ELEVATED PHOSPHORUS ENHANCES PRODUCTIVITY AND REDUCES COMMON DISEASES OF MULBERRY PLANT

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ABSTRACT

Elevated phosphorus (P) may improve productivity and suppresses common diseases of mulberry plant. This study was undertaken to quantify elevated level of P supply for mulberry cultivation with respect to the age of mulberry plant. A field experiment was conducted at Bangladesh Sericulture Research and Training Institute (BSTRI), Rajshahi, Bangladesh to find out the effect of elevated P on growth, leaf yield, leaf quality, nutrient uptake and infestation of common diseases of mulberry plant. Six levels of P (0, 40, 80, 120, 160 and 200 kg/ha/yr) along with BSRTI recommended basal doses (RBD) of nitrogen (N) and potassium (K) through 4 split doses were applied during mulberry plant production. Result showed that the leaf yield was increased by 71.67% for 6-10 year's plant due to application of 160 kg/ha/yr P with four split doses through BSRTI recommended basal doses of N and K. Similarly, the leaf quality parameters viz: moisture (%), Chlorophyll-a, Chlorophyll-b, crude protein (%), soluble carbohydrate (%), total sugar (%) and reducing sugar (%) except total mineral (%) were increased by 11.63, 5.13, 9.09, 44.00, 42.21, 30.62 and 18.49 % respectively for the same treatment. The average incidence percentages of common disease like powdery mildew, leaf spot and leaf rust diseases were reduced by 26.77, 62.07 and 38.54 % respectively under the same fertilizer management. This study concluded that the elevated P enhances mulberry leaf yield and quality as well as suppresses the common diseases incidence of mulberry plant.

Keywords: chlorophyll, leaf quality, powdery mildew, leaf spot, leaf rust, silk cocoon

1. INTRODUCTION

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

Phosphorus (P) has a positive response on mulberry crops under irrigated condition (Kasiviswanathan and Iyengar, 1966; Ray *et al*. 1973). The P influences the yield and leaf quality of mulberry plant (Bose *et al*. 2009). The P is also the most important plant nutrient that has a key role in the growth, metabolism and development of mulberry plants (Gallegos-Cedillo *et al.* 2016).

Mulberry plant is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et al.* 1990; Yashihiko 1995). Khan *et al.* (2004) reported that in Kashmir valley among the Mulberry diseases like leaf spot and powdery mildew are the major foliar diseases of mulberry which are the impediments in the production of quality leaf feed (Khan *et. al.* 2004). Powdery mildew, leaf spot and leaf rust are the major foliar fungal diseases which reduce the leaf production as well as depletion of leaf quality of mulberry plant (Rabbel 1995). Therefore, it is essential to investigate the impact of elevated phosphorus on common diseases of mulberry plant.

There is no study available to quantify elevated P effect on mulberry productivity and suppression of common disease during mulberry growth period. The present study quantifies the optimum level of P fertilizer need to be supplied in soil along with BSRTI, recommended basal dose (RBD) of N and K to get maximum mulberry leaf yield and quality. Therefore, studies were carried out to see the effect of different levels of phosphorus on growth attributes, leaf yields, leaf quality, nutrients uptake and common diseases of mulberry plant. It was hypothesized that the application of different levels of P with recommended basal doses of N and K will be enhanced the leaf yield, quality as well as suppress the infestation of common diseases of mulberry plant.

2. MATERIALS AND METHODS

2.1. Experimental site

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

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 phosphorus 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 the experimental plots:

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

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

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

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

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

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

2.5. Recorded growth attributes

Growth attributes namely, node per meter, length of longest shoot per plant, total branch number per plant, total branch height per plant (cm), total shoot weight per plant (g), 10 leaf area per plant (cm^2), 10 leaf weight per plant (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 d 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_2SO_4) (Podder *et al*. 2012). Soil available S (ppm) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen 1996). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et al.* 2012). The available P of the soil was determined by spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by Olsen

method with 0.5 M NaHCO$_3$ as outlined by Huq and Alam (2005). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979).

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 powdery mildew, leaf spot and leaf rust 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:

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

2.9. Statistical Analysis

The growth and yield contributing data were analyzed by using the Genstat 12.1th ed^{n} for Windows (Lawes Agricultural Trust, UK) and one-way ANOVA was performed to detect differences for each parameter among the treatments. Sigma Plot 12.5 versions was used for representing the results as a figure form. The leaf quality, 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 phosphorus on post harvest soil properties of mulberry garden

The average physicochemical properties of the post harvest experimental soil are presented in table-1. The average post-harvest soil pH, OM, N, P, K, Zn, Ca and Mg for (0-5) year's plant were 7.4 to 8.1, 1.21 to 1.61%, 0.06 to 0.9%, 10.3 to 18.8 micro g/g, 0.16 to 0.19 meq/100 g soil, 0.54 to 0.66 micro g/g, 17.35 to 17.55 meq/100 g soil and 2.31 to 2.56 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 7.3 to 8.2, 1.23 to 1.63%, 0.07 to 0.09%, 10.3 to 18.9 micro g/g, 0.18 to 0.20 meq/100 g soil, 0.55 to 0.66 micro g/g, 17.33 to 17.53 meq/100 g soil and 2.29 to 2.57 meq/100 g soil respectively.

Table 1: Effect of different phosphorus levels on physicochemical properties of the post harvest soil

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

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

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

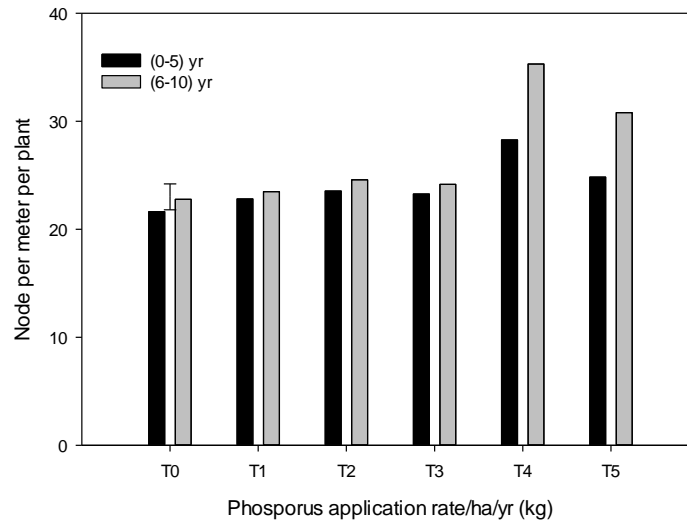### 3.2.1. Node per meter per plant

The average node per meter of mulberry plant was highly significant ($P < 0.001$) both for the plant ages and elevated 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 (6-10 year's plant) plant for the application of 160 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr (T_4) in four split doses. Also the interactive effect between plant ages and fertilizer treatment was significantly ($P < 0.01$) differ (Table 2, Fig. 1). The minimum average node per meter was 21.63 in (0-5) year's plant for Control.

Table 2: 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/pant (g)	10 Leaf area/pla nt (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.

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

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

3.2.2. 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 elevated doses of phosphorus ($P < 0.001$). But the interactive effect of plant age and p fertilizer treatment was not significantly differed for the length of longest shoot of the mulberry plant. However, the maximum average length of longest shoot was 165.13 cm in (6-10) year's mulberry plant for the treatment of T_4, where as the minimum length of longest shoot was 122.50 cm in (0-5) year's plant for control treatment (Table 2, Fig. 2).
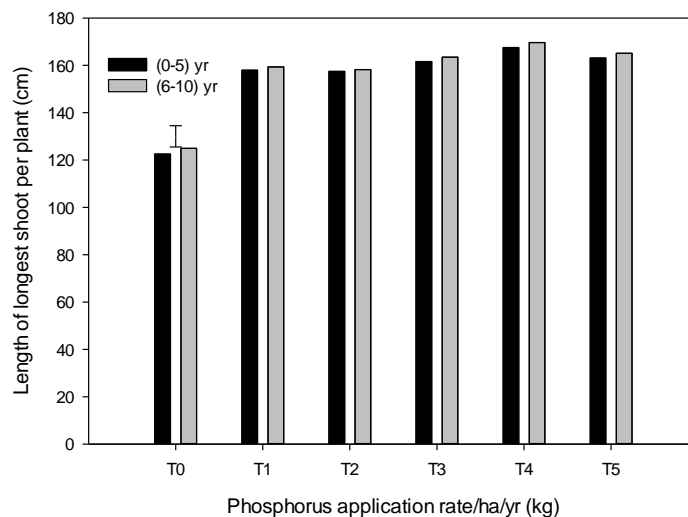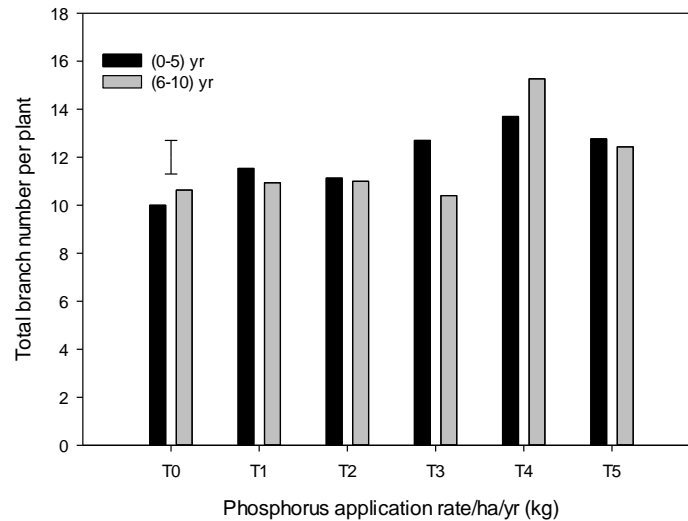
Fig. 2: Length of longest shoot per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

3.2.3. Total branch number per plant

The total branch number per plant was highly significant ($P < 0.001$) due to the P treatment. But there were no significant differences between the two ages of mulberry plant. However, the average maximum total branch number/plant was 15.27 in older (6-10 years) plant for T_4 (300 Kg N/ha/yr + 160 Kg P/ha/yr/ + 100 K/ha/yr) (Table 2, Fig. 3).
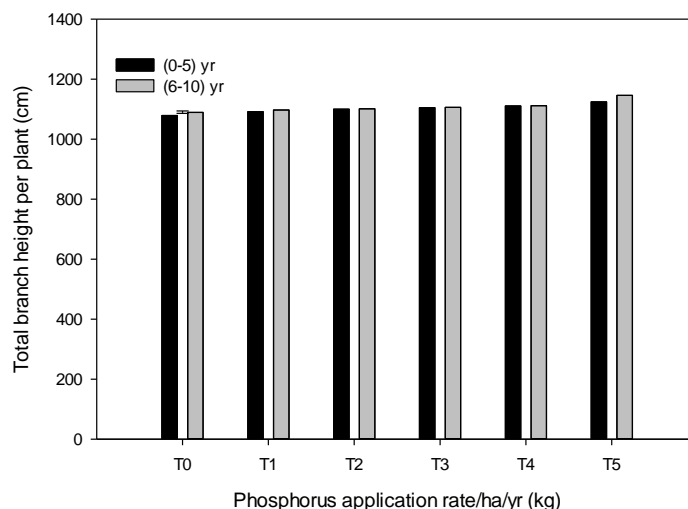
Fig. 3: Total branch number per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

3.2.4. Total branch height per plant (cm)

The total branch height of mulberry plant was highly significant ($P < 0.001$) due to the ages of mulberry plant, phosphorus fertilizer treatment and also the interactive effect (plant age's × treatment). The maximum average total branch height per plant was 1145.67 cm in (6-10) year's plant for T_4 treatment and the minimum height was 1078.72 cm in (0-5) year's plant for the control treatment (Table 2, Fig. 4).

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

3.2.5. Total shoot weight per plant (g)

The total shoot weight of mulberry plant was significantly ($P < 0.001$) increased due to the application of different levels of phosphorus fertilizer. The maximum average total shoot weight was 827.55 g in (6-10) year's mulberry plant for the treatment of T_4 whereas, the minimum total shoots weight was 755.29 g for control treatment (Table 2, Fig. 5).
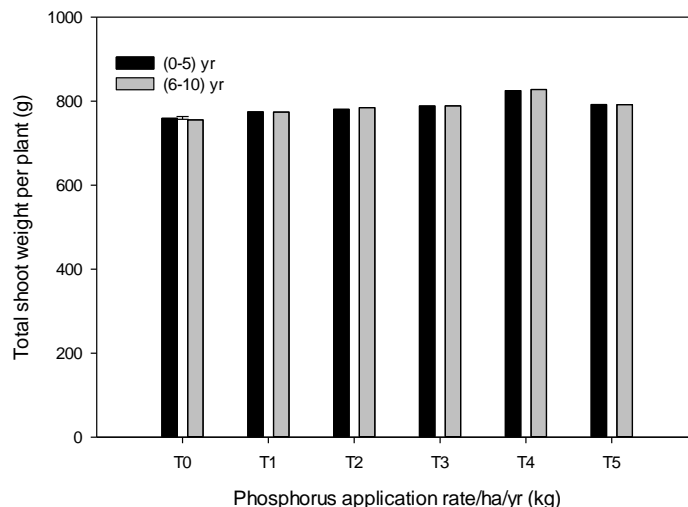
Fig. 5: Total shoot weight per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

3.2.6. 10 leaf area/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 (300 Kg N/ha/yr + 160 Kg P/ha/yr/ + 100 K/ha/yr) treatment which was significantly differ only for the P levels. But the average 10 leaf area was non significant due to the plant ages and the interactive effect between plant ages and P treatment. However, the minimum 10 leaf area was 476.98 cm^2 in (0-5) year plant for Control (Table 2, Fig. 6).
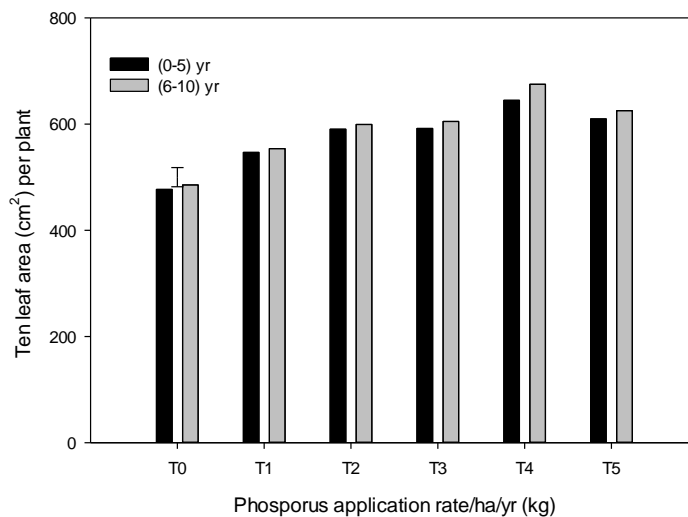
Fig. 6: 10 leaf area/plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

3.2.7. 10 leaf weight per plant (gm)

The differences in the average ten leaf 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 10 leaf weight was 46.67 gm in (6-10) year's plant for the application of 160 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr in four split doses. Even the interactive effect between mulberry plant age and P treatment was significantly differed. However, the minimum 10 leaf weight was 35.33 gm in (0-5) year's plant for control (Table 2, Fig. 7).
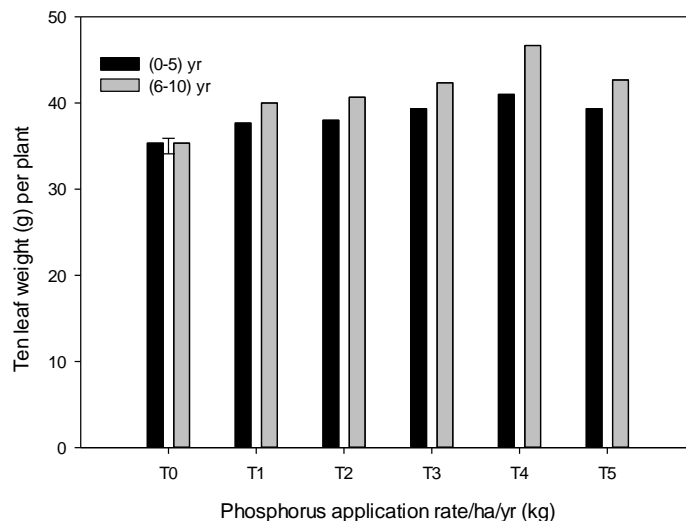
Fig. 7: Ten leaf weight per plant in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P= 0.05) different levels of phosphorus and mulberry plant age interactions.

3.2.8. Total leaf yield/ha/year (MT)

The average total leaf yield/ha/year was highly significant ($P < 0.001$) for mulberry plant ages, P levels and the interactive effect between plant ages and P treatment respectively. The highest total leaf yield per hectare per year was 47.69 metric ton in (6-10) year's plant due to the application of 160 kg P/ha/yr with 300 kg N and 100 kg K/ha/yr in four split doses. However, the minimum leaf yield per hectare per year was 27.78 metric ton in (0-5) year's plant for control (Table 2, Fig. 8).
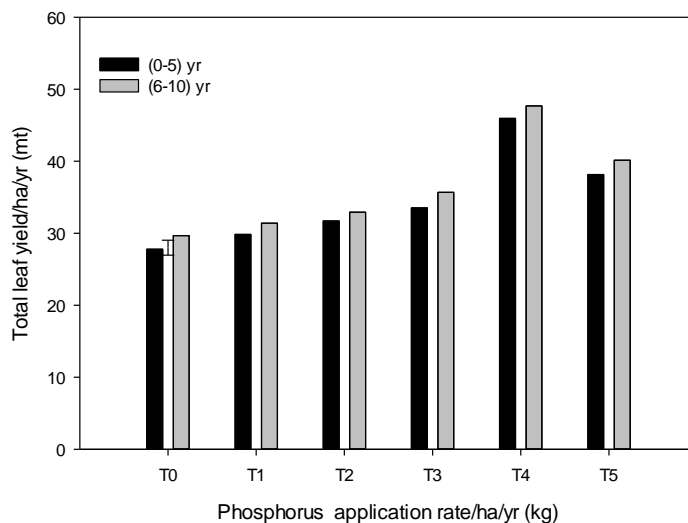
Fig. 8: Total leaf yield/ha/year in mulberry plants as influenced by various levels of P management practices. Where, T_0 = 0 kg P/year, T_1 = 40 kg P/year, T_2 = 80 kg P/year, T_3 = 120 kg P/year, T_4 = 160 kg P/year and T_5 = 200 kg P/year. Vertical bar represent LSD (P = 0.05) different levels of phosphorus and mulberry plant age interactions.

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

3.3.1. 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) year's plant for the treatment of T_4 (300 kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr) which was statistically similar with the treatment of T_2. The minimum moisture (%) 65.93 was recorded in the leaf of (0-5) years mulberry plant for control (Table 3).

3.3.2. Chlorophyll-a (micro g/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 micro g 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 micro g for T_1 and T_3 (Table 3).

3.3.3. Chlorophyll-b (micro g/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 micro g in (6-10) year's mulberry plant for the treatment of T_5 and the minimum Chlorophyll-b was 48.36 micro g in (0-5) year's plant for control (Table 3).

3.3.4. Total Mineral (%)

The total mineral content in mulberry leaves was significantly improved due to the plant ages and P levels. The maximum total mineral was found 10.07 % in the leaves of (6-10) year's plant for T_4 treatment which was statistically similar with T_3. However, the minimum total mineral was 8.23 % in the leaves of (0-5) year's plant for control (Table 3).

3.3.5. Crude Protein (%)

The ages of mulberry plant and 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) year's plant for the T_4 treated mulberry plant. However, the minimum crude protein was 14.18 % in (0-5) year's plant for control (Table 3).

3.3.6. Soluble Carbohydrate (%)

The soluble carbohydrate content in mulberry was significantly changed due to the plant ages and application of different level of P. Between the (0-5) and (6-10) year's mulberry plant the maximum soluble carbohydrate was 9.77 % in (6-10) year's plant for T_4 treated plant. However, the minimum soluble carbohydrate was 6.65 % in the leaves of (0-5) year's plant for control (Table 3).

3.3.7. 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 was 6.10 % in the leaves of (6-10) year's plant for T_4 treated mulberry plant. Conversely, the minimum total sugar was 4.48 % in (0-5) year plant for control (Table 3).

3.3.8. Reducing Sugar (%)

The reducing sugar (%) in mulberry leaves was significantly increased due to the 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) year's plant for T_4 treated plant. However, the minimum reducing sugar was 3.03% in (0-5) year's plant for control (Table 3).

3.4. Effect of phosphorus on nutrients uptake by mulberry plant

Nitrogen, phosphorus and potassium uptake by the mulberry leaves was significantly increased due to the mulberry plant ages and gradated doses of phosphorus. Among the six levels of phosphorus the maximum nitrogen, phosphorus and potassium uptake were 143.21, 24.44 and 64.72 kg/ha/yr respectively in (6-10) year's plant for the application of 160 kg P/ha/yr with BSRTI recommended basal dose of N and K (Table 4).

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

The common infestation of powdery mildew, leaf spot and leaf rust diseases in (6-10) year's mulberry plant were drastically reduced due to the elevated P application in soil. The average powdery mildew, leaf spot and leaf rust incidence percentage were comparatively in the high level of P application. In case of powdery mildew and leaf spot diseases the average lower incidence percentages were 1.27 and 0.58 respectively for the treatment of T_4 (120 kg P/ha/yr). But the lower average incidence percentage of leaf rust was 0.96 for the application of 90 kg P/ha/yr with four split doses of BSRTI recommended basal dose of N and K. 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 phosphorus on mulberry leaf yield and quality

Elevated doses of P 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 respectively were applied with BSRTI recommended N and K @ 300 kg N and 100 kg K/ha/yr in four splits doses for mulberry plant production. The growth and yield contributing components of mulberry plant such as nodes per meter, total branch number, length of longest shoot, total shoot weight, total branches height, 10-leaf area, 10-leaf weight per plant and total leaf yield/ha/year were significantly ($P \leq 0.001$) increased due to the application of 160 Kg P/ha/yr with 300 Kg N/ha/yr and 100 K/ha/yr as compared to the other treatments (Table 2). The maximum leaf yield was 47.69 mt/ha/year for the treatment of T_4 (300 kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr) which was 60.79 % higher than the maximum average yield of control 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 2). 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 for T_4 (300

kg N/ha/yr + 160 kg P/ha/yr + 100 kg K/ha/yr) treated mulberry plant. Our findings are more or less similar with the previous findings of Paul *et al.* (2009). They were applied four levels of P in four split doses viz; 0 kg, 100 kg, 150 kg and 200 kg P/ha/yr with 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 found 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 were applied five levels of P_2O_5 as a basal @ 0, 15, 30, 45 and 60 kg/ha/yr and found that the plant height, leaf area and leaf yield with moisture contents were significantly increased due to P application from 30 kg to 60 kg P_2O_5/ha/yr over the control, the maximum being with 60 P_2O_5/ha/yr. 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.

4.2. Impact of mulberry plant ages on leaf yield and quality

The leaf yield and quality of mulberry plant was significantly increased by the ages of plant. In our study the (6-10) year's mulberry plant was gave the maximum leaf yield with superior leaf quality than the (0-5) year's plant. We applied 0 kg P, 40 kg P, 80 kg P, 120 kg P, 160 kg P and 200 kg P/ha/yr respectively with BSRTI recommended N and K @ 300 kg N and 100 kg K/ha/yr 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 found for (6-10) year's mulberry plant than the (0-5) year's plant. However, the maximum average mulberry leaf yield was 47.69 mt/ha/year which was 3.79% greater than the maximum average yield 45.95 mt of (0-5) year's plant. Most of the leaves quality parameters except percentage mineral were also significantly increased due to the ages of mulberry plant whereas 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 in (6-10) year's mulberry plant. In case of (0-5) year's plant 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. But our speculation is due to the increased nutrient demand and absorption of (6-10) years plants compared to (0-5) years plants, regardless of P level, 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.

4.3. Phosphorus enhances the nutrient uptake by the mulberry plant

Nitrogen phosphorus and potassium uptake in mulberry leaf were found significant in (6-10) year's plant for the application of 160 kg P/ha/yr with BSRTI recommended basal dose of N and K which was corroborated with the findings of Bose *et al.* (2009). They were applied 0, 15, 30, 45 and 60 kg P/ha/yr with 150 kg N and 50 kg K/ha/yr respectively and found that the nitrogen, phosphorus and potassium uptake were found to be statistically significant up to 60 kg P/ha/yr which were 114.70, 12.48 and 54.67 kg/ha/yr respectively may be due to the synergistic interaction effect of higher dose of phosphorus. Our speculation was the higher levels of phosphorus (160 kg P/ha/yr) was comparatively optimum and available which influenced the N, P and K uptake by the mulberry which is lined with the speculation of Prasad *et al.* (1992). They reported that application of phosphate significantly influenced the N and P uptake of mulberry.

4.4. Effect of elevated phosphorus on mulberry diseases infestation

Elevated phosphorus with BSRTI recommended basal doses of N and P suppress the incidences of powdery mildew, leaf spot and leaf rust diseases. Among the six levels of phosphorus the minimum powdery mildew and leaf spot infestation were 1.27% and 0.58% respectively for the application of 120 kg K with 300 kg N and 100 kg K/ha/yr for four split doses. But in case of leaf rust the lower incidence percentage was 0.96% for the treated of 90 kg P with 300 kg N and 100 kg K/ha/yr in four split doses. However, no study is available that elevated phosphorus reduces the foliar disease of mulberry plant. But, a study was conducted by Nwogbaga *et al.* (2015) who found that the downy mildew and other fungal diseases of Cucumber (*Cucumis sativus* L.) were significantly reduces due to the foliar application of NPK at the rate of 19.181 kg/ha. Similarly, Huber *et al.* (1999) found that P is most effective when it is applied to control the fungal disease of seedlings due to the faster root development allows to the plant to escape

disease. Our speculation is that P is the essential element of the building blocks of life, the ribonucleic acids (RNA), as well as being required for many additional biochemical and physiological processes including energy transfer, protein metabolism, and other functions which may builds the defense mechanism against the fungal diseases of mulberry plant, as result the infestation of powdery mildew, leaf spot and leaf rust were comparatively low.

5. CONCLUSION

This study demonstrated that the application of elevated phosphorus in soil with BSRTI recommended basal dose of N and K is a progressive fertilizer management approach for mulberry cultivation. The elevated phosphorus application in soil enhances mulberry plant growth, leaf yield, mulberry leaf quality and suppresses common diseases of mulberry plant. Out of the six levels of phosphorus the application of 160 kg P with BSRTI recommended basal dose of 300 kg N and 100 kg K per/ha/yr through four split doses gave the best performances among all the treatments. Therefore, this study concluded that 160 kg P per hectare per year in combination with BSRTI recommended basal dose of nitrogen and potassium can be recommended to the sericulture farmers to obtain a higher leaf yield with superior nutritive value by suppress common diseases viz: powdery mildew, leaf spot and leaf rust of mulberry plant.

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