

# Elevated Potassium Enhances Leaf Productivity and Suppresses Foliar Diseases of Mulberry Plant

F. Ahmed, R. Sultana

Department of Mulberry. Bangladesh Sericulture Research and Training Institute, Rajshahi  
6207, Bangladesh

M. J. Alam

Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi 6205,  
Bangladesh

O. Ahmed

Department of Mulberry. Bangladesh Sericulture Research and Training Institute, Rajshahi  
6207, Bangladesh.

M. T. Iqbal (Corresponding author)

Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi 6205,  
Bangladesh. E-mail: [toufiq\\_iqbal@yahoo.com](mailto:toufiq_iqbal@yahoo.com)

Received: Jan. 1, 2020

Accepted: Feb. 5, 2020

Published: Feb. 11, 2020

doi:10.5296/jas.v8i3.16435

URL: <https://doi.org/10.5296/jas.v8i3.16435>

## Abstract

Potassium (K) may enhance productivity and suppresses foliar diseases of mulberry plant. Existing optimum dose of K for mulberry cultivation need to be updated for suppress foliar disease and improve mulberry plant productivity. This study was conducted to renew the optimum dose of K for mulberry cultivation with respect to the ages of mulberry plant. Therefore, a field study was conducted in split plot design with three replications at Bangladesh Sericulture Research and Training Institute (BSTRI), Rajshahi, Bangladesh to find out the effect of elevated K and ages of plant on growth, leaf yield, leaf quality, nutrient uptake and infestation of foliar diseases of mulberry plant. Six levels of K (0, 30, 60, 90, 120

and 150 kg/ha/yr) along with BSRTI recommended basal doses of nitrogen (N) and phosphorus (P) were applied on two age group of plant viz: (0-5) years and (6-10) years. Result showed that the highest leaf yield 47.10 mt ha<sup>-1</sup> year<sup>-1</sup> for 6-10 year's plant at the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>). This indicated leaf yield 175.44% greater over the control but 22.69% higher than the 0-5 year's plant. Similarly, the maximum leaf quality viz: moisture, reducing sugar, total mineral, total sugar, soluble carbohydrate and crude protein were obtained in (6-10) year's plant for the same treatments which were 13.82%, 23.47%, 29.96%, 20.57%, 39.58% and 30.69% respectively greater over the control. Furthermore, the average incidence percentages of foliar diseases like leaf spot, tukra and powdery mildew were reduced by 42.34%, 58.02% and 82.96% respectively in (6-10) years plant due to the elevated doses of K like as 150 kg, 90 kg and 60 kg/ha/yr respectively with BSRTI recommended doses of N and P over the control. This findings indicated that the use of 150 kg potassium ha<sup>-1</sup> year<sup>-1</sup> had better performance on the leaf yield and quality of mulberry plant. Therefore, the application of 150 kg potassium ha<sup>-1</sup> year<sup>-1</sup> with BSRTI recommended dose of N and P both for (0-5) and (6-10) year's ages of mulberry plant cultivation is the best options for higher leaf yield and quality whereas 150 kg, 90 kg and 60 kg potassium ha<sup>-1</sup> year<sup>-1</sup> respectively are better for controlling of leaf spot, tukra and powdery mildew diseases.

**Keywords:** Chlorophyll, leaf quality, powdery mildew, tukra, silk cocoon

## 1. Introduction

Mulberry which belongs to the genus *Morus* comprising of about 68 species (Datta, 2000), is a perennial woody plant which after proper establishment can come to full yielding capability during the second year and last for over 17 years without any significant deterioration in leaf yield (Kumaresan *et al.*, 1994). Mulberry (*Morus spp.*) leaves have been the traditional feed for the silk worm (*Bombyx mori*) which are rich source of proteins, carbohydrates, chlorophyll a, chlorophyll b, total 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 crop (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 crop (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 plant is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et al.* 1990). The most common

diseases found on mulberry are leaf spot, powdery mildew and leaf-rust (Reddy et al., 2009). These pathogens are the main obstacles causing considerable loss in yield and nutritive value of mulberry foliage. Among the various diseases of mulberry plant, powdery mildew, leaf spot and tukra are the major foliar fungal 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 and Graham, 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). Application of balanced fertilizer in the soil resulted lower infection by leaf pathogen in comparison with imbalanced fertilizer application in the soil and 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).

To obtain optimum mulberry leaf yield, proper quantity of K fertilizer need to be supplied to plants along with BSRTI recommended nitrogen and phosphatic fertilizers. Therefore, studies were carried out to see the effect of different levels of potassium and ages of plant on growth attributes, leaf yields, leaf quality, nutrients uptake and suppress of foliar diseases of mulberry plant. It was hypothesized that the application of different levels of potassium on two types of plant (0-5) and (6-10) years with recommended doses of N and P will be enhanced the mulberry leaf yield, quality as well as reduces the infestation of foliar diseases both for the (0-5) and (6-10) years ages of mulberry plant.

## 2. Materials and Methods

### 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.

### 2.2 Experimental Plant

Mulberry (*Morus spp*) variety BM-11 (BM = Bangladesh Mulberry) and high-bush plantation system was used for this study. 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.

### 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 potassium fertilizer treatments were applied 20 DAPr (Days after Pruning) when the sprouting of mulberry plant was started and other cultural practices like irrigation, digging cum weeding, insect-pest management practices etc. were done as per requirement.

#### *2.4 Experimental Design and Treatments*

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

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

T<sub>1</sub>: 30 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T<sub>2</sub>: 60 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T<sub>3</sub>: 90 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T<sub>4</sub>: 120 kg K + BSRTI recommended basal dose of N and P per hectare per year.

T<sub>5</sub>: 150 kg K + BSRTI recommended basal dose of N and P per hectare per year.

#### *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 height per plant (cm), total shoot weight per plant (g), 10 leaf area per plant (cm<sup>2</sup>), 10 leaf weight per plant (gm) and total leaf yield/ha/year (mt) were recorded crop wise. Data were collected at 90 DAPr for each cropping seasons. i.e. four times data was collected in a year and the annual yield was computed by pooling the two years data.

#### *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 by followed the Vijayan *et al.* (1996), 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), 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. Nitrogen, phosphorus and potassium contents in leaf were analyzed as per the standard procedures (Piper 1996) and ultimately the uptake of these nutrients was calculated.

### 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<sub>2</sub>SO<sub>4</sub>) (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<sub>4</sub>OAC 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<sub>3</sub> 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).

### 2.8 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 respective diseases and data were collected at 60 days after pruning. Disease incidence (%) was assessed as number of total mulberry leaves per plant was infected by leaf spot, tukra 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:

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

### 2.9 Statistical Analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1<sup>th</sup> ed<sup>n</sup> 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, nutrient uptake and diseases data were statistically analyzed and mean values were evaluated by DMRT test through using the Statistic-10 software. In case of soil the mean values of post harvest soil properties were recorded for this study.

### 3. Results

#### 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 (Table 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.

#### 3.2 Growth Response of Mulberry Plant Due to Ages of Plant and Potassium Levels

##### 3.2.1 Node Per Meter

The node per meter of older leaf was highly significant ( $P < 0.001$ ) than the younger leaf of mulberry plant. Among the six fertilizer treatments the statistically maximum node/meter was found for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) The interactive effect between plant age and K fertilizer treatment was also significantly differ (Table 2, Figure 1). However, among the younger (0-5) and older (6-10) year's plant the maximum node/meter was 35.73 for the treatment of T<sub>5</sub> and (6-10) year's plant.

##### 3.2.2 Length of Longest Shoot Per Plant (cm)

The length of longest shoot of mulberry plant was highly significant ( $P < 0.001$ ) irrespective to treatments and their interactive effect. However, the maximum average length of longest shoot was 165.08 cm for T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>120</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) treatment in (6-10) year's plant and the minimum length of longest shoot was 122.17 cm in (0-5) year's plant for control treatment (Table 2, Figure 2).

##### 3.2.3 Total Branch Number Per Plant

Total branch number/plant was statistically ( $P < 0.001$ ) differ between the younger and older mulberry plant. The treatment T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) showed the maximum number of total branch/plant for the older (6-10) year's mulberry plant than the other treatments. But their interactive effect (Age × Treatment) was not significantly differ (Table 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<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) where as the minimum total branch number 10.77 was recorded in (0-5) years plant for the treatment of T<sub>0</sub> (Table 2, Figure 3).

##### 3.2.4 Total Branch Height Per Plant (cm)

The ages of mulberry plant ( $P < 0.01$ ) and levels of potassium significantly ( $P < 0.001$ ) influenced the total branch height of mulberry plant. Between the two types of mulberry plant the maximum average total branch height was 1127.69 cm in (6-10) year's plant for the treatment of T<sub>5</sub> and the minimum average total branch height was 1081.20 cm in (0-5) year's

plant for control treatment. But their interactive effect (Age  $\times$  Treatment) was not significantly differ (Table 2, Figure 4).

### 3.2.5 Total Shoot Weight Per Plant (G)

The total shoot weight of mulberry plant was significantly differing both for the ages of mulberry plant and the levels of potassium ( $P < 0.001$ ) treatment. Between the two types of mulberry plant the maximum average total shoot weight was 802.22 g in (6-10) year's plant for T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) treatment and the minimum average total shoot weight was 763.05 g in (0-5) year's plant for control treatment (Table 2, Figure 5).

### 3.2.6 10 Leaf Area Per Plant (cm<sup>2</sup>)

The 10 leaf area of older mulberry plant was significantly ( $P < 0.05$ ) affected than the younger mulberry plant. The treatment T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) gave the maximum 10 leaf area for the older mulberry leaf than the other treatments. But their interactive effect (Age  $\times$  Treatment) was not significantly differ (Table 2, Figure 6). However, among the two types of mulberry plant the maximum 10 leaf area was 699.48 cm<sup>2</sup> in (6-10) year's mulberry plant for the treatment of T<sub>5</sub> and minimum 10 leaf area was 422.16 cm<sup>2</sup> in (0-5) year's plant for the treatment of T<sub>0</sub>.

### 3.2.7 10 Leaf Weight/Plant (gm)

Ten leaf weight per plant was significantly ( $P < 0.01$ ) differ for the older mulberry plant than the younger mulberry plant. Among the six levels of K fertilizer treatments the treatment T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) was significantly ( $P < 0.001$ ) differ for the 10 leaf weight/plant. But the interactive effect of mulberry plant age and K fertilizer treatment was not statistically differ (Table 2, Figure 7). However, the maximum 10 leaf weight 47 gm was recorded in (6-10) years mulberry plant for the treatment of T<sub>5</sub> and the minimum 10 leaf weight was 32 gm in (0-5) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>).

### 3.2.8 Total Leaf Yield/Ha/Year (mt)

The total leaf yield/ha/year was highly significantly ( $P < 0.001$ ) by the age of mulberry plant. Among the six levels of K fertilizer treatments the total leaf yield/ha/yr was significantly higher for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>). The interactive effect of plant age and K fertilizer treatment was also significantly ( $P < 0.001$ ) differ for the leaf yield of mulberry plant (Table 2, Figure 8). However, between the two types of mulberry plant the maximum leaf yield was 47.10 mt/ha/year in (6-10) years mulberry plant for the treatment of T<sub>5</sub> and the minimum leaf yield was 17.10 mt/ha/year for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>).

## 3.3 Effect of Ages and Potassium Fertilizer on Leaf Quality of Mulberry Plant

### 3.3.1 Moisture (%)

The moisture (%) of mulberry plant was significantly ( $P < 0.05$ ) differ due to the plant ages and K fertilizer treatment. Among the six fertilizer treatments the maximum moisture (%) 74.14 was recorded for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) in the leaf of (6-10)

year's. However, the minimum moisture (%) 64.51 was recorded in (0-5) year's mulberry plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.3.2 Chlorophyll-a (micro g/g)

The Chlorophyll-a content in mulberry leaf varied for the plant ages and K fertilizer treatment. The maximum Chlorophyll-a 2.87 micro g was recorded in (6-10) year's plant for the treatment of T<sub>5</sub> (300 Kg N/ha/yr + 150 Kg P/ha/yr/ + 150 K/ha/yr) and similar with the leaf of (0-5) year's plant. The minimum Chlorophyll-a content was 0.10 micro g in (0-5) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.3.3 Chlorophyll-b (micro g/g)

The Chlorophyll-b content in mulberry leaf varied for mulberry plant ages and K fertilizer treatment. Among the six fertilizer treatments the maximum Chlorophyll-b 63.03 micro g was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>5</sub> (300 Kg N/ha/yr + 150 Kg P/ha/yr/ + 150 K/ha/yr) which was statistically similar with the leaf of (0-5) year's plant. The minimum Chlorophyll-b 46.94 micro g was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.3.4 Reducing Sugar (%)

The reducing sugar (%) in mulberry leaf was significantly differ both for the plant ages and K fertilizer treatment. However, the maximum reducing sugar 3.84 % was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which was statistically similar with the leaf of (0-5) year's plant. The minimum reducing sugar 3.03 % was recorded in the leaf of (0-5) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.3.5 Total Mineral (%)

The plant ages and K fertilizer treatment significantly changed the total mineral content in mulberry leaf. The maximum total mineral 10.54% % was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>3</sub> which was statistically similar with the leaf of (6-10) year's plant and the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) also. However, the minimum total mineral 8.06 % was recorded in the leaf of (0-5) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.3.6 Total Sugar (%)

The total sugar content in mulberry leaf was significantly increased due to the plant ages and K fertilizer treatment. The maximum total sugar 5.57% was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which was statistically similar with the leaf of (0-5) year's plant. On the other hand the minimum total sugar 4.54 % was recorded in the leaf of (0-5) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).



### 3.3.7 Soluble Carbohydrate (%)

The soluble carbohydrate content in mulberry was highly significant ( $P < 0.001$ ) both for the plant age and K fertilizer treatment. The maximum soluble carbohydrate 8.64 % was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which was statistically similar with the leaf of (0-5) year's plant. However, the minimum soluble carbohydrate 6.17 % was recorded in the leaf of (0-5) year's plant for the treatment of T<sub>0</sub> (Table 3).

### 3.3.8 Crude Protein (%)

The ages of mulberry leaf and K fertilizer treatment was significantly affected the crude protein content in mulberry leaf. The maximum crude protein 18.52% was recorded in the leaf of (6-10) year's plant for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which was statistically similar with the leaf of (0-5) year's plant. On the other hand the minimum crude protein 14.12 % was recorded in the leaf of (5-10) year's plant for the treatment of T<sub>0</sub> (N<sub>300</sub>P<sub>150</sub>kg ha<sup>-1</sup>year<sup>-1</sup>) (Table 3).

### 3.4 Effect of Potassium and Plant Ages on Nutrients Uptake by the Mulberry Plant

The uptakes of nitrogen, phosphorus and potassium by the mulberry plant were significantly influenced by the ages of plant and the gradated doses of potassium. Except K both the N and P uptake were also significantly increased by the interactive effect of age × treatments. However, among the six levels of potassium the maximum nitrogen, phosphorus and potassium uptake were found 95.36, 13.05 and 52.24 kg/ha/yr respectively in (6-10) year's plant for the application of 150 kg K/ha/yr with four split doses through BSRTI recommended basal dose of N and P (Table 4).

### 3.5 Effect of Potassium and Ages of Plant on Diseases Infestation in Mulberry Plant

The infestation of tukra, powdery mildew and leaf spot diseases in (6-10) year's mulberry plant were significantly inclined due to the gradated doses of soil applied potassium. The average incidence percentage of tukra, leaf spot and powdery mildew diseases were comparatively low due to the elevated doses of potassium. In case of tukra and leaf spot diseases the average lower incidence percentages were 0.79 and 0.63 respectively for the treatment of T<sub>5</sub>. But the lower average incidence percentage of powdery mildew was 0.68 for the application of 60 kg K/ha/yr with four split doses of BSRTI recommended basal dose of N and P. However, the average incidences percentages of all the three diseases were comparatively maximum for the control treatment than the others treatments (Table 5).

## 4. Discussion

### 4.1 Effect of Potassium on Mulberry Leaf Yield and Quality

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 K/ha/yr with BSRTI recommended basal dose of 300 kg N/ha/yr and 150 kg P/ha/yr showed the maximum average nodes per meter,

total branches number 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 than the other treatments. The average maximum leaf yield was 47.10 mt for T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) treatment which was 151.47% higher 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 like moisture, reducing sugar, total mineral, total sugar, soluble carbohydrate and crude protein percentage were greater for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which were 13.82%, 23.47%, 29.96%, 20.57%, 39.58% and 30.69% respectively 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 77.92% over the control treatment with the progressive increase of NPK fertilizers, leaf constituents viz: moisture, crude protein, total sugar, reducing sugar, starch and soluble carbohydrate contents increased gradually but mineral content decreased. 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<sub>2</sub>O /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<sub>2</sub>O /ha/yr as well as the total fresh leaf weight increased by 13.1 and 33.4% respectively for 45 and 135 kg K<sub>2</sub>O /ha/yr compared to the unfertilized check plot, he also reported that 135 kg K<sub>2</sub>O/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<sub>90</sub> and K<sub>135</sub> treatments, leaf protein content was 2.7 and 3.0 percent higher compared to the K<sub>0</sub> treatment. Shankar *et al.* (1999) also 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<sub>2</sub>O/ha/yr with two levels of N at 300 and 400 kg K<sub>2</sub>O/ha/yr in five split doses and get the higher leaf yield with total chlorophyll and moisture added to overall leaf quality for the treatment of N and K at 400-200 kg N-k<sub>2</sub>O/ha/yr in five splits doses, which is more or less similar with our findings. Our speculation is 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 and available. 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 inters the growth, yield and leaf quality was comparatively higher than the others treatments. This speculation is lined with the previous findings of Subbaswamy *et al.* (2001), who reported that the growth and yield of mulberry plant may 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.

#### 4.2 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 at the rate of 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 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. Between the (0-5) and (6-10) year's mulberry plant the 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/ha/year were significantly ( $P \leq 0.001$ ) greater in (6-10) year's mulberry plant than the (0-5) year's plant. The mulberry leaf yield was 22.69% higher in (6-10) year's aged plant than the (0-5) year's aged plant. The average maximum moisture, reducing sugar, mineral, total sugar, soluble carbohydrate and crude protein percentage were 74.14, 3.84, 10.54, 5.57, 8.64 and 18.52 respectively for (6-10) year's plant. Whereas in case of (0-5) year's plant the maximum moisture, reducing sugar, mineral, total sugar, soluble carbohydrate and crude protein percentage were 73.32, 3.11, 9.5, 5.07, 8.59 and 18.48 respectively. The impact of ages of mulberry plant on growth, leaves yield and leaves quality is a totally new idea, there were no such type of study was conducted in mulberry crop previously. But a study was conducted previously in marigold (*Tagetes erecta* Big. Inca Gold) 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 and 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. But our speculation is due to the higher ages of (6-10) years 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 helps to engross the maximum K uptake 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) year's mulberry plant. As a result the nodes per meter, total branches number per plant, 10-leaf area per plant, 10-leaf weight per plant, leaf yield as well as leaf quality parameters were comparatively improved in older (6-10 year's) mulberry plant than the younger (0-5 year's) mulberry plant. This speculation is more or less lined with the previous findings of Almimaida *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) found that the total length, root surface area, the root diameter and root volume of root system were significantly decreased by K deficiency. Correspondingly, Sattelmacher *et al.* (1994) also reported that root system is the main organ for nutrient uptake, ideal root morphology and activity has a great significance to nutrient absorption from soil, which play an important role in the growth and development of crops that is strongly correlated with our speculation.

#### 4.3 Elevated Potassium and Plant Ages Enhances the Nutrient Uptake of Mulberry Plant

The elevated potassium and ages of mulberry plant increased the nitrogen, phosphorus and potassium uptake of in the mulberry plant. Between the two types of mulberry plant the maximum nitrogen, phosphorus and potassium uptake were 95.36, 13.05 and 52.24 kg/ha/yr respectively in (6-10) year's plant for the treatment of T<sub>5</sub> (N<sub>300</sub>P<sub>150</sub>K<sub>150</sub> kg ha<sup>-1</sup> year<sup>-1</sup>) which was lined with the findings of Bose *et al.* (2009). They were applied 0, 15, 30, 45 and 60 kg

K/ha/yr with 150 kg N and 50 kg P<sub>2</sub>O<sub>5</sub>/ha/yr respectively and found that the nitrogen, phosphorus and potassium uptake by the mulberry were statistically increased up to 60 kg K/ha/yr which were 74.80, 7.60 and 41.40 kg/ha/yr respectively may be due to the synergistic interaction effect of higher doses of potassium. Our speculation was the applied 150 kg K/ha/yr with BSRTI recommended basal dose of 300 kg N and 150 kg P was comparatively balanced and available besides the comparatively well-developed and higher root activity of (6-10) year's plant influenced the maximum uptake of N, P and K by the mulberry because potassium is interrelated with other nutrients N, P, Na and Ca (Daliparthi 1994).

#### 4.4 Effect of Potassium and Plant Ages on Diseases Infestation in Mulberry Plant

The elevated potassium with BSRTI recommended basal doses of nitrogen and phosphorus significantly ( $P \leq 0.0001$ ) suppress the incidences of leaf spot, tukra and powdery mildew diseases respectively. Among the six levels of potassium and two aged of mulberry plant, the minimum tukra, powdery mildew and leaf spot infestation percentage were 0.61, 0.68 and 0.64% respectively in (6-10) year's plant for the application of 90 kg, 60 kg and 150 kg K/ha/yr respectively with BSRTI recommended basal doses of 300 kg N and 150 kg P/ha/yr in four split doses. However, no study is available for elevated potassium and plant age suppress foliar disease of mulberry plant. But, another study conducted by Glen Harris (1997) who 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. In almost every case the leaf spot was investigated, Where the K was low in soil, plant or low in petiole of Cotton plant. In the same way Reuveni *et al.* (1996) 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 which is similar with our findings. Similarly, in previous study, Pervez *et al.* (2007) was applied four rates of potassium (0, 62.5, 125.0, 250.0 kg K ha<sup>-1</sup>) on the two Cotton cultivars viz: CIM-448 and CIM-1100 respectively and they found that the infestation of cotton leaf curl virus disease caused by whitefly (*Bemisia tabaci* Gennadius) was reduction 12 to 38% due to addition of 250 kg K ha<sup>-1</sup>. They mention that due to the adequate potassium nutrition the content of phenols were increased which can play a beneficial role in plant resistance in addition of potassium affects plant morphology, hardening the tissues with resulting improvement in resistance to disease penetration interns the incidence of disease was reduce for the K treated cotton cultivars. Our speculation was potassium has a direct antifungal impact which was break up and defect of conidia and mycelium of fungal diseases (powdery mildew and leaf spot) in terns the incidence of powdery mildew and leaf spot in mulberry leaf were comparatively low.

However, the infestation of foliar diseases in mulberry plant was not significantly differed due to the ages of mulberry plant but the average incidence percentage of all the three diseases were comparatively minimum in (6-10) year's plant than the (0-5) year's plant. This study is totally new idea for mulberry plant but in another study Gao *et al.* (2016) were investigated the impact of different growth stages of potato for infestation of Zebra Chip diseases caused by *B. cockerelli*. They were 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. It was observed that the *B. cockerelli* infestation and Zebra Chip expression were more susceptible in younger plants at 4-week growth stage after germination than the older plants which are more or less similar with our findings.

## 5. Conclusion

This study demonstrated that the application of potassium in soil with BSRTI recommended basal dose of N and P is a proactive fertilizer management strategy for mulberry cultivation. This approach improves efficient, balanced and available uptake of essential macro and micro nutrients by the mulberry plant resulting in improvement of nutrients uptake, plant growth and development, leaf yield, quality and suppress of foliar diseases. It may be concluded from the present study that both the (0-5) and (6-10) year's mulberry plant responded to the application of 150 kg ha<sup>-1</sup> year<sup>-1</sup> of potassium fertilizer (MoP) showed better performances in respect of yield contributing characters, leaf yield, leaf quality and nutrients uptake compared to other potassium levels. However, among the six levels of potassium the 150 kg, 90 kg and 60 kg/ha/yr respectively showed better performances for reducing the infestation of leaf spot, tukra and powdery mildew diseases respectively. In addition, (0-5) year's mulberry plant was more susceptible to leaf spot, tukra and powdery mildew diseases compared to the (6-10) year's mulberry plant. So, 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 to obtain a quality and quantity mulberry leaf yield with suppress of leaf spot disease.

## Acknowledgements

The authors are grateful to the technical staff of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh for their help regarding experiment. The authors also would like to thank the Soil Resources Development Institute (SRDI), Rajshahi, Bangladesh for its help regarding soil physio-chemical properties analysis.

## References

Almeida, A. C. D., Carlos, A. C. C., Adriano, S. N., Munir, M., & Rodrigo, A. G. (2016). Influence of potassium levels on root growth and nutrient uptake of upland rice cultivars. Universidade Federal Rural do Semi-Arido Pro-Reitoria de Pesquisa e Pos-Graduacao. ISSN 0100-316X. ISSN 1983-2125.

Anonymous. (1988). Mulberry cultivation. FAO, 73, 52. <https://doi.org/10.1029/EO069i006p00073-04>

AOAC. (1980). Association of official analytical chemists. Method of analysis. 13th edition. Washington, Dc, Usa, 13044.

Arnon, D. I. (1949). Plant physiology.

Biswas, A., Alamgir, M., Haque, S. M. S., & Osman, K. T. (2012). Study on soils under shifting cultivation and other land use categories in Chittagong hill tracts. *Bangladesh Journal of Forestry Research*, 23(2), 261-265. <https://doi.org/10.1007/s11676-011-0216-2>

- Bongale U. D., & Krishna, M., C. (1996). Effect of Multinutrient foliar spray on chlorosis in M5 variety of mulberry. *Indian Journal of Sericulture*, 35, 9-12.
- Bose P. C., Dash B. D., Kar, R., & Bajpai A. K. (2009). Effect of potassium on growth, yield and nutrient uptake of mulberry (*Morus alba* l.) in eastern Ghat region of Orissa. *Journal of Crop and Weed*, 5(1), 34-37.
- Daliparthi, J., Barker, A. V., & Mondal, S. S. (1994). Potassium fractions with other nutrients in crops: A review focusing on the tropics. *Journal of Plant Nutrition*, 17, 1859-1886. <https://doi.org/10.1080/01904169409364852>
- Deborah, A., T., Alexander, X., N., & Robert, D. W. (1990). Influence of plant age on nutrient absorption for marigold seedlings. *Horticultural Science*, 25(12), 1612-1613. <https://doi.org/10.21273/HORTSCI.25.12.1612>
- Du, X. Z., Chunji, J., Xiaoguang, W., Yi Han, J. W., & Haiqiu, Y. (2017). Effect of potassium deficiency on root growth and nutrient uptake in maize (*Zea mays* L.). *Agricultural Sciences*, 8, 1263-1277. <https://doi.org/10.4236/as.2017.811091>
- Dubios, M., Giles, K. A., Hamilton, T. K., Robeos, R. A., & Smith, R. (1956). Calorimetric Determination of Sugars and Related Substances. *Analytical Chemistry*, 28, 250-256. <https://doi.org/10.1021/ac60111a017>
- Gallegos-Cedillo, V. M., Urrestarazu, M., & Álvaro, J. E. (2016). Influence of salinity on transport of nitrates and potassium by means of the xylem sap content between roots and shoots in young tomato plants. *Journal of Soil Science and Plant Nutrition*, 16(4), 991-998. <https://doi.org/10.4067/S0718-95162016005000072>
- Gutierrez, W. A., Shew, H. D., & Melton, T. A. (1997). Source of inoculums and management of rhizoctonia solani causing damping off on tobacco transplants under greenhouse conditions. *Plant Disease*, 81, 604-608. <https://doi.org/10.1094/PDIS.1997.81.6.604>
- Haber, F., & Klemensiewicz, Z. (1909). The results of their research on the glass electrode in the society of chemistry in karlsruhe. *The Journal of Physical Chemistry*.
- Harris, G. (1997). Potassium deficiency in cotton linked to leaf spot disease. *Better Crops*, 81, 2.
- Heanes, D. L. (1984). Determination of organic C in soils by an improved chromic acid digestion and spectrophotometric procedure, comm. *Soil Science and Plant Analysis*, 15, 1191-1213. <https://doi.org/10.1080/00103628409367551>
- Hiscox, J. D., & Israelstam, G. F. (1979). Different methods of chlorophyll extraction. *Canadian Journal of Botany*, 57, 1332-1332. <https://doi.org/10.1139/b79-163>
- Huq, I. M. S., & Alam, M. D. (2005). A handbook on analyses of soil, plant and water. Bacer-Du, University of Dhaka, Bangladesh. pp. 13-40.
- Jianrong F., Changgeng Z., Lina, J., & Zheng, W. (1995). Potassium improves yield and

quality of mulberry leaves. *Better Crops*, 79, 4.

Loomis, E. W., & Shull, A. C. (1937). *Methods in plant physiology*. McGraw-Hill Book Company, New York.

Miah, M. A. B. (1989). *Studies on the growth and yield of mulberry (Morus alba L.)*. Ph.D. Thesis. University of Rajshahi, Bangladesh.

Miller, L. G. (1972). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry*, 426-428. <https://doi.org/10.1021/ac60147a030>

Paul, N. K., & Qaiyyum, M. A. (2009). Effect of different levels of NPK fertilizer and irrigation on yield and nutritive quality of mulberry leaf. *Bangladesh Journal of Agricultural Research*, 34(3), 435-442. <https://doi.org/10.3329/bjar.v34i3.3969>

Pervez, H., Ashraf, M., Makhdom, M. I., & Mahmood, T. (2007). Potassium nutrition of cotton (*Gossypium hirsutum* L.) in relation to cotton leaf curl virus disease in Aridi soils. *Pakistan Journal of Botany*, 39(2), 529-539.

Petersen, L. (1996). *Soil analytical methods soil testing management and development*. Soil Resources Development Institute, Dhaka, Bangladesh, 1-28.

Piper, C. S. (1950). *Soil and plant analysis*. Adelaide University. Hassel Press, Australia. 368p.

Piper, C. S. (1996). *Soil and Plant Analysis*, Hans Publishers, Bombay.

Podder, M., Akter, M., Saifullah, M. S. A., & Roy, S. (2012). Impacts of plough pan on physical and chemical properties of soil. *Journal of Environmental Science & Natural Resources*, 5(1), 289-294. <https://doi.org/10.3329/jesnr.v5i1.11594>

Rabbel, M. A. (1995). *Studies on important fungal diseases of mulberry (Morus sp.) leaf in Bangladesh and their control*. PhD Thesis, University of Rajshahi, Bangladesh.

Rai, V. R., & Mamtha, T. (2005). Seedling diseases of some important forest tree species and their management. In: *Working Papers of the Finish Forest Research Institute*, 11. <https://doi.org/10.1596/1813-9450-3685>

Reuveni, M., & Reuveni, R. (1996). Foliar applications of mono-potassium phosphate fertilizer inhibit powdery mildew development in nectarine trees. *Plant Pathology*, 20(3), 253-258. <https://doi.org/10.1080/07060669809500391>

Sattelmacher, B., Gerendas, J., & Thoms, K. (1993). Interaction between root growth and mineral nutrition. *Environmental and Experimental Botany*, 33, 63-73. [https://doi.org/10.1016/0098-8472\(93\)90056-L](https://doi.org/10.1016/0098-8472(93)90056-L)

Sengupta, A. K., Kumar, P., & Baig, M. G. (1990). *Hand book of pest and disease control of mulberry and silkworm*. Escap, Thailand. pp. 88.

Shankar, M. A., & Rangaswamy, B. T. (1999). Effect of applied nitrogen and potassium on mulberry leaf yield and quality in relation to silkworm cocoon characters, *Better Crops*

*International, India, 13(2), 20-21.*

Soltanpour, P. N., & Workman, S. (1979). Modification of the  $\text{nh}_4\text{hco}_3$ -dtpa soil test to omit carbon black. *Communications in Soil Science and Plant Analysis, 10*, 1411-1420. <https://doi.org/10.1080/00103627909366996>

Subbaswamy, M. R., Singhvi, N. R., Vedavyasa, K., Srinivasan, E. B., & Sarkar, A. (2001). Non exchangeable potassium source as a soil testing tool for potassium management in mulberry. *proc. nat. sem. Mullberry Sericulture. Res. Bangalore*, pp. 208-212.

Subbiah, V. B., & Asija, G. L. (1956). A rapid procedure for estimation of available nitrogen in soils. *Current Science, 25*, 259-260.

Vijayan, K., Tikader, A., Das, K. K., Roy, B. N., & Pavan, K. T. (1996). Genotypic influence on leaf moisture content and moisture retention capacity in mulberry (*Morus* spp.). *Bull. Sericulture Research, 7*, 95-98.

Wong, S. Y. (1923). The use of persulfate in the estimation of nitrogen by the arnold-gunning modification of kjeldahl's method. *Journal of Biological Chemistry, 55*, 427.

Yadav, R. C. (1983). Sulphate of potash - a quality fertilizer for quality crops. *Farmer Parliament, 18*, 14-15.

### **Copyright Disclaimer**

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).