Project ID - 545

Competitive Research Grant

Sub-Project Completion Report

on

Effect of Nitrogen, Phosphorus and Potassium on Growth, Yield and Leaf Quality of Mulberry

Project Duration

July 2017 to September 2018

Mulberry Section, Bangladesh Sericulture Research and Training Institute

Submitted to

Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
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Citation

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Acknowledgement

The execution of CRG sub-project has successfully been completed by Bangladesh Sericulture Research and Training Institute using the research grant of USAID Trust Fund and GoB through Ministry of Agriculture. We would like to thank to the World Bank for arranging the grant fund and supervising the CRGs by BARC. It is worthwhile to mention the cooperation and quick responses of PIU-BARC, NATP 2, in respect of field implementation of the sub-project in multiple sites. Preparing the project completion report required to contact a number of persons for collection of information and processing of research data. Without the help of those persons, the preparation of this document could not be made possible. All of them, who made it possible, deserve thanks. Our thanks are due to the Director PIU-BARC, NATP 2 and his team who given their whole hearted support to prepare this document. We hope this publication would be helpful to the agricultural scientists of the country for designing their future research projects in order to generate technology as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. It would also assist the policy makers of the agricultural sub-sectors for setting their future research directions.

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Acronyms

BSRTI	Bangladesh Sericulture Research and Training Institute
BSDB	Bangladesh Sericulture Development Board
DG	Director General
BARC	Bangladesh Agricultural Research Council
MT	Metric Ton
BM	Bangladesh Mulberry
RCBD	Randomized Completely Block Design
DAP	Days After Pruning

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Executive Summary

A 15 months BARC (NATP) funded research project entitled “Effect of nitrogen, phosphorus and potassium on growth, yield and leaf quality of mulberry” was conducted at the research field and laboratories of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi during the period from July, 2017 to September, 2018 to determine N, P and K requirements and optimum age of mulberry plants to get higher yield and better quality of mulberry leaves. The six treatments executed for individual trials on N, P and K requirements of mulberry plants were: (a) N: 0, 80, 160, 240, 320 and 400kg/ha/yr; (b) P: 0, 40, 80, 120, 160 and 200 kg/ha/yr; and (c) K: 0, 30, 60, 90, 120 and 150 kg/ha/yr. Blanket doses of P & K for N trial; N & K for P trial and N & P for K trial were fixed as per recommended doses of BSRTI. Research results indicated that all of the three added nutrient elements (N, P and K) favored in increasing growth, yield and improving quality of mulberry leaves. The leaf yield increased with increased rates of N, P and K application. The highest leaf yield in case of N trial was 51.88 Mt/ha/yr found in older plants of 6-10 yrs. of age with the application of N @ 400 kg/ha/yr. All the growth and quality parameters of leaves exhibited the best performance in this treatment. In case of P trial, the highest leaf yield of 47.69 Mt/ha/yr was also noted in the older plants with the application of 160 kg P/ha/yr. The growth and quality parameters of leaves were found to be superior in this treatment. In case of K trial, the highest leaf yield (45.3 Mt/ha/yr) was recorded in older (6-10 yrs) mulberry plants with the application of 150 kg K/ha/yr having better growth and quality of leaves as well. It may thus be concluded that N, P and K requirements of mulberry plants at BSRTI (Rajshahi) experimental field soil are 400 kg, 160 kg and 150 kg /ha/yr, respectively to give the maximum yield of better quality of mulberry leaves. The older plants of 6-10 years of age are superior to the younger plants (less than 5 years) for producing higher amount of better quality mulberry leaves.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Effect of Nitrogen, Phosphorus and Potassium on Growth, Yield and Leaf Quality of Mulberry
2. Implementing organization: Bangladesh Sericulture Research and Training Institute (BSRTI)
3. Name and full address with phone, cell and E-mail of PI/Co-PI (s):

Principal Investigator (PI) : **Faruque Ahmed**
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4. Sub-project budget (Tk):

4.1 Total: 20.00 Lac.

4.2 Revised (if any): 2000000.00

5. Duration of the sub-project: July, 2017 to September, 2018

5.1 Start date (based on LoA signed): 12.07.2017

5.2 End date: 30 September 2018

6. Justification of undertaking the sub-project:

Sericulture is one of the most important agro based industries which play a vital role in alleviating the rural unemployment and improving the soci-economic status of rural folk. Among the major contributing factors for quality as well as successful cocoon harvest out of total contribution mulberry leaves contributes 38.20%, climate 37.00%, rearing techniques 9.30%, silkworm race 4.20%, silkworm egg 3.10 and others 8.20 (Miyashita, 1986). Besides, about 70% of silk protein synthesized by the silkworm is derived directly from protein content in mulberry leaves. So, the quality and quaintly mulberry leaf production per unite area is the pre requisite for profitable and sustainable sericutural production. Now in the field level average mulberry leaf production is 20-25 mt/ha/yr in Bangladesh (Bari, 2002). On the other hand, the other mulberry producing countries like India and China average leaf production is 30-50 mt/ha/yr and 25-30 mt/ha/yr respectively (Nisar *et al.,* 2012). According to Jaiswal *et al.* (2005) mulberry

leaf productivity is highly dependent on plant nutrients like NPK fertilizers. Literature available from different countries suggests that mulberry plant responds well to nitrogen applications especially with respect to the leaf yield and the quality of foliage which can be improved by supplying of phosphatic and potassic fertilizers along with nitrogen (Basavanna *et al*., 1974; Kasiviswanathan *et al.*, 1979 and Bongale, 1994). Generally, 300 kg N/ha/yr, 150 kg P/ha/yr and 100 kg K/ha/yr with 4 split doses are applied for mulberry plant production in Bangladesh, which is recommended by BSRTI (2000). But these fertilizers doses are not satisfactory or balanced for quality and quantity mulberry leaf production. Due to intensive mulberry cropping system (4 times leaf harvest/year) causes depletion of nutrients in soil (Shashidhar *et al.,* 2009). Besides the age of mulberry plant is a great factor for leaf production, because a mulberry plant give the leaf yield from 20-25 years. According to Rajaram *et al.* (2013) mulberry plant is a perennial crop can be maintained for several years in the field, selection of suitable land and follow-up of recommended package of practices are inevitable for potential productivity. It is also well known that the requirement of fertilizers for mulberry plant production should differ based on the age of mulberry plant. But in our country the common doses of N, P and K fertilizers recommended previously by BSRTI (1990) previously has been practiced for mulberry cultivation of all ages. So, the expected average mulberry leaf production and leaf quality in Bangladesh could not be achieved in farmer's level. But it was found that the mulberry leaf production and quality is highly dependable on the balanced and effective fertilizers management practices. According to Nasreen *et al*. (1999), good quality leaf production in mulberry is highly dependent on the supply of various inputs especially N and P fertilizers. Pau *et al.* (2009), found that comprising 300 kg N, 150 kg P, and 100 kg K/ha/yr along with two irrigations per month gave higher leaf yield, leaf moisture and leaf nutrient contents of mulberry plants (var. BM-3).Though, previously the recommended doses of N, P and K were determined on the basis of irrigation frequency, but now a day it is not satisfactory for quality and qualitatively mulberry leaf production especially in sericulture farmer's level. The low leaf yield and quality of mulberry plant in Bangladesh is attributed to a number of reasons i.e., poor fertilizer management, non replenishment of soil nutrient, inadequate fertilizer use, lack of fertilizer management including setting of N_2 application etc. In addition no activities in Bangladesh were done previously on N, P and K requirement of mulberry plants based on its ages. It has now become essential to know the effective doses of N, P and K fertilizers on the basis of ages of mulberry plants to achieve higher yield of better quality mulberry leaves in Bangladesh.

7. Sub-project goal: Improved quality and increased quantity of mulberry leaf production ensured

8. Sub-project objective (s):

- ✓ To determined the of N, P and K requirement of mulberry plants.
- ✓ To achieve higher yield of mulberry leaves.
- ✓ To improve leaf quality of mulberry of plants.

9. Implementing location (s): Experimental Field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi.

10. Methodology in brief:

Total three (03) experiments were conducted to evaluate the effect of N, P and K fertilizers on growth, leaf yield and leaf quality under two ages (0-5 and 6-10 year's) mulberry plants. Each experiment was conducted on two ages of plant and repeated for the 04 consecutive cropping seasons. The square high bush mulberry plantation system and variety: BM-11 was followed for this study. To achieve the output of this study the following three experiments was conducted on two ages of plant:

Experiment-1: Optimization of N for growth, leaf yield and leaf quality of mulberry.

Treatments:

T_0= 0 N (No application of N fertilizer)
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
T_5= 400 kg N/ha/yr

Phosphorus (P) and potassium (K) were applied @ 150 kg/ha/yr and 100 kg/ha/yr, respectively.

Experiment-2: Optimization of P for growth, leaf yield and leaf quality of mulberry.

Treatments:

T_0 = 0 P (No application of P fertilizer)
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
T_5= 200 kg P/ha/yr

Nitrogen (N) and Potassium (K) were applied @ 300 kg N/ha/yr and 100 kg K/ha/yr, respectively.

Experiment-3: Optimization of K for growth, leaf yield and leaf quality of mulberry.

Treatments:

T_0 = 0 K (No application of K fertilizer)
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
T_5= 150 kg K/ha/yr

Nitrogen (N) and Phosphorus (P) were applied @ 300 kg N/ha/yr and 150 kg P/ha/yr, respectively.

(All experiments were conducted on two aged plants (0-5 years and 6-10 years plants).

Experimental Design: Randomized Completely Block Design (RCBD)

Replication: 03

Location: Experimental Field of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi.

Plot Size: 5 m × 4 m

Spacing: Plant-Plant = 0.92 m and Line-Line = 0.92 m

Number of plant/Plot: Twenty (20)

Season: Three (03) crop seasons like S_1 (August-October), S_2 (November-January) and S_3 (February-April).

Plantation system: Square High Bush

Mulberry Variety: BM-11

Fertilizer Dose: <u>Nitrogen treatments:</u>

N was applied as per treatment but P and K as per recommended dose of BSRTI (150 kg P/ha/yr/ and 100 kg K/ha/yr respectively). All the fertilizers were applied after 15-20 days of pruning with 4 equal splits through local placement method.

Phosphorus treatments:

P fertilizer was applied as per treatment. N and K as per recommended fertilizer dose of BSRTI (300 kg N/ha/yr/ and 100 kg K/ha/yr respectively). All the fertilizers were applied after 15-20 days of pruning with 4 equal splits through local placement method.

Potassium treatments:

K fertilizer was applied as per treatment but N and P fertilizers were applied as per recommended dose of BSRTI (300 kg N/ha/yr/ and 150 kg P/ha/yr respectively). All the fertilizers were applied after 15-20 days of pruning with 4 equal splits by local placement method.

Cultural practices: Mulberry garden was pruned three times like - S_1 (August), S_2 (November) and S_3 (February) at 3 (three) months interval. The other cultural practices like irrigation, soil blossoming cum weeding and disease–pest management were done normally as per needed. Organic fertilizer (cowdung) was applied accordingly in each experimental plot @ 18-20 mt/ha/yr..

Data recorded:

To estimate the effect of NPK fertilizers on growth, leaf yield and leaf quality characters of mulberry plant all the 06 experiments were conducted in three crop seasons with 3 replications for this period. The data on growth and leaf yield parameters were collected for each crop season after 90 days of pruning and leaf quality was analyzed for 60 days of pruning for each crop season. Data on growth, leaf yield and leaf quality of mulberry plants were collected three times for this research. Following parameters were considered for data collection:

Growth and Yield Parameters:

Growth Parameters

(i) **Node per meter per plant**

The number of node per meter was determined by counting the number of node per meter manually for each of the plant each after 90 days of pruning.

(ii) **Total number of branches per plant**

The total branch number per plant was determined by counting the number of branch per plant manually for each of the plant each after 90 days of pruning.

(iii) **Total branch length per plant (cm)**

The total branch length was determined through measuring the length of all the branches of a plant by the measuring tape each after 90 days of pruning.

(iv) **Length of longest shoot per plant (cm)**

The length of the longest shoot for randomly selected each plant was measured by the measuring tape each after 90 days of pruning.

(v) **Total shoot weight per plant (g)**

The total shoot weight was determent by weight all shoots of a plant by the weighing balance each after 90 days of pruning.

Leaf Yield Parameters:

(i) **10 leaf area (cm^2/ plant)**

Randomly selected 10 leaves per plant were measured by the Green Leaf Area Meter.

(ii) **Weight of 10 green leaves per plant (g)**

Randomly selected 10 leaves for each plant and weighed by using the weighing balance each after 90 days of pruning.

(iii) **Total leaf yield (mt/ha/yr)**

At maturity of leaf (after 90 days of pruning) the total green leaf yield per hectare per year was determined by using the following formula:

Leaf yield$(mt/\ ha\ /\ year\ )$ = $\frac{Leaf\ weigh\ \ (gm)\ of\ per\ m^2\ plant \times nulber\ of\ crop\ season\ per\ year \times 10000\ m^2}{1000 \times 1000}$

Leaf Quality Parameters:

In case of leaf quality characters of mulberry plant the following parameters were recorded by using the specific methods respectively:

1. Moisture percentage (%)
2. Chlorophyll-a
3. Chlorophyll-b
4. Reducing sugar (%)
5. Total mineral (%)
6. Total sugar (%)
7. Soluble carbohydrate (%)
8. Crude protein (%)

Procedure of leaf quality analysis

The leaf samples of mulberry plant was collected in paper bags at 60 days after pruning at different heights of the plant (top, middle and bottom) and composite leaf samples were prepared. The collected leaves were shade dried for three days and then dried in hot air oven at 70°C for one hour and was grounded into powder for chemo-assay. The leaves obtained from different treatments were used for estimation of bio-chemical constituents viz: leaf moisture (%) by Vijayan *et al.* (1996) method, total sugar and reducing sugar content by Dinitrosalicylic acid (DNS) method of Miller (1972) and procedure of Loomis *et al.* (1973), crude protein contents by Kjedhal method of Wong (1923), Chlorophyll-a and Chlorophyll-b content were estimated following the procedure outlined by Hiscox and Israelstam (1979) using the spectrophotometer and were computed using the standard formulae (Arnon, 1949) and was expressed on fresh weight basis, total mineral (%) contents by the method of Vijayan *et al.* (1996) and soluble carbohydrate content by the method of Loomis and Shull (1937) were used.

Table 1. Inherent physicochemical properties of the experimental soil of (0-5 years) and (6-10 years) ages of mulberry garden

Soil pH		**OM (%)**		**N (%)**		**P (µg/g)**		**K (meq/100 g soil)**		**Zn (µg/g)**		**S (mg/kg)**	
Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)	
(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)
7.6	8.1	1.23	1.06	0.06	0.04	9.9	10.1	0.13	0.13	0.49	0.5	17.18	17.17

Procedure of soil physicochemical properties analysis

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). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979). Soil available S (mg kg-1) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen, 1996).

Statistical analysis

Mulberry plant growth and composition data were analyzed by a one-way analysis of variance for the main effects of mulberry plant. All statistical analysis was conducted using Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK). SigmaPlot 12.5 version was used for representing results as a figure form. Leaf quality was analyzed using the Statistical Analysis System (SAS 9.1.3).

11. Results and discussion:

Experiment-1: Optimization of nitrogen (N) for growth, leaf yield and leaf quality of mulberry Growth response of mulberry plant due to ages of plant and nitrogen Node per meter

The node per meter of older leaf was significantly ($P < 0.001$) higher than the younger leaf of mulberry plant. Among the six fertilizer treatments the treatment T_5 (N_{400} P_{150} K_{100} kg/ha/yr) exhibited statistically the highest number of nodes in both the older (6-10 years) and younger (< 5 years) mulberry plants. But their interactive effect between plant age and N_2 fertilizer was not significantly different (Table 1, Figure 1). However, among the two types of mulberry plant the maximum node per meter 34.30 was found for (6-10) year's plant.

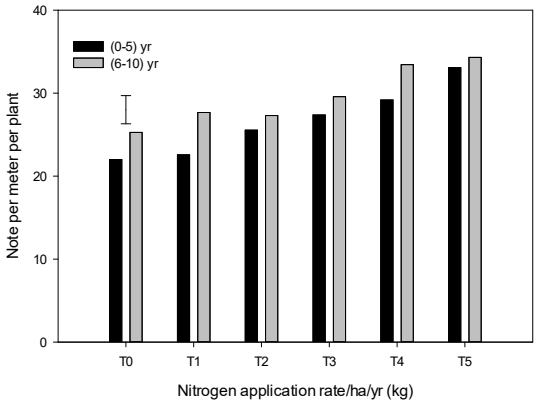

Figure 1. Node per meter in mulberry plants as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Total number of branches per plant

Total branch per plant was statistically ($P < 0.001$) differ between the younger and older mulberry plant. The treatment T_5 (N_{400} P_{150} K_{100} kg/ha/yr) showed the significant number of total branch per plant in both the older and younger mulberry plant as compared to the other treatments. But their interactive effect (Age × Treatment) was not significantly differ (Table 1, Figure 2). Among the younger and older mulberry plant the maximum total branch number/plant was obtained (16.67) in older (6-10 years) mulberry plant.

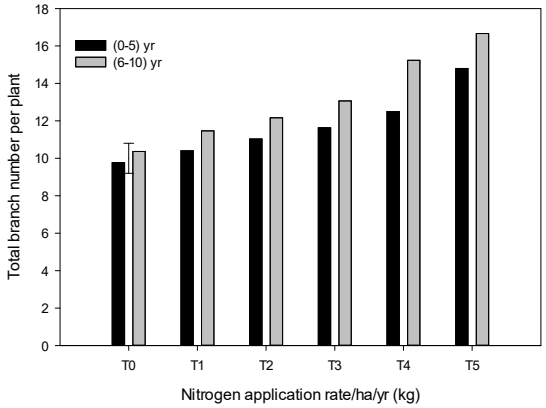

Figure 2. Total number of branches per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Total branch length per plant (cm)

The total length of branches per plant differed significantly for nitrogen treatment ($P \leq 0.001$), plant types ($P \leq 0.001$) and also the interactive effect of (Age × Treatment) ($P \leq 0.01$). Between the two types of plant the average maximum total branch height per plant was 1145.67 cm in (6-10) year's plant for T_5 treatment and the average minimum height was 1079.61 cm in (0-5) year's plant for control treatment (Table 1 and Figure 3).

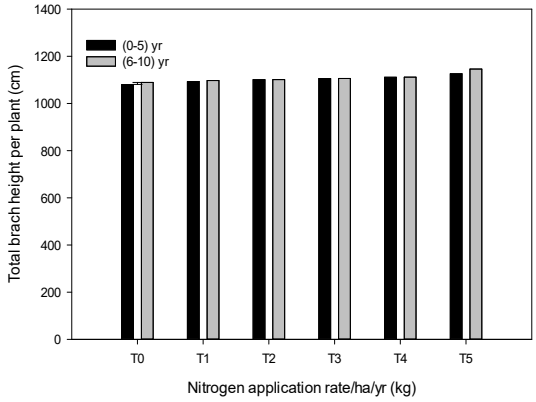

Figure 3. Total branch length per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Length of longest shoot per plant (cm)

The length of longest shoot was significantly (P < 0.001) increased with increment of the rate of N application in the mulberry plant. Among the six doses of nitrogen the average maximum length of shoot was found for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) than the other treatments. There was no significant difference between the plant types and the interactive effect (Age × Treatment) (Table 1, Figure 4). However, between the two types of mulberry plant the maximum average length of shoot was 168.32 cm^2 for older (6-10) and minimum 124.55 cm for (0-5) year's mulberry plant.

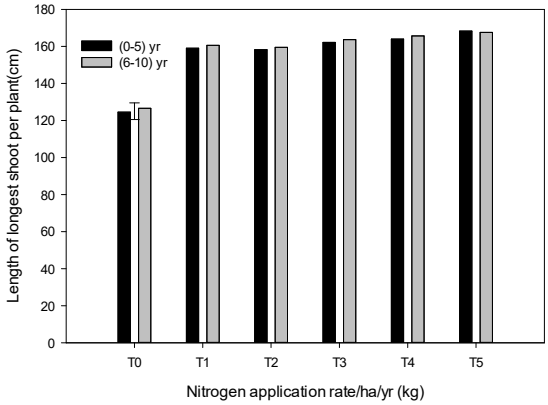

Figure 4. Length of longest shoot per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Total shoot weight per plant (g)

The total shoot weight per plant was not significantly differed both for the ages of mulberry plant and the interactive effect (Age × Treatment) (Table 1, Figure 5). The average maximum total shoot weight was 828.38 g for T_5 (N_{400} P_{150} K_{100} kg/ha/yr) treatment which was statistically ($P \leq 0.001$) greater than those of other treatments. The minimum total shoot weight was 756.36 g in (6-10) year's plant for control treatment.

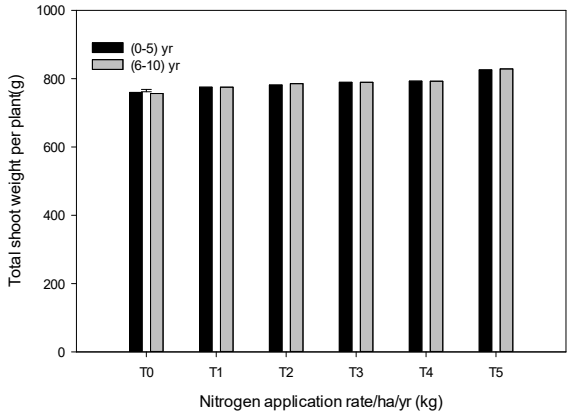

Figure 5. Total shoot weight per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

10 leaf area per plant (cm^2)

The mean leaf area of 10 leaves of older mulberry plant was significantly ($P < 0.05$) affected by N application than the younger mulberry plant. The treatment T_5 (N_{400} P_{150} K_{100} kg/ha/yr) showed the highest mean leaf area both for the older and younger mulberry leaf than the other N treatments. But their interactive effect (Age × Treatment) did not differ significantly both for the younger and older mulberry plant (Table 1, Figure 6). However, among the two types of mulberry plant the maximum mean leaf area of 743.74 cm^2 was found for older (6-10) mulberry leaf.

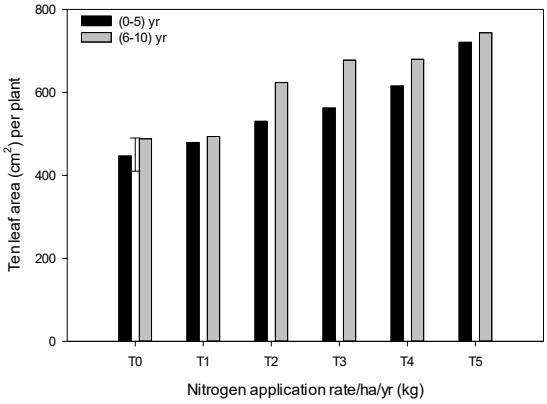

Figure 6. 10 leaf area per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Weight of 10 leaves per plant (g)

The weight of 10 leaves per plant varied significantly ($P < 0.05$) for the older mulberry plant than the younger mulberry plant. Among the six N_2 fertilizer treatments the treatment T_5 (N_{400} P_{150} K_{100} kg/ha/yr) was significantly ($P < 0.001$) higher both for the older and younger mulberry plant. he interactive effect of mulberry plant age and N fertilizer treatment was not statistically different (Table 1, Figure 7). The maximum weight of 10 leaves 50.37 g was recorded in older (6-10 years) mulberry plant and in case of (0-5) years mulberry plant the highest 10 leaf weight per plant was 47.40 gm.

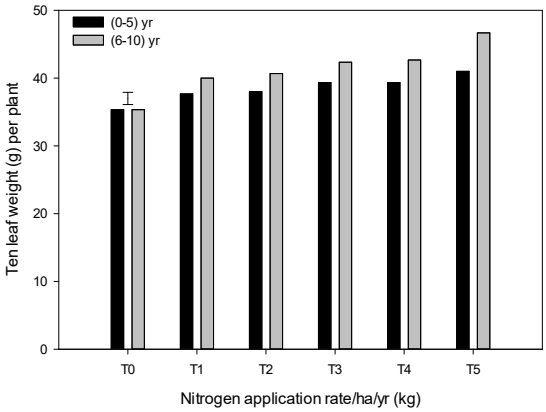

Figure 7. Weight of 10 leaves per plant in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of nitrogen and mulberry plant age interactions.

Table-1: Effect of different levels of nitrogen on mulberry plant production

Factors	Node/Meter	Total branch number/plant	Length of longest shoot/plant (cm)	Total branch height/plant (cm)	Total shoot weight/plant (g)	10 Leaf Area/plant (cm^2)	10 Leaf weight/plant (g)	Total Leaf Yield/ha/yr (mt)
Age	***	***	N.S	***	N.S	*	*	***
Treatments	***	***	***	***	***	***	***	***
Age × Treatment	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.

Total leaf yield/ha/year (mt)

The total leaf yield of mulberry plants increased significantly with increased rate of N application up to the highest level (N_{400} P_{150} K_{100} kg/ha/yr) in T_5 treatment (Table 1, Figure 8). The highest leaf yield of 51.88 mt/ha/yr was recorded in T_5 treatment from older (6-10 years) mulberry plants. Under each treatment the older plants (6-10 years) gave higher leaf yield as compared to the younger (0-5 years) mulberry plants.

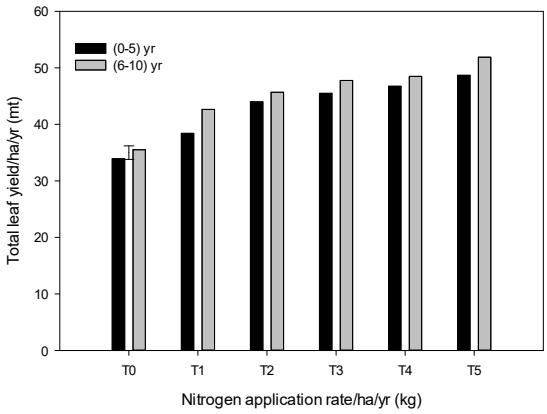

Figure 8. Total leaf yield/ha/year in mulberry as influenced by various levels of N management practices. Where, T_0 = 0 kg N/ha/yr, T_1 = 80 kg N/ha/yr, T_2 = 160 kg N/ha/yr, T_3 = 240 kg N/ha/yr, T_4 = 320 kg N/ha/yr and T_5 = 400 kg N/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of nitrogen and mulberry plant age interactions.

Effect of ages of mulberry plant and nitrogen on leaf quality of mulberry plant

Moisture (%)

The moisture (%) of mulberry leaves was significantly changed due to the plant ages and N fertilizer treatment. Among the six fertilizer treatments the maximum leaf moisture 78.59 % was found in older (6-10 years) plants where the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr). The minimum moisture 67.78 % being noted in younger (0-5 years) mulberry plants in the treatment of T_0 (Table 2).

Chlorophyll-a (Mg/g)

The Chlorophyll-a content in mulberry leaves was statistically varied due to both the plant ages and N treatments. The maximum Chlorophyll-a (5.41 Mg/g) was recorded in (6-10 years) old plant for the treatment of T_5 and the minimum value being noted (1.07 Mg/g in younger plants (0-5years) for the treatment of T_0 (Table-2).

Chlorophyll-b (M g/g)

The plant ages and N_2 fertilizer treatment significantly changed the Chlorophyll-b content in mulberry leaves. Among the six fertilizer treatments the maximum Chlorophyll-b (59.23 Mg/g) was recorded in 6-10 years aged mulberry plant for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr). On the other hand, the minimum Chlorophyll-b (45.73 Mg/g) was also recorded in 6-10 years aged mulberry plant for the treatment of T_3 (N_{240} P_{150} K_{100} kg/ha/yr) (Table-2).

Reducing Sugar (%)

The reducing sugar in mulberry leaf did not differ statistically both for the plant ages and N fertilizer treatment. However, the maximum reducing sugar 4.09 % was recorded in older (6-10 years) plant for the treatment of T_5 which was statistically similar to the treatments of T_2, T_3 and T_4 (Table 2).

Table-2: Effect of different level of nitrogen and ages of mulberry plant on bio-chemical constituents in mulberry leaf

Treatments	Moisture (%)		Chlorophyll-a (Mg/g)		Chlorophyll-b (Mg/g)		Mineral (%)		Crude Protein (%)		Carbohydrate (%)		Total Sugar (%)		Reducing Sugar (%)	
	Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)	
	(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	67.78g	68.96f	1.07g	2.87c	50.98h	45.84i	8.81e	8.96e	16.14i	17.07h	7.44e	7.66de	4.75f	4.85f	3.12f	3.18f
T_1	71.22e	71.72e	1.47ef	4.36b	52.3f	52.22fg	9.95d	9.99d	16.70hi	17.69g	7.94d	7.97d	4.98ef	5.31d	3.32ef	3.58de
T_2	73.82d	73.93d	1.41ef	5.35a	52.07g	55.85c	9.92d	10.03d	19.61f	20.32e	9.41c	10.00b	5.19de	5.44d	3.99ab	4.09a
T_3	74.09d	75.35c	1.49e	2.88c	55.53d	45.73i	10.51c	10.62c	21.75cd	22.52b	9.77bc	10.09ab	5.77c	5.96bc	3.63cd	3.88abc
T_4	76.84b	77.18b	2.02d	4.37b	55.23e	55.87c	11.11ab	11.37a	21.24d	22.29bc	9.89b	10.10ab	6.09b	6.19b	3.81bcd	3.86abcd
T_5	77.19b	78.59a	1.37f	5.41a	57.73b	59.23a	10.66c	10.72bc	22.81ab	23.22a	9.92b	10.44a	6.18b	6.51a	3.88abc	4.08ab

Total Mineral (%)

The plant ages and N_2 fertilizer treatment significantly changed the total mineral content in mulberry leaves. The maximum total mineral 11.37% was recorded in the leaf of older (6-10 years) plants for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) which was statistically similar with the leaf of (0-5) year's plant. However, the minimum amount of 8.81 % was recorded in younger (0-5 years) plants for the treatment of T_0 (Table 2).

Total Sugar (%)

The total sugar content in mulberry leaves increased considerably due to the plant ages and N_2 fertilizer treatment. The maximum total sugar (6.51%) was recorded in the leaf of older (6-10 years) plants for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr). The minimum total sugar of 4.75% was recorded in younger (0-5 years) plants for the treatment of T_0.

Soluble Carbohydrate (%)

The soluble carbohydrate content in mulberry leaves was significantly higher due to the plant age but not statistically differ due to the N_2 treatment. The maximum soluble carbohydrate 10.44 % was recorded in the leaf of older (6-10 years) plants for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) which was statistically similar to the treatments T_3 and T_4. However, the minimum soluble carbohydrate (7.44 %) was recorded in (0-5 years) plants for the treatment of T_0 (Table 2).

Crude Protein (%)

The age and N fertilizer treatment created a significant effect on the crude protein content in mulberry leaves. The maximum crude protein (23.22%) was recorded in the leaf of older (6-10 years) plants for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) which was statistically similar to the leaves of younger (0-5) years) plants. On the other hand the minimum crude protein (16.14%) was recorded in the leaf of younger (0-5 years) plants for the treatment of T_0 (Table 2).

Discussion

Effect of nitrogen on mulberry leaf yield and quality

The increased doses of N significantly improved the leaf yield and quality of mulberry plant. In our study we applied six levels of N at the rate of 0 kg, 80 kg, 160 kg, 240 kg, 320 kg and 400 kg N/ha/yr, respectively with BSRTI recommended P and K @ 150 kg P and 100 kg K/ha/yr in four splits doses. The experimental result showed that the yield contributing characters of mulberry plant viz: nodes per meter, total number branches per plant, total branch height per plant, length of longest shoot per plant, total shoot weight per plant, 10-leaf area per plant, 10-leaf weight per plant and total leaf yield/ha/year were highly significant ($P \leq 0.001$) for the treatment of T_5 (N_{400} P_{150} K_{100} kg/ha/yr) as compared to the other treatments (Table 1). The highest mulberry leaf yield was 51.88 mt/ha/year for the treatment of T_5 which was 46.14 % higher than the maximum yield of control treatment. However, the interaction effect of plant age × fertilizer treatments was not statistically significant ($P \leq 0.05$) except total branch length per plant (cm) (Table 1). Similarly, the maximum average biochemical properties viz: moisture (78.59%), chlorophyll-a (5.41 Mg/g), chlorophyll-b (59.23 Mg/g), total sugar (6.51%), soluble carbohydrate (10.44%), reducing sugar (4.08%) and crude protein (23.22%) were recorded for T_5 treated mulberry plant which was statistically higher than the other treatments. These findings are 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 treatments, the rate of 400 kg N/ha/yr with two irrigation showed as significantly the best performance both for the yield components (plant height, number of branches per plant, number of leaves per branches and leaf yield per plant) and leaf quality parameters (leaf moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral) which is more or less similar to our findings. Such results was also reported by Miah (1989) who found that the application of 400 kg N with 200 kg P and 150 kg K led to increase the mulberry leaf yield by 77.92% over the control treatment and the leaf constituents viz: leaf moisture, chlorophyll-a, chlorophyll-b, total sugar (%), soluble carbohydrate (%), reducing sugar and crude protein (%) except total mineral contents increased gradually due to progressive increase of NPK fertilizers. Ray (1978) also applied 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 compared to the control (T_0) treatment, leaf yield per plant in T_1, T_2 and T_3 were increased by 25.96, 41.60 and 49.29%, respectively. Similarly, Shinde et al. (2012) found that the application of 360 kg N: 180 kg P: 180 kg K/ha/yr gave the maximum number and average weight of leaves and length of mulberry plant. Application of N with P and K @ 400, 150 and 100 kg/ha/yr respectively might be optimum to fulfill the physiological development of the plants and led to perform best in terms of growth, yield and quality of mulberry plants and the leaves as well. Rafiq et al. (2010) reported that maximum leaf area and total leaf biomass of plants are a determinant of higher crop yield.

Impact of ages of mulberry plant on leaf yield and quality

Increased ages of mulberry plant significantly increased the leaf yield and quality of mulberry plants. Results of this study showed that 6-10 year's mulberry plant gave the maximum leaf yield with better leaf quality as compared younger plants of less than 5 years age. For the present study six N treatments, doses (0, 80, 160, 240, 320 and 400 kg/ha/yr) were applied along with blanket dose of 150 kg P and 100 kg K /ha/yr to see the effects on leaf yield and quality as well as the growth of mulberry plants of two ages, less than 5 years and 6-10 years. It reseals from the trial that nodes per meter, total branches number per plant, total branch height per plant, 10-leaf area per plant, 10-leaf weight per plant and total leaf yield/ha/year except length of longest shoot and total shoot weight per plant were significantly increased for 6-10 years plant than the 0-5 years plant. However, the maximum average mulberry leaf yield was 51.88 mt/ha/year for 6-10 years plant which was 6.57 % higher than the maximum average yield of 48.68 mt/ha/yr as noted in younger plants of less than 5 years of age. The leaves quality viz: moisture, chlorophyll-a, chlorophyll-b, total sugar, soluble carbohydrate, reducing sugar and crude protein were also better in older plants of 6-10 years of age. Such type of study is totally new in mulberry crop. The older plants haring deeper rooting system might be more capable and efficient to explore more nutrients as compared to the younger mulberry plants of less than 5 years of age. Thus, led to perform better in terms of growth of mulberry plants and the leaf yield and quality at older age (6-10 years). Deborah et. al. (1990) found that the N absorption is 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 fertilizer levels (N at 20, 50, 80 and 100 mg /Liter); solution nutrient levels in the medium and found N absorption 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. Similarly, Leghari et al., (2016) reported that when the plants roots completely developed and leaves also become wider in size then the N utilization increases, besides 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 help in N use efficiency.

Experiment-2: Optimization of phosphorus (P) for growth, leaf yield and leaf quality of mulberry

Growth response of mulberry plant due to ages of plant and Phosphorus

Node per meter per plant

The average node per meter of mulberry plant was highly significant ($P < 0.001$) both for the plant ages and increased P application. Among the six levels of P and two ages of mulberry plant the maximum average node/meter was 35.30 in the leaves of older (6-10 years) plant was recorded in the treatment T_4 (N_{300} P_{160} K_{100} kg/ha/yr) in four split doses. Also the interactive effect between plant ages and fertilizer treatment differed significantly ($P < 0.01$) (Table 1, Figure 1). The minimum average node per meter was 21.63 in younger plants of less than 5 years of age (control treatment).

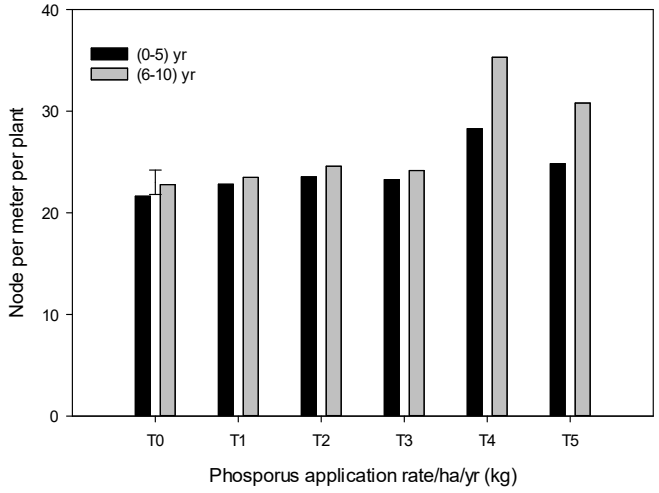

Figure 1. Node per meter per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

Length of longest shoot per plant (cm)

The length of longest shoot of mulberry plant was significantly increased due to the ages of mulberry plant ($P < 0.05$) and the increased doses of phosphorus application ($P < 0.001$). But the interactive effect of plant age and P fertilizer treatment could no create any significant impact on the length of longest shoot of the mulberry plant. However, the maximum average length of shoot was 165.13 cm recorded in older plants (6-10 years) in the treatment of T_4, the minimum length of the longest shoot (122.50 cm) being noted in younger mulberry plants of less than 5 years of age in T_0 treatment (Table 1, Figure 2).

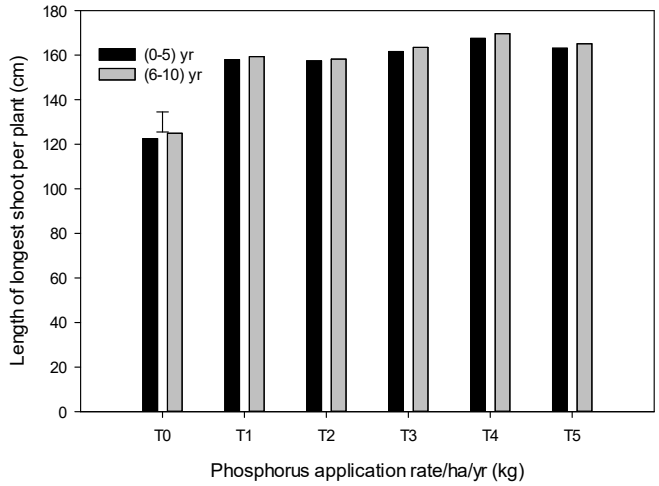

Figure 2. Length of longest shoot per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total number of branches per plant

The effect of P treatments on total number of branches of mulberry plant was highly significant ($P < 0.001$), but the response of plant ages was not significant. However, the average maximum total number of branches of mulberry plant was 15.27 in older plants (6-10 years) in T_4 (N_{300} P_{160} K_{100} kg/ha/yr) (Table 1, Figure 3).

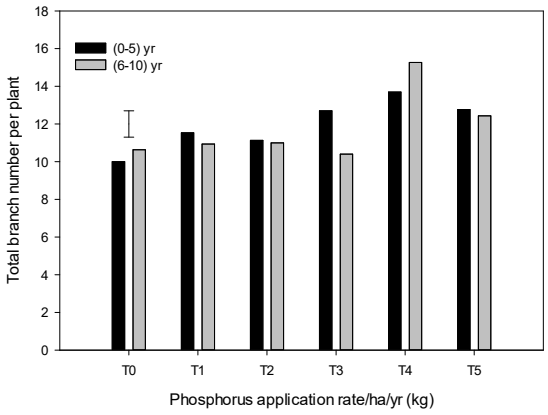

Figure 3. Total number of branches per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total length of branches per plant (cm)

The individual and interaction effect of ages of mulberry plants and P treatments on the totallength of branches was highly significant ($P < 0.001$). The maximum average total branch length per plant was 1145.67 cm in older (6-10 years) plants for T_4 treatment and the minimum height was 1078.72 cm in younger (0-5 years) plants for the control treatment (Table 1, Figure 4).

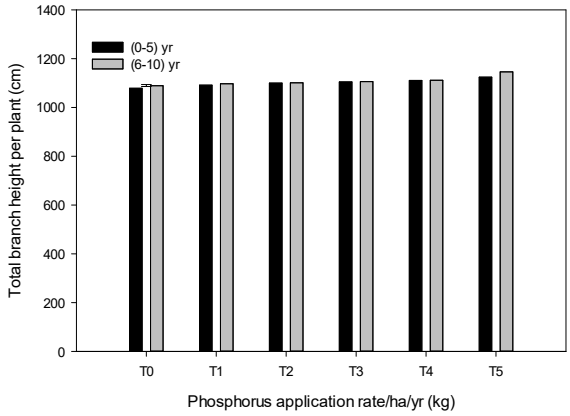

Figure 4. Total length of branches per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total shoot weight per plant (g)

The total shoot weight of mulberry plant was significantly ($P < 0.001$) increased due to increased rate of application of phosphorus fertilizer up to 160 kg/ha/yr (T_4). The maximum average total shoot weight was 827.55 g in older plants 6-10 years of age in T_4 treatment. The minimum shoot weight being noted in younger leaves (755.29 g) of less than 5 years of age for control treatment (Table 1, Figure 5).

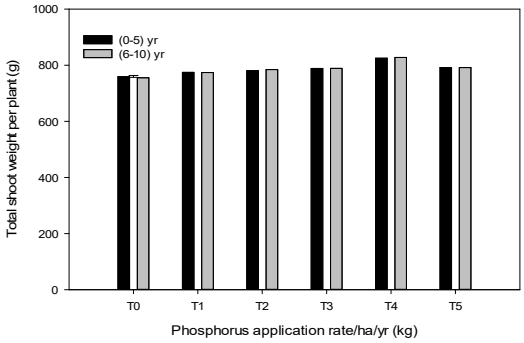

Figure 5. Total shoot weight per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

10 leaf area per plant (cm^2)

The maximum average 10 leaf areas per plant was 674.89 cm^2 in (6-10) year's plant for T_4 (N_{300} P_{160} K_{100} kg/ha/yr) treatment which was significantly higher than rest of the P treatments. P treatments could not create any significant variation in leaf area better the mulberry plants of different ages. However, the minimum average leaf area (476.98 cm^2) was recorded in younger plants of less than 5 years of age in T_0 treatment (Table 1, Figure 6).

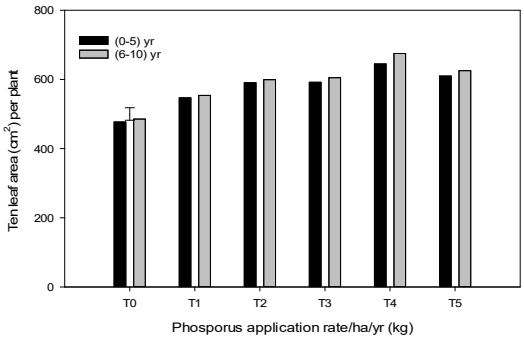

Figure 6. 10 leaf area per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of phosphorus and mulberry plant age interactions.

Table 1: Effect of different levels of Phosphorus on mulberry plant production

Factors	Node/ Meter	Total branch number	Length of longest shoot/plant (cm)	Total branch height/plant (cm)	Total shoot weight/plant (g)	10 Leaf area/plant (cm^2)	10 Leaf weight/plant (g)	Total Leaf Yield/ha/yr (mt)
Age	***	n.s	*	***	n.s	n.s	***	***
Treatments	***	***	***	***	***	***	***	***
Age × Treatment	**	*	n.s	**	n.s	n.s	*	n.s.

Weight of 10 leaves per plant (g)

The differences in the average of ten leaves weight per plant were highly significant ($P < 0.001$) both for the plant ages and the P levels. Among the six P levels the maximum average leaf weight of 46.67 g recorded in 6-10 years plant due to the application of 160 kg P/ha/yr along with 300 kg N and 100 kg K/ha/yr in four split doses. The interactive effect between mulberry plant age and P treatment was significant. However, the mean minimum leaf weight (35.33 g) noted in 0-5 year's plant in T_0 treatment (Table 1, Figure 7).

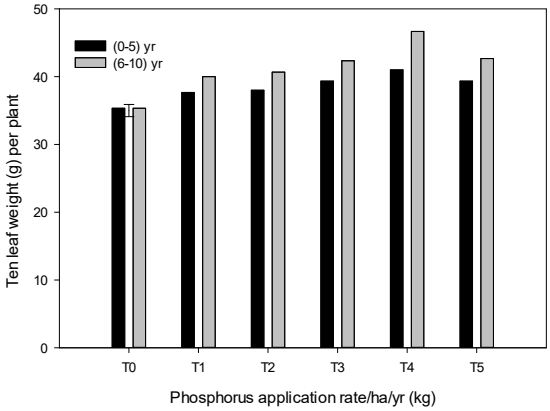

Figure 7. Weight of 10 leaves per plant in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Total leaf yield (mt/ha/yr)

The individual and interactive effects of plant age and P doses on total leaf yield of mulberry plants was highly significant (Table 1, Figure 8). The highest total leaf yield 47.69 mt/ha/yr was recorded in T_4 treatment (N_{300} P_{160} K_{100} kg/ha/yr) in older plants of 6-10 years of age. The lowest total leaf yield of 27.78 mt/ha/yr being noted in younger plants of less than 5 years of age in the control (T_0) treatment.

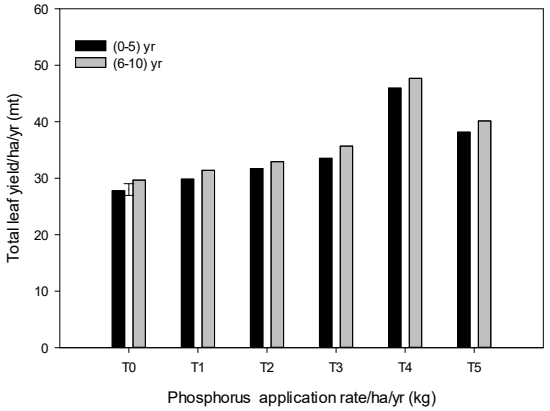

Figure 8. Total leaf yield (mt/ha/yr) in mulberry as influenced by various levels of P management practices. Where, T_0 = 0 kg P/ha/yr, T_1 = 40 kg P/ha/yr, T_2 = 80 kg P/ha/yr, T_3 = 120 kg P/ha/yr, T_4 = 160 kg P/ha/yr and T_5 = 200 kg P/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

Effect of ages of mulberry plant and phosphorus on leaf quality of mulberry
Moisture (%)

The moisture (%) of mulberry leaf was significantly increased due to the plant ages and P levels. Among the six fertilizer treatments the maximum moisture 74.59% was recorded in the leaf of 6-10 years plant for the treatment of T_4 (N_{300} P_{160} K_{100} kg/ha/yr) which was statistically similar with the treatment of T_2. The minimum leaf moisture 65.93% was recorded in the leaf of 0-5 years mulberry plant for control treatment (Table 2).

Chlorophyll-a (Mg/g)

The Chlorophyll-a content in mulberry leaf was not statistically improved due to the plant ages and P treatment. However, the maximum Chlorophyll-a 2.46 Mg was recorded in the leaf of 6-10 year's plant for the treatment of T_5 and the minimum Chlorophyll-a was 1.74 Mg for T_1 and T_3 treatments (Table 2).

Chlorophyll-b (Mg/g)

The plant ages and P levels did not significantly change the Chlorophyll-b content in mulberry leaf. However, the maximum Chlorophyll-b was 59.95 Mg in 6-10 year's mulberry plants for the treatment of T_5 and the minimum Chlorophyll-b was 48.36 Mg in 0-5 year's plants for control treatment (Table 2).

Table: 2 Effect of different level of phosphorus and ages of mulberry plant on Bio-chemical constituents in mulberry leaf

Treatments	Moisture (%)		Chlorophyll-a (Mg/g)		Chlorophyll-b (M g/g)		Mineral (%)		Crude Protein (%)		Carbohydrate (%)		Total Sugar (%)		Reducing Sugar (%)	
	Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)		Plant age (years)	
	(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	65.93h	66.82g	1.91bc	2.34ab	48.36b	51.29ab	8.28i	8.31i	14.88l	15.18j	6.65i	6.87h	4.48i	4.67g	3.03g	3.19f
T_1	72.16c	71.20d	1.74c	2.44a	52.09ab	55.62a	8.41h	8.63f	15.62i	15.18j	7.05g	7.09g	4.61h	4.75f	3.25e	3.33d
T_2	73.90b	74.01ab	2.34ab	1.91bc	48.36b	51.30ab	9.97cd	9.93de	19.57f	16.95h	7.77f	7.78f	4.73f	5.09e	3.71b	3.67b
T_3	67.93f	72.7c	1.74c	2.45a	52.08ab	55.60a	9.99bc	10.03ab	18.28g	20.41dc	9.34d	8.71e	5.95c	5.71d	3.19f	3.28de
T_4	72.76c	74.59a	2.15abc	2.46a	52.08ab	55.95a	8.38h	8.53g	21.63b	21.86a	9.59c	9.77a	6.08a	6.10a	3.72b	3.78a
T_5	69.67e	67.91f	2.43ab	1.92bc	48.35b	51.31ab	9.91e	10.07a	20.23e	20.49c	9.55c	9.67b	6.07b	6.07b	3.62c	3.61c

Total mineral (%)

The total mineral content in mulberry leaves was significantly improved due to the plant ages and increased P levels. The maximum total mineral was found 10.07 % in the leaves of 6-10 year's plant in T_4 treatment which was statistically similar with T_3. However, the minimum total mineral was 8.23 % in the leaves of 0-5 years plant for control treatment (Table 2).

Crude protein (%)

The ages of mulberry plant and increased level of P fertilizer significantly increased the crude protein content in mulberry leaf. Among the two ages of mulberry plant the maximum crude protein was 21.86 % in 6-10 years plant for the T_4 treated mulberry plant. The minimum crude protein was 14.18 % in 0-5 years plant in control treatment (Table 2).

Soluble carbohydrate (%)

The soluble carbohydrate content in mulberry was significantly changed due to the plant ages and application of different level of P. The maximum soluble carbohydrate (9.77 %) was recorded in 6-10 year's plants in T_4 treated plants. However, the minimum soluble carbohydrate (6.65%) being noted in the leaves of 0-5 year's plants in the control treatment (Table 2).

Total sugar (%)

The ages of mulberry plant and levels of P significantly improved the total sugar content in mulberry leaves. Among the six levels of P the maximum total sugar 6.10 % was recorded in the leaves of 6-10 years plant for T_4 treated mulberry plant. Conversely, the minimum total sugar was 4.48 % in 0-5 years plants for control treatment (Table 2).

Reducing sugar (%)

The reducing sugar in mulberry leaves was significantly increased due to the higher ages of mulberry plant and levels of P fertilizer. Among the two ages of mulberry plant, the maximum reducing sugar was 3.78 % in the leaves of 6-10 years plant for T_4 treated plant. The minimum amount of reducing sugar was 3.03% in 0-5 year's plants in control treatment (Table 2).

Discussion

Effect of phosphorus on yield and quality of mulberry leaf

Elevated doses of P up to 160 kg/ha/yr considerably increased the leaf yield and quality of mulberry plant. 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 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 growth and yield contributing components of mulberry plant such as nodes per meter, total number of branches per plant, length of longest shoot, total shoot weight, total branches height, mean leaf area, mean leaf weight per plant and total leaf yield/ha/year were significantly ($P \leq 0.001$) increased with increased rate of P application up to 160 Kg P/ha/yr with 300 kg N/ha/yr and 100 kg K/ha/yr. The maximum leaf yield was 47.69 mt/ha/year was recorded for the treatment of T_4 (N_{300} P_{160} K_{100} kg/ha/yr) which was 60.79 % higher than that recorded in the control (T_0) treatment. The interactive effect of plant age × P treatments the growth and yield contributing characters except length of longest shoot, total shoot weight, 10 leaf area (cm^2) per plant and total leaf yield/ha/year were also significantly differed (Table 1). Likewise, the nutritional components viz: moisture (%), crude protein (%), total sugar (%), soluble carbohydrate (%) and reducing sugar (%) except chlorophyll-a, chlorophyll-b and total mineral (%) were also significantly improved in T_4 (N_{300} P_{160} K_{100} kg/ha/yr) treated mulberry plant. The present findings are more or less similar with the

previous findings of Paul *et al.* (2009), where four levels of P in four split doses viz; 0 kg, 100 kg, 150 kg and 200 kg P/ha/yr were applied along with N and K. Among the four levels of P the maximum values both for the yield components (plant height, number of branches per plant, number of leaves per branches and leaf yield per plant) and leaf quality parameters viz: leaves moisture, crude protein, reducing sugar, total sugar, starch and soluble carbohydrate except mineral were noted for the application of 200 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr. Similarly, Bose *et al.* (2009) found the significant impact of elevated P on mulberry leaf yield and quality. They opined that due to the involvement of phosphorus in cell division and development of meristamatic tissue, energy storage, and help in promotion of root and shoot the growth and yield of mulberry may be increased. In the present trial application of P at 160 kg/ha/yr may be optimum to fulfill the requirement of physiological characters to accelerating the cell division and growth of mulberry plants. Similarly, Shankar (1997) reported the positive effects of phosphorus on stimulating root growth, increasing many leaf quality parameters and increasing foliage production in mulberry. Likewise, Singh *et al*. (2016) reported that next to nitrogen, phosphorus is very important essential nutrients for plant growth and is found in every living plant cell which 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.

Impact of mulberry plant ages on leaf yield and quality

The leaf yield and quality of mulberry plant was significantly increased by the increased ages of plant. In the present study the older mulberry plants of 6-10 years of age gave the maximum leaf yield with superior leaf quality than the younger ages of less than 5 years. P was applied at 0 kg, 40 kg, 80 kg, 120 kg, 160 kg and 200 kg/ha/yr along with BSRTI recommended doses of N and K @ 300 kg N and 100 kg K/ha/yr, respectively in four splits doses for mulberry plant production. Between the (0-5) and (6-10) year's mulberry plant the maximum average growth and yield contributing parameters viz: nodes per meter per plant, length of longest shoot per plant, total branches height per plant, 10-leaf weight per plant and total leaf yield/ha/year were recorded for older plants of 6-10 years of age as compared to younger plants. However, the maximum average mulberry leaf yield was 47.69 mt/ha/year which was 3.79% higher than the maximum average yield (45.95 mt) noted in younger plants. Most of the leaves quality parameters except percentage mineral were also significantly increased due to the higher ages of mulberry plant. The maximum average moisture, Chlorophyll-a, Chlorophyll-b, crude protein, soluble carbohydrate, total sugar and reducing sugar were 74.59, 2.46, 55.95, 21.86, 9.77, 6.10 and 3.78 (%) respectively recorded in 6-10 year's mulberry plants. In case younger plants of 0-5 years the maximum average moisture, Chlorophyll-a, Chlorophyll-b, crude protein, soluble carbohydrate, total sugar and reducing sugar percentage were 73.90, 2.43, 52.09, 21.63, 9.59, 6.08 and 3.72 (%) respectively. This type of study was not conducted previously in mulberry crop. But, Deborah *et al.* (1990) found that the P absorption is 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 is more or less similar with our findings. However, they did not explain the causes of high P absorption by the older plant. It may be due to the increased nutrient demand and absorption by the older plants compared to the younger ones. It may be attributed to the well developed larger root system of the older mulberry plant accessing a greater volume of the soil which is corroborates with the findings of Radha *et al.* (1988). They reported that deficiency of phosphorus in nutrient solution reduced shoot length, root length, shoot weight, root weight and ultimately reduced the total leaf yield, confirming the importance of phosphorus.

Experiment-3: Optimization of potassium (K) for growth, leaf yield and leaf quality of mulberry

Growth response of mulberry plant due to ages of plant and potassium

Node per meter

The number of nodes per meter of mulberry plants increased significantly wit increased rates of K application and with higher ages of the plants (Table 1, Figure 1). The higher number of nodes per meter (35.73) was recorded in T_5 (N_{300} P_{150} K_{150} kg/ha/yr) treatment in older plants of 6-10 years of age.

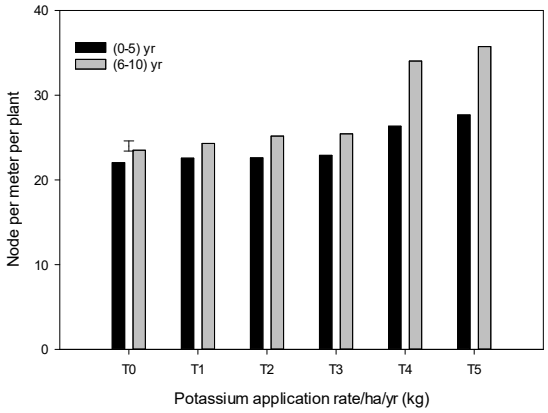

Figure 1. Node per meter per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of potassium and mulberry plant age interactions.

Length of longest shoot per plant

The length of longest shoot of mulberry plant significantly ($P < 0.001$) differed for different levels of potassium, plant ages and their interactive effect. The maximum average length of the longest shoot was 165.08 cm for T_4 treatment in older plants of 6-10 years. On the other hand the minimum length of the longest shoot was 122.17 cm recorded in younger plants of less than 5 years in T_0 treatment (Table 1, Figure 2).

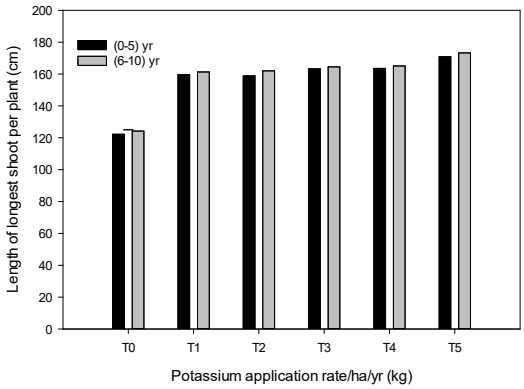

Figure 2. Length of longest shoot per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of potassium and mulberry plant age interactions.

Total number of branches per plant

Total branch number/plant was statistically ($P < 0.001$) differ between the younger and older mulberry plant. The treatment T_5 (N_{300} P_{150} K_{150} kg/ha/yr) gave the maximum number of branches per plant for the older (6-10) year's mulberry plants. But their interactive effect (Age × Treatment) was not significantly different (Table 1, Figure 2). Among the younger and older mulberry plant the maximum total branch number/plant was 14.57 in older (6-10 years) mulberry plant for the treatment of T_5 where as the minimum total branch number 10.77 was recorded in (0-5) years plant for the treatment of T_0 (Table 1, Figure 3).

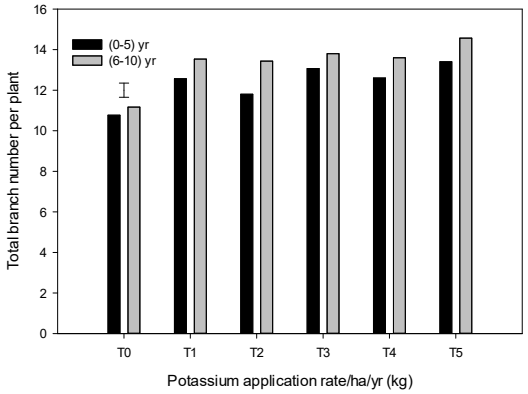

Figure 3. Total number of branches per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of potassium and mulberry plant age interactions.

Total length of branches per plant (cm)

The ages of mulberry plant ($P < 0.01$) and levels of potassium significantly favored ($P < 0.001$) influenced the total branch length of mulberry plant. Between the two types of mulberry plant the maximum average total branch height was 1127.69 cm in older plants 6-10 years for the treatment of T_5 and the minimum average total branch length was 1081.20 cm in younger plants < 5 years plant for control treatment (T_0). The interactive effect (Age × Treatment) was not significant (Table 1, Figure 4).

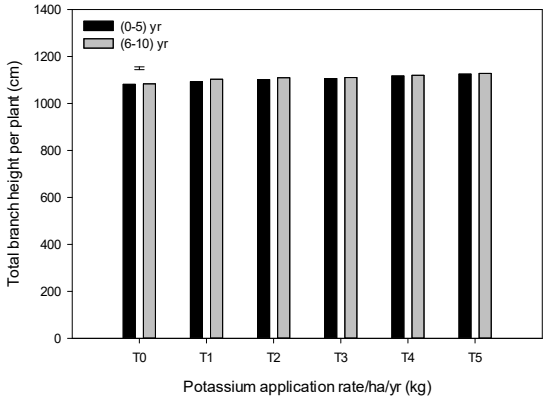

Figure 4. Total length of branches per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of potassium and mulberry plant age interactions.

Total shoot weight per plant (g)

The total shoot weight of mulberry plant significantly varied both for the ages of mulberry plant and the levels of potassium ($P < 0.001$) treatment. Between the two ages of mulberry plant the maximum average

total shoot weight of 802.22 g was recorded in 6-10 years plants in T_5 (N_{300} P_{150} K_{150} kg/ha/yr) treatment and the minimum average total shoot weight (763.05 g) in younger plants (< 5 years age) in control treatment (T_0) (Table 1, Figure 5).

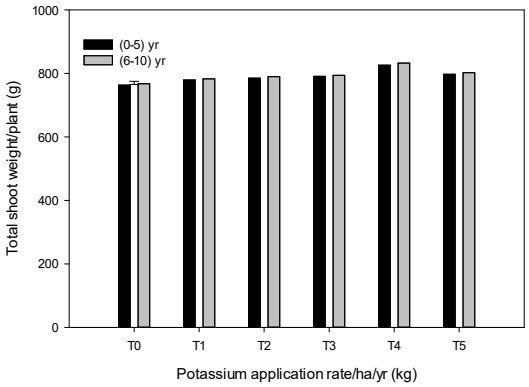

Figure 5. Node per meter per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of potassium and mulberry plant age interactions.

Table-1: Effect of different levels of potassium fertilizer on mulberry plant production

Factors	Node/ Meter	Total branch number/plant	Length of longest shoot/plant	Total branch height/plant	Total shoot weight/plant	10 Leaf Area (Cm^2)	10 Leaf weight (g)	Total Leaf Yield/ha/yr (mt)
Age	***	***	***	**	*	*	**	***
Treatments	***	***	***	***	***	***	***	***
Age × Treatment	***	n.s	***	n.s	n.s	n.s	n.s	n.s

Ten leaf area per plant (cm^2)

The leaf area of 10 leaves of older mulberry plants (6-10 years age) was found to the significantly highest (699.48 cm^2) under T_5 (N_{300} P_{150} K_{150} kg/ha/yr). The lowest value (422.16 cm^2) being recorded in younger leaves of < 5 years old plants in T_0 (control) treatment (Table 1, Figure 6).

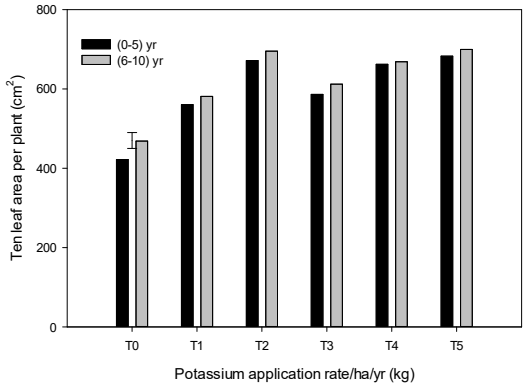

Figure 6. Node per meter per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (*P*= 0.05) different levels of potassium and mulberry plant age interactions.

Weight of 10 leaves per plant (g)

Ten leaf weight per plant was significantly ($P < 0.01$) different for the older mulberry plant than the younger mulberry plants (Table 1, Figure 7). Among the six P fertilizer treatments the treatment T_5 (N_{300} P_{150} K_{150} kg/ha/yr) produced significantly ($P < 0.001$) highest weight of 10 leaves (47 g) for older plants (6-10 years age). The lowest value (32 g) was recorded in younger plants (< 5 years age) in treatment T_0 (control).

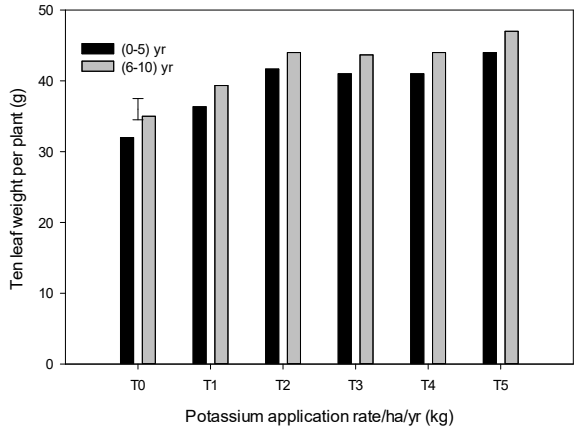

Figure 7. Node per meter per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of potassium and mulberry plant age interactions.

Total leaf yield (mt/ha/yr)

The total leaf yield of mulberry plants significantly increased with increased age of the plant and the increased rate of K application to the soil (Table 1, Figure 8). The highest leaf yield of 45.3 mt/ha/yr was recorded in older plants of 6-10 years age in treatment T_5 (N_{300} P_{150} K_{150} kg/ha/yr). The lowest yield (27.21 mt/ha/yr) being noted in the younger plants of less than 5 years of age in T_0 treatment (control).

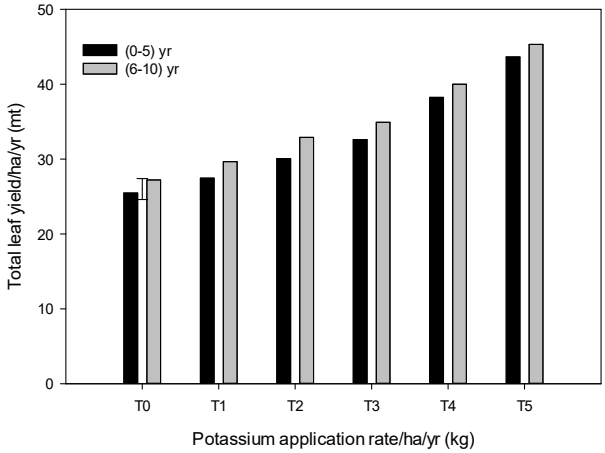

Figure 8. Node per meter per plant in mulberry as influenced by various levels of K management practices. Where, T_0 = 0 kg K/ha/yr, T_1 = 30 kg K/ha/yr, T_2 = 60 kg K/ha/yr, T_3 = 90 kg K/ha/yr, T_4 = 120 kg K/ha/yr and T_5 = 150 kg K/ha/yr. Vertical bar represent LSD (P= 0.05) different levels of potassium and mulberry plant age interactions.

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

Moisture (%)

The moisture (%) of mulberry plant was significantly ($P < 0.05$) different due to the plant ages and K fertilizer treatment. Among the six fertilizer treatments the maximum moisture (%) 74.61 was recorded for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) in the leaf of 6-10 years plant which was statistically similar with the leaf of < 5 years plant. However, the minimum moisture (%) 64.46 was recorded in younger < 5 year mulberry plant for the treatment of T_0 (Table 2).

Chlorophyll-a (Mg/g)

The Chlorophyll-a content in mulberry leaf varied statistically ($P < 0.05$) due to the plant ages and K fertilizer treatment. The maximum Chlorophyll-a 2.87 Mg/g was recorded in older (6-10 years) plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar to the leaf of < 5 years plant. The minimum Chlorophyll-a content was 0.10 Mg/g in younger plants for the treatment of T_0 (Table 2).

Table: 2 Effect of different levels of potassium fertilizer on Bio-chemical constituents in mulberry leaf

Treatments	Parameters															
	Moisture (%)		Chlorophyll-a (micro g/g)		Chlorophyll-b (micro g/g)		Reducing Sugar (%)		Total Mineral (%)		Total Sugar (%)		Soluble Carbohydrate (%)		Crude Protein (%)	
Plant age	(0-5) yr	(6-10) yr	(0-5) yr	(6-10) yr	(0-5) yr	(6-10) yr	(0-5) yr	(6-10) yr	(0-5) yr	(6-10) yr	(0-5) yr	(6-10) yr	(0-5) Yr	(6-10) yr	(0-5) yr	(6-10) yr
T_1	67.53d	70.31 d	1.13 d	1.70 d	50.35c d	48.67 d	3.12c d	3.15c d	9.27c	8.33 d	4.69 d	4.66 d	6.24e	6.86 d	15.26 d	15.44 e
T_2	69.47c	70.60 d	1.33 c	1.70 d	51.32b c	57.77 c	3.22c	3.26b c	9.42b c	8.57 c	4.81 c	4.72 d	6.52d	6.84 d	16.38 c	16.55 d
T_3	70.39b c	71.47 c	1.31 c	1.97 c	53.09a b	62.02 b	3.57b	3.39b	9.74a	9.68 a	4.80 c	4.86 c	8.00c	7.97 c	17.54 b	17.53 c
T_4	71.14b	73.74 b	2.16 b	2.40 b	51.18c	61.99 b	3.58b	3.66a	9.59b	9.66 a	4.92 b	5.11 b	8.22b	8.25 b	17.67 b	18.42 b
T_5	73.33a	74.61 a	2.41 a	2.87 a	53.93a	63.03 a	3.63a	3.74a	9.51b	9.52 b	5.07 a	5.36 a	8.58a	8.90 a	19.49 a	19.66 a
T_0	64.46e	69.64		1.50	49.11d	46.94	3.03d	3.09d	8.06d	8.13	4.56	4.63	6.17e	6.32	14.12	14.79

Chlorophyll-b (micro g/g)

The Chlorophyll-b content in mulberry leaf significantly ($P < 0.05$) changed for mulberry plant ages and K fertilizer treatment. Among the six fertilizer treatments the maximum Chlorophyll-b 63.03 Mg/g was recorded in the leaf of 6-10 year's plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar with the leaf of < 5 years plant. The minimum Chlorophyll-b 46.94 Mg/g was recorded in the leaf of 6-10 years plant for the treatment of T_0 (Table 2).

Reducing sugar (%)

The reducing sugar (%) in mulberry leaf significantly differed both for the plant ages and K fertilizer treatment. The maximum amount of reducing sugar (3.74%) was recorded in the leaf of 6-10 years plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar with the leaf of < 5 year's plant. The minimum reducing sugar (3.03%) was recorded in the leaf of < 5 years plant for the treatment of T_0 (Table 2).

Total mineral (%)

The plant ages and K fertilizer treatment significantly changed the total mineral content in mulberry leaf. The maximum total mineral of 9.74 % was recorded in the leaf of older (6-10) year's plant for the treatment of T_3 which was statistically similar with the leaf of older plant and the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) also. However, the minimum total mineral (8.06%) was recorded in the leaf of < 5 year's plant for the treatment of T_0 (Table 2).

Total sugar (%)

The total sugar content in mulberry leaf was greatly increased due to the plant ages and K fertilizer treatment. The maximum total sugar 5.36 % was recorded in the leaf of 6-10 years plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar with the leaf of < 5 years plant. On the other hand the minimum total sugar 4.50 % was recorded in the leaf of < 5 years plant for the treatment of T_0 (Table 2).

Soluble carbohydrate (%)

The soluble carbohydrate content in mulberry was significantly changed due to the plant age and K fertilizer treatment. The maximum soluble carbohydrate (8.90%) was recorded in the leaf of 6-10 years plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar with the leaf of < 5 years plant. The minimum soluble carbohydrate (6.17%) was recorded in the leaf of < 5 years plant for the treatment of T_0 (Table 2).

Crude protein (%)

The ages of mulberry leaf and K fertilizer treatment significantly affected the crude protein content in mulberry leaf. The maximum crude protein (19.66 %) was recorded in the leaf of 6-10 years plant for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was statistically similar to the leaf of < 5 years plant. The minimum crude protein (14.12%) was noted in the leaf of < 5 years plant for the treatment of T_0 (Table 2).

Discussion

Effect of potassium on yield and quality of mulberry leaf

Application of 150 kg K/ha/yr with BSRTI recommended 300 kg N/ha/yr and 150 kg P/ha/yr in four split doses significantly ($P \leq 0.05$) increased the mulberry leaf yield and quality. Among the six levels of K the application of 150 kg K/ha/yr with BSRTI recommended basal dose of 300 kg N/ha/yr and 150 kg P/ha/yr gave the maximum average nodes per meter, total number of branches, length of longest shoot, total shoot weight, 10-leaf area, 10-leaf weight and total leaf yield than the other treatments. The average maximum leaf yield was 45.30 mt/ha/yr for T_5 (N_{300} P_{150} K_{150} kg/ha/yr) treatment which was 66.48 % upper than the average maximum leaf yield of control treatment. The elevated doses of K also improved the leaves quality of mulberry. Among the various leaf quality parameters the maximum moisture, chlorophyll-a, chlorophyll-b, total sugar, soluble carbohydrate, reducing sugar and crude protein except total mineral were found for the treatment of T_5 (N_{300} P_{150} K_{150} kg/ha/yr) which was 7.14%, 91.33%, 28.34%, 15.77%, 40.82%, 21.03% and 32.93% respectively greater over the control treatment. Our findings are similar with the previous results of Miah (1989), where 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. 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/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, he also reported 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) also found the significant effect of K on mulberry leaf yield and quality. They 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/ha/yr in five split doses and got 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, which is more or less similar with our findings. It is assumed now the present findings that the 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. As a result the uptake of K by the mulberry plant was higher which may be improved the metabolic functions related to N and P uptake, enzyme activities, water relations, energy transformation, protein and starch synthesis, favors the growth, yield and leaf quality was comparatively higher than the others treatments.

Impact of mulberry plant age on leaf yield and quality

Age of the mulberry plant significantly ($P \leq 0.05$) influenced the mulberry leaf yield and quality. Six levels of K were applied to soil at the rate of 0, 30, 60, 90, 120 and 150 kg K/ha/yr 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 mulberry plant as soil applied. With respect to plant ages significantly better growth and yield contributing characters viz: nodes per meter, total branches number, total branch height, length of longest shoot, total shoot weight, 10-leaf area, 10-leaf weight per plant and total leaf yield were recorded in older mulberry plants of 6-10 years old as compared to younger ones (< 5 years age). The highest leaf yield (45.30 mt/ha/yr) recorded in older mulberry plants which was 3.8% higher than the yield (43.64 mt/ha/yr) in younger plants. The average maximum moisture, chlorophyll-a, chlorophyll-b, reducing sugar, total sugar, soluble carbohydrate and crude protein percentage were 74.61, 2.87, 63.03, 3.74, 5.36, 8.9 and 19.66, respectively for 6-10 years plant. In case of 0-5 years plant the maximum moisture, chlorophyll-a, chlorophyll-b, reducing sugar, total sugar, soluble carbohydrate and crude protein percentage were 73.33, 2.41, 53.93, 3.63, 5.07, 8.58 and 19.49, respectively. The impact of ages of mulberry plant on growth, leaves yield and leaves quality is a new idea, there was no such type of study conducted in mulberry crop previously. But a study was conducted previously in marigold (*Tagetes erecta* Big. Inca Gold) by Deborah *et al.* (1990). Those 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 and it was 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. But our speculation is due to the higher ages (6-10 years) of mulberry plant. The root development and establishment in older plants was good as well as the root system was deeper, larger, high values of root length density and root diameter that favored in extracting the maximum K from the soil as well as contributed the rapid and maximum photosynthesis interns enhances the physiological activity, N and P use efficiency by the 6-10 years mulberry plants. This assumption is more or less lined with the previous findings of Almimeida *et al.* (2016), who 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) that the total length, root surface area, the root diameter and root volume of root system were significantly decreased by K deficiency.

12. Research highlight/findings :

- The leaf yield and leaf quality of older mulberry plants of 6-10 years of age was comparatively superior to the younger plants of less than 5 years of age under the application of N, P and K fertilizers.
- The N requirement of mulberry plant was found to be 400 kg/ha/yr with BSRTI recommended basal dose of 150 kg P and 100 kg K/ha/yr respectively, to achieve the higher leaf yield potential and the maximum leaf quality viz. moisture (%), chlorophyll-a, chlorophyll-b, total sugar (%), soluble carbohydrate (%), reducing sugar and crude protein (%).
- In case of P the maximum leaf yield was found with the application of 160 kg P/ha/yr along with BSRTI recommended basal dose of 300 kg N and 100 kg K/ha/yr. The best leaf quality such as moisture (%), crude protein (%), total sugar (%), soluble carbohydrate (%) and reducing sugar (%)

except chlorophyll-a, chlorophyll-b and total mineral (%) were also noted under the same dose of P.

- Potassium (K) application of at the rate of 150 kg/ha/yr along with BSRTI recommended basal dose of 300 kg N and 150 kg P/ha/yr, gave the highest leaf yield of mulberry plants having the best leaf quality viz. maximum moisture, chlorophyll-a, chlorophyll-b, total sugar, soluble carbohydrate, reducing sugar and crude protein except total mineral.

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B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	Laptop-01, Printer-01 and UPS-01	89200.00	Laptop-01, Printer-01 and UPS-01	89200.00	100% achieved
(b) Lab & field equipment	Electronic balance-02 and Chlorophyll meter-01	218700.00	Electronic balance-02 and Chlorophyll meter-01	218700.00	100% achieved
(c) Other capital items					

2. Establishment/renovation facilities: N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized: N/A

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					N/A
(b) Workshop					N/A

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	204515.00	182320.00	182320.00	0	100	
B. Field research/lab expenses and supplies	1231587.00	1220391.00	1220391.00	0	100	
C. Operating expenses	171652.00	153426.00	153426.00	0	100	
D. Vehicle hire and fuel, oil & maintenance	00	00	00	0	-	
E. Training/workshop/seminar etc.	00	00	00	0	-	
F. Publications and printing	48000.00	00	00	0	-	
G. Miscellaneous	36346.00	33161.70	30620.00	2541.70	92.34	
H. Capital expenses	307900.00	301656.00	301656.00	0	100	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
Determination of N, P and K requirements of mulberry plants for maximizing yield and quality of the leaves.	Determined optimum dose of nitrogen for improving quality and yield of mulberry leaves.	Visible and measurable	Mulberry leaf yield and quality was improved
	Optimum dose of phosphorus determined for better quality and yields of mulberry leaves.	Visible and measurable	Mulberry leaf yield and quality was improved
	Optimum dose of potassium determined for increased yield and quality of mulberry leaves.	Visible and measurable	Mulberry leaf yield and quality was improved

E. Materials Development/Publication made under the Sub-project: N/A

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication			
Information development			
Other publications, if any			

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

Optimum doses of nitrogen, phosphorus and potassium were determined for producing better quality and increased yield of mulberry leaves.

ii. **Generation of new knowledge that help in developing more technology in future**

1. N, P and K have a significant effect on leaf yield and quality of mulberry plant.
2. Ages of mulberry plant has a significant effect on leaf yield and quality

iii. Technology transferred that help increased agricultural productivity and farmers' income

N/A

iv. Policy Support

N/A

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

ii) Field Monitoring (time & No. of visit, Team visit and output):

Team Visit	Time	No. of visit	Output
PIU-BARC, NATP-2	07.09.2017 20.02.2018	02	
Internal Monitoring by Director (BSRTI) and DG (BSDB)	08.11.2017 15.02.2018 12.07.2018	03	-
Other Visitors: 1. Professors and Students, Department of Agronomy & Agricultural Extension, Rajshahi University. 2. Professors and Students, Department of Crop Sciences, Rajshahi University.	15.02.2018 21.06.2018	02	-

I. Lesson Learned/Challenges (if any)

i) Understanding about a successful project monitoring and auditing process.

ii) Management process and techniques for executing of a project.

J. Challenges (if any)

1. Such type of study was totally new idea for mulberry cultivation.
2. Limitation of time for executing this research because mulberry is a perennial crop.
3. Timely delivered of the fund.
4. Fund disbursement procedure was trouble to continue the project in time.

Signature of the Principal Investigator
Date ……..
Seal

Counter signature of the Head of the organization/authorized representative
Date ……..
Seal