% respectively for the application of 10 MT/ha/year Seri waste compost followed by the 10 MT/ha/year Cow dung compost, VC, MB, FM, RH, LF and control treatments respectively. Conversely, the maximum incidence of powdery mildew, leaf spot and tukra were 11.35, 11.31 and 9.98 % respectively for control treatment (15.5).

Table 15.5. Incidence of common mulberry foliar diseases under various fertilizers management

Treatments	Powdery mildew	Leaf spot	Tukra
C	11.35a	11.31a	9.98a
LF	9.56b	10.11a	8.08b
FM	4.40c	5.55c	3.62c
VC	3.70c	4.10cd	3.10cd
RB	8.32b	7.73b	6.76b
MB	3.92c	4.62cd	3.57cd
CD	3.36c	3.06de	1.87de
SW	3.11c	2.36e	1.07e

Here, C = Control, LF = 2 ml Liquid fertilizer/L water, RH = 3.5 MT Rice husk biochar/ha/year, MB = 3.5 MT Mineral enriched biochar ha/year, SW = 10 MT Seri waste compost/ha/year, CD = 10 MT Cow dung compost/ha/year, VC = 5 MT Vermi compost/ha/year and FM = 7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above diseases incidences results showed that the SW compost significantly reduced the incidence of powdery mildew, leaf spot and tukra diseases in mulberry plant. The minimum incidence percentage of powdery mildew was recorded 3.11 in SW treatment which was statistically similar with the treatments of CD, VC, MB and FM respectively. However, the incidence of powdery mildew was 72.60% lower in SW treatment over the incidence percentage of control treatment. Similar, in case of leaf spot disease the minimum incidence was 2.36% also for the same (SW) treatment which was statistically similar with the treatment of CD. However, the maximum incidence of leaf spot was 11.31% in control treatment. This incidence % was 79.13% higher than the incidence % of SW treatment. Correspondingly, the incidence percentage of tukra disease in control treatment was significantly higher than the SW and CD treatments respectively. The minimum incidence percentage of tukra disease was 1.07 in SW treatment which was statistically similar with CD treatment. The maximum incidence percentage of tukra disease was 9.98 in control treatment. The tukra incidence of SW treatment was 89.28% reduced followed by the control treatment (Table 17.5). Such type study was not available in mulberry crop. But, Maji *et. al.,* (2013) was applied 15 MT/ha/year the sericulture wastes: silkworm liters, unused mulberry leaves and weeds as vermi compost for mulberry cultivation. They found that the severity of powdery mildew and leaf spot diseases of mulberry plant was significantly reduced. They also found that the incidence of powdery mildew and leaf spot diseases were 4.07 and 5.93 respectively for application of 15 MT/ha/year Vermi-compost (prepared by using the sericulture waste: silkworm liters, unused mulberry leaves, weeds of mulberry field which was similar with the Seri-waste compost of this study) whereas the severity of powdery mildew and leaf spot diseases in control treatment were 10.06 and 15.22 respectively which was similar with the findings of this study. They speculated that the severity of powdery mildew and leaf spot diseases could be due to increased levels of soil microbial activity leading to increased competition and antagonism in the rhizosphere as well as enriched soil beneficial microflora.

In addition, supply of nutrients for robust growth and bring forth resistance to diseases under Seri-waste compost treated mulberry plant. In case of tukra disease the similar finding was observed by Samuthiravelu *et. al.,* (2012). They imposed 0.20% Seriboost as a foliar spray was made 500L/ha with hand sprayer in the evening hours thrice at 15, 25 and 35 days after pruning. They found that the incidence of tukra mealy bug (*Maconellicoccus hirsutus*) were 46.12%, 43.56% and 18.18% respectively in 20, 30 and 40 days after pruning (DAP) whereas in case of control treatment the incidence of tukra mealy bug (*Maconellicoccus hirsutus*) were 48.25%, 47.85% and 21.15% respectively in 20, 30 and 40 DAP. This finding was more or less similar with this experimental finding. However, in this study the infestation of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra in Seri waste compost might be reduced due to the maximum organic proportion of macro and micro nutrients of Seri waste compost. That could be helped to enrich the soil beneficial mycoflora and produced fungi toxic substances during organic matter decomposition or induction of systemic resistance in the host plant. Resulting, the incidences of foliar diseases in SW treated mulberry plant were reduced compared to the other fertilizer treatments. Because the decomposition of organic waste is a complex process involving various biochemical activities of microorganisms, especially the *Bacillus, Pseudomonas, Trichoderma, aspergillus, Belaromuces,* etc. Therefore, to speed up the process of decomposition, the culture of these microbes could be added along with sericultural wastes. In addition, the species of *Bacillus, Pseudomonas, Trichoderma* and *Verticillium*are also known to be the potential biocontrol agent of plant diseases (Kalaiyarasan *et. al.,* 2015).

15.7 COMBINED EFFECT OF VARIOUS FERTILIZERS MANAGEMENT WITH BSRTI RECOMMENDED BASAL DOSE OF NPK ON FOLIAR DISEAESES OF MULBERRY PLANT

Basal along with liquid fertilizer, rice husk biochar, mineral enrich biochar, seri-waste compost, cow dung compost, vermi compost and farm yard manure were used in several experimental chapters (Chapter 4 to Chapter 9). Combined impact of these fertilizers managements with basal on incidences of common foliar diseases of mulberry were discussed as below:

Powdery mildew, leaf spot and tukra are the major foliar diseases of mulberry plant. That causes enormous losses of mulberry leaf yield, leaf quality as well as leaf productivity. The incidences of these foliar diseases were statistically differed among the various fertilizer treatments. However, the minimum incidence of powdery mildew, leaf spot and tukra were 2.07%, 1.07% and 1.02% respectively for the combined application of 10 MT/ha/year Seri waste compost (SW) with BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year (B) followed by the B+CD, B+VC, B+MB, B+FM, B+RH, B+LF and B treatments respectively. Conversely, the maximum incidence of powdery mildew, leaf spot and tukra were 10.69, 10.13 and 8.21 percentages respectively for the single application of B treatment (Table 15.6).

Table 15.6. Incidences of common mulberry foliar diseases under combined fertilizer management.

Treatments	Powdery mildew	Leaf spot	Tukra
B	10.69a	10.13a	8.21a
B+LF	9.17a	8.0b	7.19a
B+FM	4.16c	4.74c	3.39bc
B+VC	3.16cd	3.37cd	2.61cd
B+RH	6.0b	6.69b	5.10b
B+MB	4.78bc	4.15cd	3.17c
B+CD	2.18d	2.49de	1.32d
B+SW	2.07d	1.07e	1.02d

Where, B = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, B+LF = B+2 ml Liquid fertilizer/L water, B+RH = B+3.5 MT Rice husk biochar/ha/year, B+MB = B+3.5 MT Mineral enriched biochar/ha/year, B+SW = B+ 10 MT Seri-waste compost/ha/year, B+CD = B+10 MT Cow dung compost/ha/year, B+VC = B+5 MT Vermi-compost/ha/year and B+FM = B+7 MT Farm yard manure/ha/year. Vertical bar represents LSD (P = 0.05) different fertilizer treatments. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above results presented that the combined application of SW with BSRTI recommended basal dose of NPK (B+SW) considerably reduced the incidence of foliar diseases in mulberry. Among the three common foliar diseases the minimum incidence of powdery mildew was 2.07%. This incidence % of powdery mildew was statistically similar with the incidence % of B+CD (2.18%) and B+VC (3.16%) treatments respectively. However, the powdery mildew incidence percentage was 80.64% lower in B+SW treatment and 79.61% lower for B+CD treatment respectively over the single application of B treatment. Similarly, in case of leaf spot disease the minimum incidence was recorded for the B+SW treatment which was statistically similar with treatment of B+CD. However, the minimum incidence percentage of leaf spot was 1.07 for B+SW treated mulberry plot. The incidence % of leaf spot disease for B+SW treatment was 89.44% lower than the B treatment. Correspondingly, the incidence of tukra disease was also differed among the fertilizer treatments. The maximum incidence percentage of tukra was 8.21 for the B treatment that was similar with B+LF treatment. The minimum incidence percentage was 1.02 for B+SW which was statistically similar with the treatments of B+CD (1.32%) and B+VC (2.61%) respectively. However, the incidence of tukra was 87.58% and 83.92% respectively lower in B+SW and B+CD treatments respectively followed by the single application of B treatment. Interestingly, the incidence percentage of all the three diseases viz: powdery mildew, leaf spot and tukra caused by *Phyllactinia corylea, Cercospora moricola and mealy bug pest Maconellicoccus hirsutus* in B+LF was statistically similar with the B treatment (Table 15.6).

However, there was no information available about these diseases in literature that occurred due to seri-waste amendment. Maji *et. al.,* (2013) was applied 15 MT/ha/year of sericulture wastes: silkworm liters, unused mulberry leaves and weeds on mulberry field as a compost with NPK (168:90:56). They found that the severity of powdery mildew and leaf spot diseases of mulberry plant was significantly reduced. They also found that the incidences of powdery mildew and leaf spot diseases were 4.07 and 5.93% respectively for application of 15 MT/ha/year compost (prepared by using the sericulture waste: silkworm liters, unused mulberry leaves, weeds of mulberry field) with NPK (168:90:56). Furthermore, the severity of powdery mildew and leaf spot diseases were 10.06 and 15.22 respectively for control treatment. This finding was lined with this experimental finding. They speculated that the severity of powdery mildew and leaf spot diseases were reduced might be due to increased levels of soil microbial activity leading to increased competition and antagonism in the rhizosphere as well as enriched soil beneficial microflora. In addition, supply of nutrient for robust growth and bring forth resistance to diseases under Seri-waste compost plus inorganic NPK (168:90:56). However, in this study the B+SW treatment was reduced the incidence of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra might be due to the maximum organic and inorganic proportion of macro and micro nutrients. That could be enhanced the soil beneficial mycoflora and produced fungi toxic substances during organic matter decomposition or induction of systemic resistance in the host plant.

Thus, the combined application of B+SW treatment was reduced the foliar diseases incidence compared to the other fertilizer treatments. Because, the decomposition of organic waste is a complex process involving various biochemical activities of microorganisms, especially the *Bacillus, Pseudomonas, Trichoderma, aspergillus, Belaromuces,* etc. These microbes increased the decomposition rate when added along with sericultural wastes. Furthermore, the species of *Bacillus, Pseudomonas, Trichoderma* and *Verticillium*are are the potential bio control agent of plant diseases (Kalaiyarasan *et. al.,* 2015).

15.8 EFFECT OF ELEVATED NPK APPLICATION ON MULBERRY PLANT PRODUCTIVITY

The elevated doses of nitrogen, phosphorus and potassium were used in several experimental chapters (Chapter 12 to Chapter 14). The comparative effect of these fertilizers managements with basal on mulberry plant productivity were discussed as below:

Elevated N application tended to be increased mulberry plant productivity (Figure 17.11 to Figure 17.15).

The total branch number per plant of mulberry was significantly ($P \geq 0.01$) differed by the various fertilizer treatments. The more marked increasing trend was found for the elevated nitrogen treatment (EN). However, the recorded total branch number was 12.11, 15.66, 15.83 and 16.18 for the application of B, EK, EP and EN treatments respectively (Figure 15.11; Table 15.7).

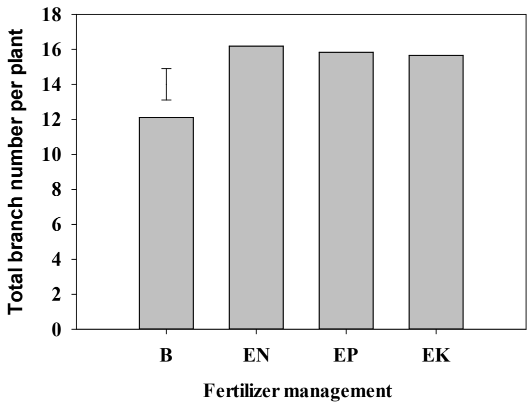

Figure 15.11. Total branch number per plant in mulberry as influenced by the fertilizer treatments. Where, Basal = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The significant ($P \geq 0.05$) trend was observed among the treatments in respect of node per meter of mulberry. However, the obtained node per meter was 20.45, 22.83, 23.07 and 23.18 for the basal, EK, EP and EN treatments respectively (Figure 15.12; Table 15.7).

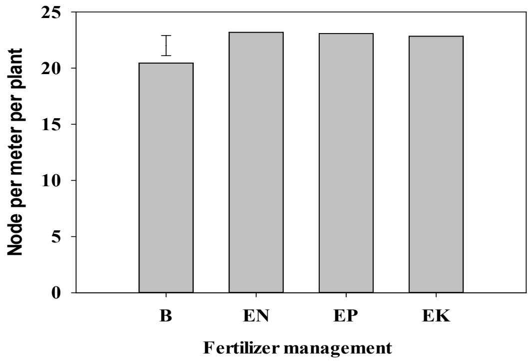

Figure 15.12. Node per meter per plant in mulberry as influenced by the fertilizer treatments. Where, Basal = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

Table 15.7. Effect of different levels of NPK on mulberry plant production

Factors	Total branch number/plant	Node/Meter	10 Leaf areas (cm^2)	10 Leaf weights (g)	Total leaf yield/ha/yr (MT)
Treatments	**	*	***	***	***

Where, * ** and *** represent probability of >0.05, ≤0.05, ≤0.01 and ≤0.001. Values were means of three replicates.

The 10 leaf areas of mulberry plant was highly significant (P ≥ *0.001*) by the fertilizer treatments. The more remarkable increasing trend was found for the EN treatment. The recorded 10 leaf areas were 529.57, 594.68, 600.12 and 604.60 cm^2 due to application of basal, EK, EP and EN treatments respectively (Figure 15.13; Table 15.7).

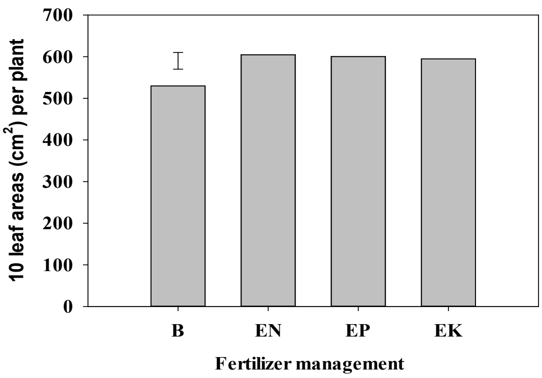

Figure 15.13. 10 leaf areas per plant in mulberry as influenced by the fertilizer treatments. Where, Basal = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The highly significant (P ≥ *0.001*) trend was observed among the treatments in respect of 10 leaf weights of mulberry. The more marked increasing trendy was found for the EN treatment. However, the noted 10 leaf weights were 24.31, 45.25, 45.62 and 46.83 g for the treatments of basal, EK, EP and EN respectively (Figure 17.14; Table 17.7).

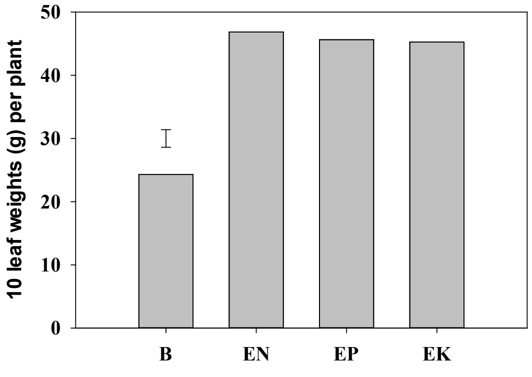

Figure 15.14. 10 leaf weights per plant in mulberry as influenced by the fertilizer treatments. Where, Basal = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The total leaf yield of mulberry was highly significant (P ≥ *0.001*) by the fertilizer treatments. The more remarkable increasing trend was observed for the EN treatment. However, the recorded leaf yield of mulberry was 27.92, 45.62, 46.83 and 47.20 MT/ha/yr due to application of basal, EK, EP and EN treatments respectively (Figure 17.15; Table 17.7).

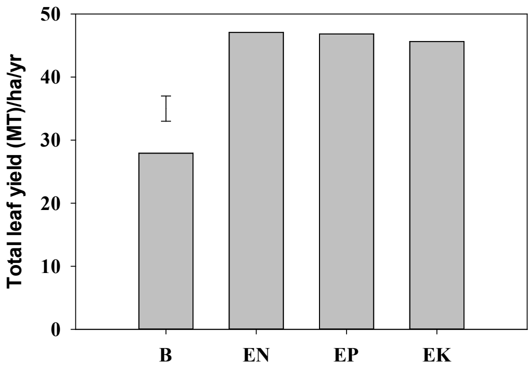

Figure 15.15. Total leaf yield per hectare per year in mulberry as influenced by the fertilizer treatments. Where, Basal = BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The above findings showed that the elevated doses of inorganic fertilizer had a significant impact on mulberry plant production. In this study 400 kg N, 160 kg P, 150 kg K/ha/year with BSRTI respective doses of NPK and BSRTI recommended basal dose of $N_{300}P_{150}K_{100}$ kg/ha/year were applied for mulberry cultivation. Among the four types of fertilizer treatments the growth and yield contributing attributes of mulberry plant viz: total branch number, node per meter, 10 leaf areas and 10 leaf weights per plant were significantly increased by the elevated dose of 400 kg N/ha/year along with 150 kg P and 100 kg K per hectare per year with four split doses (EN) followed by the elevated doses of P, K and BSRTI recommended basal doses of NPK (Table 17.7). The average maximum leaf yield was recorded 47.20 MT for the EN treatment which was 69.05% greater over the BSRTI recommended basal dose of NPK. The 2nd highest leaf yield was 46.83 MT for the application of 160 kg P/ha/year along with 300 kg N and 100 kg K per hectare per year with four split doses (EP). This leaf yield was 67.73% higher over the BSRTI recommended basal dose of NPK (Basal). These findings were similar with the previous findings of Paul *et. al.,* (2009). They were applied 0 kg, 200 kg, 300 kg and 400 kg N/ha/yr with P and K for mulberry cultivation. They found that among the four levels nitrogen the plant height, number of branches, number of leaves per branches and leaf yield per plant were significantly highest for the application of 400 kg N/ha/yr.

Similarly, Shinde *et. al.,* (2012) also found that the application of 360 kg N: 180 kg P: 180 K/ha/year gave the higher number of leaf, average weight of leaves and height of mulberry plant than the other treatments. In the same way, Bose *et. al.,* (2009) also found the significant impact of elevated P on mulberry leaf yield. They were applied five levels of P_2O_5 as a basal @ 0, 15, 30, 45 and 60 kg/ha/yr and found that the plant height, leaf area and leaf yield were significantly increased due to P application from 30 kg to 60 kg P_2O_5/ha/yr over the control, the maximum being with 60 P_2O_5/ha/yr. However, they did not explain their speculation about their experimental findings. The application of elevated 400 kg N with 150 P and 100 kg K/ha/yr gave the maximum growth attributes as well as leaf yield of mulberry plant could be due to the applied EN treatment was comparatively balanced nutrients proportion than the elevated P and K. That might be influenced the optimum availability of N as key elements of plant growth and development as well as the other related nutrients specially P and K. Resulting, enhanced the maximum N and others related nutrients uptake form the soil, assimilation and utilization through the proliferated mulberry roots. In terms, directly improved the several key functions viz: including energy transfer, photosynthesis rate and nutrient movement within the plant cell, also many structural, genetics, metabolic components and various physiological processes. Consequences, the growth, development, leaf area production, leaf area duration as well as net assimilation rate of mulberry plant for the EN treated mulberry plant was increased as well as the growth attributes specially the leaf yield was increased compared to the elevated dose of P and K, which was lined with the previous finding of Singh *et. al*., (2016). They reported that next to nitrogen, phosphorus and potassium are the important essential nutrients for plant growth, involved in several key plant functions, including energy transfer, photosynthesis rate, and nutrient movement within the plant and others related parts of mulberry plant. Because, nitrogen is the most imperative element for proper growth and development of plants which significantly increases and enhances the yield by playing a vital role in biochemical and physiological function of plants Shah *et. al.,* (2016).

15.9 EFFECT OF ELEVATED NPK APPLICATION ON LEAF QUALITY OF MULBERRY PLANT

The elevated doses of nitrogen, phosphorus and potassium were used in several experimental chapters (Chapter 12 to Chapter 14). The comparative effect of these fertilizers managements with basal on leaf quality of mulberry were discussed as below:

Elevated N application tended to be improved mulberry leaf quality:

The more or less similar trend was found for the bio-chemical constituents of mulberry leaf viz: moisture, crude protein, mineral, total sugar and soluble carbohydrate percentage of mulberry leaf due to application of elevated doses of nitrogen (EN), phosphorus (EP) and potassium (EK) respectively. However, the more marked improving trend was found for the EN treatment except total mineral percentage. Among the four types of fertilizer management the maximum average moisture percentage was 74.39 for EN treated mulberry leaf. Similar, the maximum crude protein percentage was 19.49 also for the EN treated mulberry leaf. The maximum mineral percentage was 11.53 for EP treated mulberry leaf which was statistically similar among the all treatments. The maximum total sugar was 5.96% for EN treatment followed by the EP, EK and Basal treatments respectively. The soluble carbohydrate percentage was statistically differed only with the Basal treatment. However, the maximum soluble carbohydrate was 9.68% for the EN treatment followed by the EP, EK and Basal treatments respectively. Conversely, the minimum moisture, crude protein, mineral, total sugar and soluble carbohydrate percentage were 70.23, 15.50, 9.98, 4.99 and 7.72 respectively due to basal treated mulberry leaf (Table 15.8).

Table 15.8. Leaf quality status of mulberry plant under various fertilizers management

Treatments	Moisture (%)	Crude protein (%)	Total Mineral (%)	Total sugar (%)	Soluble carbohydrate (%)
Basal	70.23b	15.50b	9.98a	4.99a	7.72b
EN	74.39a	19.49a	11.00a	5.96a	9.68a
EP	73.91a	19.45a	11.53a	5.90a	9.53ab
EK	73.48a	19.38a	11.22a	5.73a	9.37ab

Where, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above findings represented that the elevated doses of inorganic fertilizer had a wider impact on improving the leaf quality of mulberry. Among the four types of fertilizer treatments the elevated dose of 400 kg N/ha/year with BSRTI recommended doses of 150 kg P and 100 kg K per hectare per year with four split doses was increased the moisture, crude protein, total sugar and soluble carbohydrate 5.92%, 20.47%, 19.44% and 25.39% respectively over the basal treatment. However, the mineral contains was 15.53 % greater over the basal due to application of EP treatment (Table 17.8). This finding was similar with the previous findings of Paul *et. al.,* (2009). They were applied 0 kg, 200 kg, 300 kg and 400 kg N/ha/yr respectively with P and K for mulberry production. They found that the application of 400 kg N/ha/yr with two irrigations showed the higher amount of leaf moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral. In the same way, Miah (1989) was applied 400 kg N with 200 kg P and 150 kg K for mulberry cultivation. He found that the application of 400 kg N was increased the leaf constituents viz: moisture (%), chlorophyll-a, chlorophyll-b, total sugar (%), soluble carbohydrate (%), reducing sugar and crude protein (%) except total mineral contents gradually due to progressive increased doses of NPK fertilizers. Among the three types of elevated doses viz: nitrogen, phosphorus and potassium, the elevated nitrogen showed the better performances in terms of leaf quality could be due to the maximum availability and uptake of N as a key elements as well as other nutrients by the mulberry plant. That might be ensured the nutritious growth and development of mulberry plants. Resulting, the leaf quality was improved for the EN treatments as compared to the other treatments. Because, nitrogen is the very essential key element for plant growth and development.

Furthermore, N is involved in several key plant functions, including energy transfer, photosynthesis rate, transformation of sugars and starches, nutrient movement within the plant and others related parameters that positively enhance the growth and quality of mulberry plant. The above speculation was lined with the previous finding of Singh *et. al*., (2016). They reported that nitrogen is very important essential nutrients for plant growth and is found in every living plant cell. It also involved in several key plant functions, including energy transfer, photosynthesis rate, transformation of sugars and starches, nutrient movement within the plant and others related parameters that positively enhance the growth, leaf yield and quality of mulberry plant. Similarly, Barker *et. al.,* (1974) reported that nitrogen is the essential constituent of protein, nucleic acids, chlorophyll and growth hormones. Besides, proper growth and development of plants require optimum supply of nitrogen. Because, too little application of N directly reduces crop yield while excess supply of N also causes negative effects on plant and this issue getting focus continuously in crop production (Magistad *et. al.,* 1945).

15.10 EFFECT OF ELEVATED NPK APPLICATION ON SUPPRESSES OF FOLIAR DISEASES OF MULBERRY PLANT

The elevated doses of nitrogen, phosphorus and potassium were used in several experimental chapters (Chapter 12 to Chapter 14). The comparative effect of these fertilizers managements with basal on incidence of mulberry foliar diseases were discussed as below:

Elevated NPK application tended to be suppressed the foliar diseases of mulberry plant (Table 17.9).

Though the leaf yield and leaf quality of mulberry plant was increased by the elevated doses of nitrogen (N) followed by the phosphorus (P) and potassium (K) respectively but in case of foliar disease incidence the reverse results was found in this study. However, more or less similar trend was observed for the incidences of foliar diseases viz: powdery mildew, leaf spot and tukra among the various fertilizer treatments except basal treatment. In case of powdery mildew the recorded lowest incidence percentage was 6.55 for the elevated dose of potassium (EK). Conversely, the higher incidence percentage of powdery mildew was 10.69 for basal treatment. Similarly, the minimum incidence of leaf spot was 7.53% for the same fertilizer (EK) management and the maximum incidence percentage was 10.80 for the basal treatment. Correspondingly, the minimum incidence of tukra was 6.57% also for the EK treatment. On the other hand, the maximum incidence of tukra was 8.21% also for the BSRTI recommended basal doses $N_{300}P_{150}K_{100}$ kg/ha/year (Basal) treatment. However, the incidences of all the three foliar diseases were comparatively reduced by the elevated doses of K, P and N respectively over the BSRTI recommended basal dose of N, P and K respectively (17.9).

Table 15.9. Incidence of mulberry foliar disease under elevated NPK and Basal fertilizer management

Treatments	Powdery mildew	Leaf spot	Tukra
Basal	10.69a	10.80a	8.21a
EN	7.20b	8.83b	7.06a
EP	6.72b	8.49bc	6.73a
EK	6.55b	7.53c	6.57a

Here, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}K_{100}$ kg NPK/ha/year, EP = $N_{300}P_{160}K_{100}$ kg NPK/ha/year and EK = $N_{300}P_{150}K_{150}$ kg NPK/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above findings showed that the elevated doses of potassium had a wider impact on reduced the incidences of foliar diseases in mulberry plant as compared to the elevated doses of phosphorus and nitrogen respectively. Among the three diseases, the minimum incidence of powdery mildew was 6.55% in EK treatment which was statistically similar with the incidences of treatments EP and EN respectively. But this incidence was 38.73% lower than the incidence % of basal treatment. Similar, in case of leaf spot disease the minimum incidence % was 7.53 for the EK treatment which was also statistically similar with the treatment of EP. The EK treatment was reduced the leaf spot incidence was 30.28% followed by the basal treatment. The minimum incidence of tukra disease was 6.57% which was statistically similar among the treatments. However, the tukra incidence was 19.98% reduced in EK treatment over the basal treatment (Table 17.9). However, no study was found through internet searching that elevated potassium reduces the foliar disease of mulberry plant. But, for the other crop, Nwogbaga *et. al,.* (2015) found that the downy mildew and other fungal diseases of Cucumber (*Cucumis sativus* L.) were significantly reduced due to the foliar application of NPK at the rate of 19.181 kg/ha.

The combined application of elevated K with recommended basal doses of N and P reduced the incidences of powdery mildew, leaf spot and tukra of mulberry plant compared to the other treatments could be due to the elevated K dose was balanced with the nitrogen and phosphorus doses. That could be increased the phenols content in mulberry plant which can played a beneficial role in plant resistance against the pathogen. In addition the elevated potassium might be affected the more water and nutrient absorption, improving the plant morphology, hardening the plant tissues and developing the strong cell wall against the pathogen infection as well as insect attack. Resulting, the plant became more strong and resistant against the fungal pathogen and insect penetration. Thus, the incidences of powdery mildew, leaf spot and tukra were reduced by the elevated dose of potassium followed by the other treatments.

The above assumption was similar with the previous findings of Pervez *et. al.,* (2007). They reported that the adequate potassium nutrition increased the content of phenols which can play a beneficial role in plant resistance. In addition, potassium affects plant morphology, hardening the tissues with resulting improvement in resistance to disease penetration. In terms, the incidence of disease was reduced for the application of potassium. Similarly, Zeru (2017) reported that potassium helps for more water and nutrient absorption, photosynthesis, photosynthate translocation and helping the plant to develop strong cell wall to keep the plant more strong and resistant to the diseases and pest.

The incidence of foliar diseases for the elevated dose of phosphorus was next to potassium might be due to developed defense mechanism against the fungal diseases and mealy bug pest of mulberry plant. Because, P could be enhanced the biochemical and physiological processes as well as changed the others metabolic functions as a essential element of the plant. This speculation was lined with the previous findings of Prabhu *et. al.,* (2007). They reported that phosphorus is an essential element of the building blocks of life and the ribonucleic acids (RNA). Furthermore, phosphorus is required for many additional biochemical and physiological processes including energy transfer, protein metabolism and other functions of the plant.

However, the elevated dose of nitrogen was increased the incidences of all the three foliar diseases compared to the elevated doses of phosphorus and potassium respectively due to the extreme nitrogen application. Because, excess N could be promoted the more vegetative growth, development, increased the softness and succulence of mulberry leaf. In addition, excessive nitrogen might be reduced the formation of plant mineral nutrition in plant cell which act as a mechanical barriers against the fungal penetration. In terms, the incidence of powdery mildew, leaf spot and tukra were increased in EN treatment followed by the EP and EK respectively.

The above assumption was lined with the previous comments of Srivastava (2017). He reported that if nitrogen application is excess then the plant exhibit more vegetative growth, becomes soft and succulent, which makes the plant to be easily affected and become less resistant to pathogen. Similarly, Zeru (2017) reported that excessively high nitrogen levels lower the Si content and increase susceptibility to fungal diseases. Because, the accumulation of silicon (Si) in the cell walls help the form a protective physical barrier to fungal penetration in plant.

15.11 EFFECT OF MULBERRY PLANT AGES AND ELEVATED NPK APPLICATION ON MULBERRY PLANT PRODUCTIVITY

Mulberry leaf yield varies irrespective to age groups and elevated NPK application. Two ages group of mulberry plant were considered in this study. These are 0-5 years and 6-10 years.(6-10) years ages of mulberry plant and elevated N application tended to be increase mulberry plant productivity (Figure 17.16 to Figure 17.20). The total branch number per plant was highest in EN followed by EP and EK. However, between the two age groups of mulberry plant the maximum average total branch number was 16.49 in (6-10) year's plant for the EN treatment. Conversely, the minimum average total branch number was 15.43 in (0-5) year's plant for the EK treated mulberry plant (Figure15.16; Table 15.10).

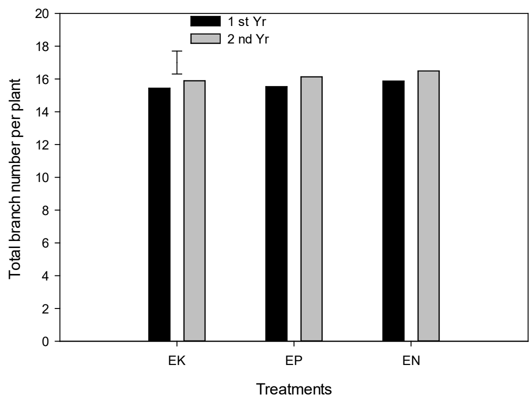

Figure 15.16. Total branch number per plant in mulberry as influenced by the fertilizer treatments and the ages of mulberry plant. Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. (0-5) yr = (0-5) year's ages of mulberry plant and (6-10) yr = (6-10) year's ages of mulberry plant. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The node per meter of mulberry was significantly ($P \geq 0.05$) differed by the ages of plant (Table 17.10). Between the two ages of mulberry plant the maximum average node per meter was 23.69 in (6-10) year's plant for EN treated mulberry plant followed by the EP (23.57) treatment. However, in case of (0-5) year's plant the average node per meter was 22.68, 22.57 and 22.35 for EN, EP and EK treated mulberry plant respectively. On the contrary in case of (6-10) years plant the average node per meter was 23.69, 23.57 and 23.31 for EN, EP and EK treated mulberry plant respectively (Figure15.17).

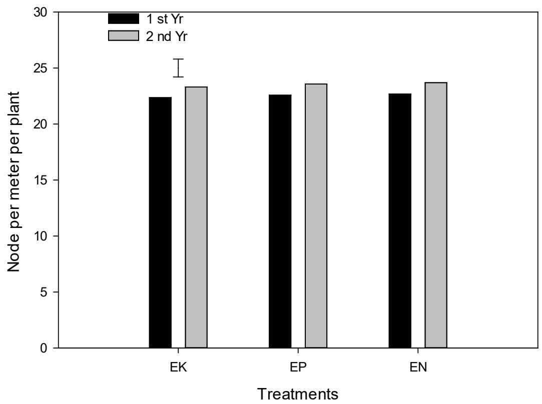

Figure 15.17. Node per meter per plant in mulberry as influenced by the fertilizer treatments and the ages of mulberry plant. Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. (0-5) yr = (0-5) year's ages of mulberry plant and (6-10) yr = (6-10) year's ages of mulberry plant. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

Table 15.10. Effect of different levels of NPK and plant ages on mulberry plant productivity

Factors	Total branch number/plant	Node/Meter	10 leaf areas/plant (cm^2)	10 leaf weights/plant (g)	Total leaf yield/ha/yr (MT)
Age	n.s	*	***	n.s.	***
Treatments	n.s	n.s	***	*	n.s.
Age × Treatment	n.s	n.s	n.s	n.s	n.s.

Where, n.s., * ** and *** represent not significant, probability of >0.05, ≤0.05, ≤0.01 and ≤0.001, respectively. Values were means of three replicates.

The 10 leaf areas of mulberry plant was highly significant ($P \geq 0.001$) both for the fertilizers treatments and ages of mulberry plant (Table 17.10). However, among the three types of fertilizer treatments the maximum average 10 leaf area was 608.35 cm^2 in (6-10) year's plant for EN treatment followed by the EP (602.37 cm^2) and EK (597.89 cm^2) respectively in (6-10) year's plant. Conversely, the minimum 10 leaf areas were 600.85 cm^2, 597.87 cm^2 and 591.47 cm^2 in (0-5) year's plant for the EN, EP and EK treatments respectively (Figure15.18).

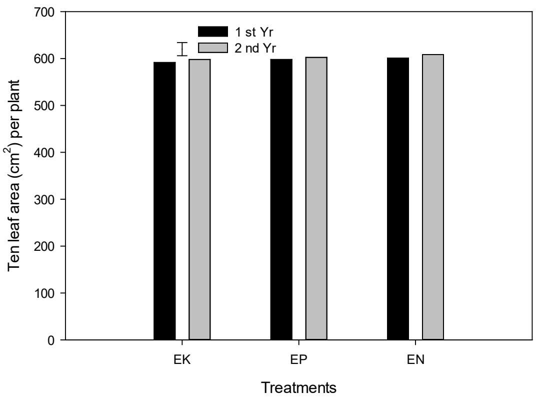

Figure 15.18. 10 leaf areas per plant in mulberry as influenced by the fertilizer treatments and the ages of mulberry plant. Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. (0-5) yr = (0-5) year's ages of mulberry plant and (6-10) yr = (6-10) year's ages of mulberry plant. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The 10 leaf weights of mulberry plant were significantly ($P \geq 0.05$) differed among treatments (Table 17.10). Between the two types of mulberry plant the maximum average 10 leaf weights was 47.24 g in (6-10) year's plant for the EN treated mulberry plant followed by the EP (46.57 g) and EK (45.37 g) treatments respectively. However, in case of (0-5) year's plant the average 10 leaf weights were 46.41 g, 45.67 g and 45.13 g respectively for the EN, EP and EK treatments respectively (Figure15.19).

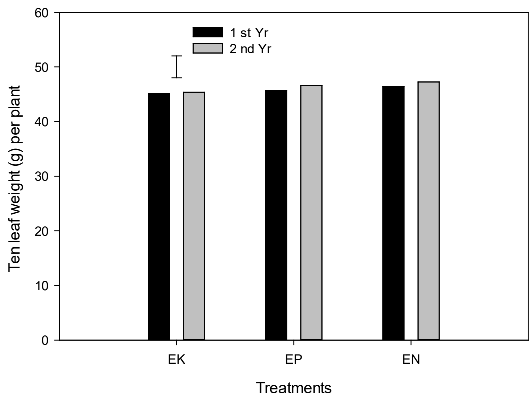

Figure 15.19. 10 leaf weight per plant in mulberry as influenced by the fertilizer treatments and the ages of mulberry plant. Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. (0-5) yr = (0-5) year's ages of mulberry plant and (6-10) yr = (6-10) year's ages of mulberry plant. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The total leaf yield of mulberry plant was highly significant ($P \geq 0.001$) by the mulberry plant ages (Table 17.10). Between the two types of mulberry plant the maximum average total leaf yield was 48.93 MT in (6-10) year's plant for the EN treatment followed by the 48.77 MT and 47.10 MT per hectare per year for EP and EK treatments respectively. However, in case of (0-5) year's plant the average total leaf yield were 45.46, 44.89 and 44.13 MT per hectare per year for EN, EP and EK treatments respectively (Figure15.20).

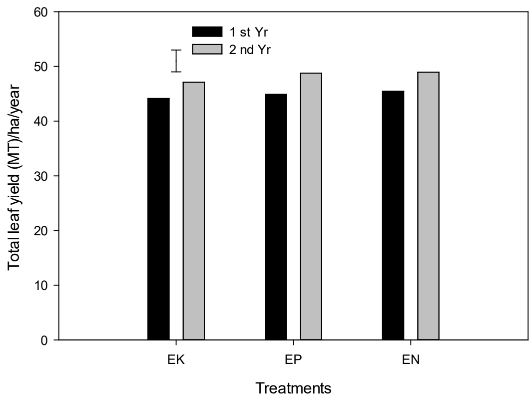

Figure 15.20. Total leaf yield per hectare per year in mulberry as influenced by the fertilizer treatments and the ages of mulberry plant. Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. (0-5) yr = (0-5) year's ages of mulberry plant and (6-10) yr = (6-10) year's ages of mulberry plant. Vertical bar represent LSD (P = 0.05) different fertilizer treatments.

The above findings showed that between the two aged plant, (6-10) year's ages of mulberry plant gave the maximum values both for the yield components (number of total branches, node per meter, 10 leaf areas and 10 leaf weights per plant) and leaf yield for the application of elevated 400 kg N with BSRTI recommended 150 kg P and 100 kg K/ha/year (EN) in mulberry plant followed by the elevated phosphorus (EP) and elevated potassium (EK) treated mulberry plant respectively. Even the leaf yield was 7.63% increased in (6-10) year's plant compared to the maximum leaf yield of (0-5) year's plant for the same (EN) treatment. Among the three fertilizer treatments the maximum leaf yield was 48.93 MT/ha/yr for EN treatment which was 3.89% greater than the maximum leaf yield of EK treatment.

The similar type study in mulberry crop was limited but these findings were more or less similar with the previous findings of Paul *et. al.,* (2009). They were applied four levels of nitrogen (0 kg, 200 kg, 300 kg and 400 kg N/ha/yr), phosphorus (0, 100, 150 and 200 kg N/ha/yr) and potassium (0, 75, 100 and 125 kg N/ha/yr) respectively for mulberry cultivation. Their results showed that the increasing rate of NPK (400 kg N with 200 kg P and 125 kg K per hectare per year) gave the significantly highest values for the yield components (plant height, number of branches per plant, number of leaves per branches) and leaf yield per plant. This finding was lined with this experimental finding. Similarly, Miah (1989) also found that the application of N, P, and K fertilizers at the rate of 400 kg N, 200 kg P, and 150 kg K/ha/yr respectively increased the leaf yield was 77.92% over the control.

The (6-10) year's age and elevated 400 kg N/ha/year treated mulberry plant gave the maximum growth and leaf yield compared to the (0-5) year's ages EP and EK treated mulberry plant could be due to the well developed, larger and deeper root system as well as larger leaves of older (6-10 years) plant. In addition, the maximum availability of plant key element (N) through elevated nitrogen could be contributed the rapid and maximum photosynthesis as well as enhanced the physiological activity and N use efficiency followed by the (0-5) year's old younger mulberry plant and elevated phosphorus and potassium treatments respectively. As a results, the N as well as the other related nutrients especially P, K uptake form the soil, assimilation and utilization through the proliferated mulberry roots of (6-10) year's plant was comparatively maximum. That might be directly improved the several key functions, including energy transfer, photosynthesis rate, nutrient movement within the plant cell, also many structural, genetics, metabolic components and various physiological process.

Consequence, the growth, development, leaf area production, leaf area duration as well as net assimilation rate of (6-10) year's ages of mulberry plant over the (0-5) year's plant was improved. Resulting the growth and leaf yield of (6-10) year's mulberry plant was better in elevated nitrogen (EN) treated (0-5) year's phosphorus and potassium treated mulberry plant. Because, when the plants roots completely developed and leaves also become wider in size then the N utilization increases. Furthermore, the deeper root system enhances the intake of N, while larger leaves contribute rapid and maximum photosynthesis process which stimulates physiological activity of plant that may help in N use efficiency (Leghari *et. al.*, 2016). Similarly, Deborah *et. al.,* (1990) found that the N absorption was increased with plant age of marigold seedlings.

15.12 EFFECT OF MULBERRY PLANT AGES AND ELEVATED NPK APPLICATION ON LEAF QUALITY OF MULBERRY PLANT

The similar trend was found for leaf qualities of mulberry irrespective to age groups and elevated doses of NPK except moisture percentage. There were two ages' groups of mulberry plant viz: (0-5) and (6-10) years were considered for this study.

However, between the two types of mulberry plant the maximum moisture % was 75.59 in (6-10) year's ages of older mulberry plant due to application of EN treatment. Conversely, the minimum moisture % was 72.77 in (0-5) year's ages of younger mulberry plant for the EK treatment. Similarly, the recorded maximum crude protein was 20.17% in older (6-10 years) mulberry plant also for the EN treated mulberry leaf. On the contrary, the minimum crude protein % was 18.81 in the leaf of younger (0-5 years) plant. Correspondingly, the recorded maximum total mineral was 12.33% in the leaf of older mulberry leaf due to application of EP treatments. Conversely, the minimum total mineral % was 10.87 for the leaf of younger plant due to treated of EK treated treatment. The recorded maximum total sugar and soluble carbohydrate were 6.19% and 10.44% respectively also for the leaf of older mulberry plant due to application of EN treatment (Table 15.11).

Table 15.11. Leaf quality status of mulberry plant under various fertilizers management.

Treatment	Moisture (%)		Crude protein (%)		Total Mineral (%)		Total sugar (%)		Soluble carbohydrate (%)	
EN	73.19b	75.59a	18.81a	20.17a	10.87a	11.13a	5.73a	6.19a	8.92a	10.44a
EP	72.84b	74.97a	18.78a	20.13a	10.73a	12.33a	5.69a	6.10a	8.89a	10.17a
EK	72.77b	73.97ab	18.77a	19.99a	10.57a	11.87a	5.53a	5.93a	8.77a	9.97a

Where, Basal = BSRTI recommended dose of $N_{300}P_{150}K_{100}$ kg/ha/year, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above results showed that between the two types of mulberry plant, (6-10) year's ages of plant gave the maximum leaf qualities viz: moisture, crude protein, total sugar and soluble carbohydrate except total mineral due to application of elevated 400 kg N with BSRTI recommended 150 kg P and 100 kg K/ha/year (EN) followed by the elevated phosphorus (EP) and elevated potassium (EK) treated mulberry plant respectively. This study also represent that the moisture, crude protein, total sugar and soluble carbohydrate % of (6-10 years) ages of mulberry plant were 3.88, 7.46, 11.93 and 19.04 respectively higher than the elevated dose of potassium (EK). The above findings were similar with the earlier findings of Paul *et. al.,* (2009). They were used 0 kg, 200 kg, 300 kg and 400 kg N/ha/yr with various levels of P and K. Their findings showed that among the various level of N with various levels of P and K the 400 kg N/ha/yr gave the superior qualities of leaf moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral. The speculation was due to the maximum availability of N and well developed deeper root system of (6-10 years) ages of mulberry plant the leaf qualities were more improved by the EN treated mulberry plant compared to the EP and EK treated (0-5 years) ages plant. Because, N is the essential key element for plant growth and development as compared to the P and K.

In addition, the root established and root size of 6-10 years mulberry plant could be more improved than the 0-5 years mulberry plant. As a results, the N as well as the other related nutrients especially P, K uptake form the soil, absorption and exploitation through the proliferated mulberry roots of (6-10) year's plant was comparatively better. These passive roles could be improved the energy transfer, photosynthesis rate, nutrient movement within the plant cell, metabolic components and various physiological process as well as ensured better growth and establishment of 6-10 years ages of mulberry plant. Resulting, the leaf qualities were greater in 6-10 years ages of EN treated mulberry leaf followed by the EP and EK respectively. My assumption was similar with the previous findings of Leghari *et. al.*, (2016). They reported that the well developed deeper root system enhances the N uptake rate, as well as larger leaves contribute rapid and maximum photosynthesis process. In addition it may have enhanced the physiological activity through increasing the N use efficiency.

15.13 EFFECT OF MULBERRY PLANT AGES AND ELEVATED NPK APPLICATION ON SUPRESSES OF FOLIAR DISEASES OF MULBERRY PLANT

The more or less similar trend was observed for the incidences % of mulberry foliar diseases irrespective to age groups and graded doses of NPK. Two ages' groups of mulberry plant viz: (0-5) and (6-10) years were used for this study.

However, between the two age's groups of mulberry plant the lower incidence of powdery mildew was 6.10% in (6-10) year's ages of older mulberry plant for the EK treated mulberry plant. Conversely, the higher incidence of powdery mildew was 7.56% in (0-5) year's ages of younger mulberry plant for the EN treatment. Similarly, in case of leaf spot disease the lower incidence % was 6.83 in older (6-10 years) mulberry plant due to application of EK treatment followed by the EP and EN treatments respectively. This incidence % was statistically differed with the incidence % of EN treated younger mulberry plant. On the contrary, the recorded higher incidence of leaf spot was 8.79% in the leaf of younger mulberry plant also for the EN treatment. Correspondingly, the minimum incidence of tukra disease was 6.21% for the leaf of older mulberry plant due to application of EK treatment. Conversely, the recorded maximum tukra incidence was 7.33% also for the leaf of (0-5) year's ages of younger mulberry plant (Table 15.12).

Table 15.12. Incidences of mulberry foliar diseases under elevated NPK management.

Treatments	Powdery mildew (%)		Leaf spot (%)		Tukra (%)	
EN	7.56a	6.83a	8.79a	7.53ab	7.33a	6.79a
EP	7.12a	6.31a	8.53ab	7.10ab	7.09a	6.37a
EK	6.99a	6.10a	6.89b	6.83b	6.93a	6.21a

Where, EN = $N_{400}P_{150}$ K_{100} kg NPK/ha/year, EP = $N_{300}P_{160}$ K_{100} kg NPK/ha/year and EK = $N_{300}P_{150}$ K_{150} kg NPK/ha/year. Data were means of three replicates. Means followed by the same letter within a column are not significantly differed at $P \geq 0.05$ based on the Tukey test.

The above results showed that the ages of mulberry plant had a positive impact on the incidences of mulberry foliar diseases. Between the two ages groups of mulberry plant 6-10 year's ages of older mulberry plant was more reduction of mulberry foliar diseases as compared to the 0-5 year's ages of younger mulberry plant. In case of powdery mildew disease the older (6-10 years) mulberry plant was 19.31% reduction of powdery mildew incidence over the maximum incidence % of younger plant. Similarly, the incidence of leaf spot was 22.30% lower in older mulberry plant as compared to the maximum incidence of younger mulberry plant. Correspondingly, the older (6-10 years) mulberry plant was 15.28% reduced the tukra incidence followed by the maximum incidence of 0-5 year's ages of younger mulberry plant.

The result was represented that the incidences % of all the three diseases were statistically similar between the older and younger mulberry plant. But, (6-10 year's) ages of older mulberry plant was reduced the overall incidences % of all the three diseases compared to the (0-5 year's) ages of younger plant. Such type findings were hardily available for mulberry crop. But a study was conducted by the Gao *et. al*., (2016) on infestation of Zebra Chip disease caused by *B. cockerelli.* in potato. They were exposed separately at different growth stages (4, 5 and 7 weeks after germination) of potato for four different *B. cockerelli* densities (0, 5, 20 and 40 psyllids per cage) in field cages and monitored the symptoms of Zebra chip infestation. They found that the infestation of *B. cockerelli* and Zebra Chip expression was more vulnerable in younger plants at 4-week growth stage after germination than the older plants. Their finding was more or less similar with this experimental finding. The 6-10 years ages of older mulberry plant reduction the foliar diseases incidences as compared to the 0-5 years ages of younger mulberry plant could be due to the maximum K absorbed by the well developed larger and deeper root system of older mulberry plant. In terms, the phenol contained by the older plant was increased as compare to the younger plants. That beneficial role of older plant could be played resistance against the fungal pathogen penetration.

In addition, due to the higher potassium contains by the older mulberry plant could be enhanced plant morphology, hardening the cell walls with maximum improving the resistance to diseases penetration. Furthermore, K may have a direct antifungal impact for fragment and deficiency of conidia and mycelium of fungal diseases. Consequently, the incidence of powdery mildew and leaf spot caused by fungus as well as tukra disease caused by mealy bug pest was comparatively decreased by the 6-10 year's ages older mulberry plant followed by the 0-5 year's ages of younger plant. The above speculation was lined with the previous concept of Pervez *et. al,.* (2007). They reported that the sufficient potassium nutrition enhanced the phenols contain by the plant. In addition, potassium affects plant morphology and physiology. These beneficial roles can create plant resistance against the disease dissemination as well as K reduction the incidence of fungal diseases.

Chapter 16
Conclusions, limitations, implications and recommendations of the study

Chapter 16

Conclusions, limitations, implications and recommendations of the study

Sericulture is one of the most important agro based industries which cover both agriculture and industry. Sericulture also involves four distinct phases of activities viz. mulberry cultivation, silkworm rearing, reeling and weaving. Among the four phases, mulberry cultivation is initial stage of sericulture and out of total cost of sericulture, more than 50% incurred for mulberry cultivation. Therefore, production of mulberry leaf per unit area in a very reasonable cost is an important factor to establish the sericulture on sound economic base in the world. Among the major contributing factors for quality as well as successful cocoon harvest out of total contribution mulberry leaves contributes 38.20%. Besides, about 70% of silk protein synthesized by the silkworm is derived directly from protein content in mulberry leaves. So, the quality and quantity of mulberry leaf production is the pre-requisite for profitable and sustainable sericulture production. But in the field level average mulberry leaf production is 30-35 MT/ha/yr with minimum leaf quality in Bangladesh. However, it was found that the mulberry leaf production and quality as well as the incidences of foliar diseases are highly dependable on the balanced and effective fertilizer management practices of mulberry cultivation. Therefore, the present study was undertaken to evaluate an advanced fertilizer management practice that enhances productivity and suppresses foliar diseases of mulberry plant.

16.1. Conclusions

This study demonstrated that utilization of Seri-waste with BSRTI recommended fertilizer produced highest mulberry leaf yield and quality as well as less infestation of foliar disease of mulberry plant. This study also revealed that the application of 10 MT Seri-waste/ha/year with BSRTI recommended basal dose of NPK (B+SW) provided maximum number of total branch number, total branch heights, node per meter, 10 leaf areas, 10 leaf weights, total shoot weights and total leaf weights per plant followed by the combined application of B+CW, B+VC, B+MB, B+FM, B+RB, B+LF and conventional basal fertilizers management (B).

The utilization of Seri-waste also gave the maximum mulberry leaf yield with greatest moisture, crude protein, total mineral, soluble carbohydrate and total sugar percentage. The maximum leaf yield was 52.23 MT/ha/year for B+SW treatment. The mutual application of B+SW treatment also highest reduction of foliar diseases like powdery mildew, leaf spot and tukra of mulberry followed by the B+CW, B+VC, B+MB, B+FM, B+RB, B+LF and B fertilizers management, respectively.

Foliar application of nutrients to mulberry plant produced second highest mulberry leaf yield and quality. This study revealed that foliar application of nutrients with BSRTI recommended traditional basal dose of NPK (B+LF) produced the maximum number of total branch number, total branch heights, node per meter, 10 leaf areas, 10 leaf weights, total shoot weights and total leaf weights per plant followed by the combined application of (B+U) or single application of liquid fertilizer (LF). The same (B+LF) fertilizer management also produced the leaf yield was 36.77 MT/ha/year which was 7.17% greater than the leaf yield of B+U fertilizer management. The B+LF fertilizer management also improved the moisture, crude protein, total mineral, soluble carbohydrate and total sugar contain in mulberry leaf followed by the single application of basal (B), liquid fertilizer (LF) and B+U fertilizer management, respectively. Further, the B+LF fertilizer management was occurred highest suppression of powdery mildew, leaf spot and tukra diseases as compared to the B, LF and B+U fertilizer management, respectively.

Regardless of that this study presented among the inorganic fertilizer management, the application of elevated 400 kg N/ha/year with four split doses of BSRTI recommended 160 kg P and 150 kg K per hectare per year proliferated the maximum number of total branch number, total branch heights, node per meter, 10 leaf areas, 10 leaf weights, total shoot weights and total leaf weights per plant followed by the elevated doses of phosphorus and potassium respectively. Likewise, the elevated 400 kg N/ha/year was produced optimum mulberry leaf yield with higher quantity of moisture, crude protein, soluble carbohydrate and total sugar percentage compared to the graded doses of phosphorus and potassium respectively. In contrast, the elevated dose of 150 kg K/ha/year with four split doses of BSRTI recommended 300 kg N and 150 kg P per hectare per year was highest reduction of mulberry foliar diseases viz: powdery mildew, leaf spot and tukra respectively within inorganic fertilizer management.

This study confirmed that among the three foliar diseases powdery mildew infestation was most all the three crop seasons followed by the leaf spot and tukra. The maximum incidence was 10.41% for powdery mildew disease in late autumn season followed by the leaf spot (8.49%) and tukra (3.10%), respectively. Among the twelve mulberry genotypes BM-11, BM-8, and Black to powdery mildew, BM-4, BM-11 to leaf spot and BM-8, BM-10, BM-11 and S-30 were comparatively resistant to tukra disease. In addition, among the three crop seasons viz: late autumn, summer and rainy, late autumn season was relatively more susceptible to incidences of all the three foliar diseases viz: powdery mildew, leaf spot and tukra, respectively.

In addition, between the two cropping seasons autumn was more resistant to powdery mildew disease as compared to the spring season. Spring season was comparatively more susceptible to powdery mildew disease than the autumn season. Among the twelve mulberry genotypes S-30 was more resistance and BM-5 more susceptible to powdery mildew in autum season. Conversely, mulberry genotype Black was more resistant to powdery mildew disease in spring season. Similarly, BM-7 and BM-3 were more susceptible to powdery mildew disease in spring season. The optimum occurence percentage of powdery mildew disease was 14.61 in spring season for the variety of BM-7.

Aged mulberry plant production was higher than young mulberry plant production. In this study, 6-10 years age mulberry plant was considered as age mulberry plant. Whereas, 0-5 years age mulberry plant was considered as young mulberry plant. This study also concluded that the 6-10 years ages of mulberry plant was produced maximum number of total branch number, total branch heights, node per meter, 10 leaf areas, 10 leaf weights, total shoot weights and total leaf weights per plant as compared to the 0-5 year's ages of mulberry plant. The 6-10 years ages of mulberry plant gave the higher leaf yield with superior leaf qualities like moisture, crude protein, total mineral soluble carbohydrate and total sugar as compared to the 0-5 year's ages of mulberry plant. The findings of this study also indicated that the 6-10 years ages of mulberry plant was more resistant to the common foliar diseases viz: powdery mildew, leaf spot and tukra as compared to the 0-5 year's ages of mulberry plant.

16.2. Limitations of the study

- To draw confirmed conclusion, the same experiment need to be repeated other different Agro ecological zones as well as other parts in Bangladesh.
- As mulberry is a perennial plant, so the same experiment needs to be continue at least five years to make a concrete conclusion.
- Nutrients especially NPK content within the mulberry plant tissue was not considered in this study.
- The ages of the entire experimental mulberry plant was not similar. So, it was difficult to estimate the actual growth and yield performance of mulberry plant.

16.3. Implications of the study

- Seri-waste compost may be effective for better mulberry plant production compared to the BSRTI recommended NPK or conventional basal dose of NPK management for mulberry cultivation.
- Utilization of Seri-waste compost can be improved mulberry leaf qualities viz: moisture, crude protein, total mineral soluble carbohydrate and total sugar compared to the others organic or inorganic fertilizer management.
- Seri- waste compost can be used for reduction the infestation of mulberry foliar diseases like powdery mildew, leaf spot and tukra.
- If Seri-waste compost are not available than cow dung and vermi-compost may be utilized for getting optimum mulberry leaf yield and quality as well as suppression of mulberry foliar diseases infestation.

- The elevated dose of nitrogen can be introduced to obtained higher leaf yield and qualities compared to the traditional or basal NPK management for mulberry plant production.
- The elevated dose of potassium may be more effective for controlling of mulberry foliar diseases.
- The ages of mulberry plant may have a significant impact on mulberry plant productivity and reduction of foliar diseases infestation of mulberry plant.
- Mulberry genotype, cropping season and climate has can play an important role for incidence of foliar diseases infestation of mulberry plant.

16.4. Recommendations for further study

- Further study may be conducted to evaluate the effect of others organic fertilizers viz: poultry manure, cattle manure, pig manure, city wastages etc for mulberry plant production.
- Further study may be done to explore the performance of bio-fertilizers such as Arbuscular Mycorrhizae Fungi (AMF) on mulberry plant production.
- Nano particles can be introduced in mulberry cropping pattern for better mulberry plant production.
- Further research may be conducted to estimate effect of different fertilizers management practices on silkworm rearing performance.
- Further research may be executed to evaluate the performance on the combined elevated doses of NPK for mulberry plant production.

Chapter 17

References

Chapter 17

References

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Chapter 18

Appendices

Appendices

Appendix – I

Liquid Fertilizer (LF)

Application of LF through foliar spray

Photographic view 1: Liquid fertilizer (LF) that was applied in the experimental field

Seri-waste Compost (SW)

Combined SW + Basal dose of NPK

Photographic view 2: Seri-waste compost (SW) that was applied in the experimental field

Appendix – II

Rice husk biochar

Mineral enrich biochar

Photographic view 3: Biochar (Rice husk and Mineral enrich) that was applied in the experimental field

Appendix – III


Vermi-Compost Vermi-Compost

Photographic view 4: Vermi-compost that was applied in the experimental field


Cow-dung compost Cow-dung compost

Photographic view 5: Cow-dung compost that was applied in the experimental field

Appendix – IV

Farm Yard Manure

Farm Yard Manure

Photographic view 6: Farm Yard Manure that was applied in the experimental field

Photographic view 7: Powdery mildew disease affected mulberry leaf.

Appendix – V

Photographic view 8: Leaf spot disease affected mulberry leaf.

Photographic view 9: Tukra disease affected mulberry leaf