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Combined application of foliar fertilizer with basal NPK enhances mulberry leaf yield and silkworm cocoon productivity in calcareous soil

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ABSTRACT

One of the reason of low Mulberry plant (*Morus spp*.) production in calcareous soils is due to the low efficiency of soil applied fertilizers. Thus, in search of an alternative efficient fertilizer application method, field experiments were conducted at Bangladesh Sericulture Research and Training Institute (BSTRI), Rajshahi, Bangladesh in consecutive two years for achieving higher productivity of mulberry leaf and silkworm cocoon, *Bombyx mori* L. Four fertilizer management practices such as Control, Basal, Basal + Urea (B+U) and Basal + Foliar fertilizer (FF) were followed for mulberry plant production. Result showed that 3 times FF spray with basal application of NPK (305 kg N, 105 kg K and 66 kg P ha^{-1} yr^{-1} in 4 splits doses enhances biochemical constituents in mulberry leaf, leaf yield, silkworm growth as well as cocoon parameters. This study concluded that this treatment was regarded as the best fertilizer management practice which increased the mulberry leaf and cocoon productivity by 17.0 and 52.8 %, respectively over the control. Leaf quality of mulberry in terms of moisture, crude protein, soluble carbohydrate, reducing sugar and total mineral was increased by 14.0, 57.6, 85.8, 140.4 and 60.5 %, respectively in comparison with the control. Thus, foliar spray of foliar fertilizer had a good impact on sericultural productivity.

Keywords: Foliar spray, Mulberry leaf yield, Silkworm cocoon

INTRODUCTION

Mulberry (*Morus spp.)*, the host plant of silkworm (*Bombyx mori L.*), is cultivated for its foliage for rearing of silkworm to produce cocoon and silk yarn. Silkworm obtains its entire nutritional requirement from mulberry leaves as because this insect is mono-phagous and can complete its life cycle on mulberry leaves exclusively. Feeding of quality mulberry leaf is one of the important pre-requisite for producing of quality cocoon and hence, cultivation of mulberry with proper nutrient management is important. In Bangladesh, fertilizers are generally applied to soil, foliar application is seldom practiced. Availability of micronutrients particularly Zn, B, Fe, Mn, Cu in calcareous soil is low due to high soil pH and presence of $CaCO_3$ (Jahiruddin *et al.*, 2000). These elements precipitate as $CaCO_3$ (Shorrocks, 1997; Rengel, 2015; Romheld *et al.*, 1986). At pH values above 7, it has been estimated that the total concentration of inorganic Fe species in the soil solution is around 10^{-10} M (Boukhalfa *et al*., 2002), that is, 10^4 –10^5 fold lower than that required for an optimal growth of plants (Römheld *et al*., 1986). Thus, Fe deficiency is a frequent problem for many crops, particularly in calcareous soils (Mengel *et al*., 2001). In addition to micronutrient deficiency, the availability of P to plants is impaired in calcareous soil due to the formation of poorly soluble calcium phosphate minerals, with the lowest solubility of these calcium phosphate minerals at about pH 8 (Hopkin and Ellsworth, 2005). This low nutrient present in the soil are not well absorbed in deep rooted plants and translocation of nutrients to shoot is sluggish under adverse soil condition which favor soil fixation of nutrients.

To overcome this problem, foliar spray of nutrients particularly micronutrients is an option. Jamal *et al*., (2006) report that aerial spray of nutrients is preferred and gives quicker and better results than the soil application. Plant requires specific amount of certain nutrients in specific form at appropriate time for their growth and development (Sajid *et al*., 2008). Micronutrients play a major role in several metabolic activities responsible for protein, sugar and enzyme synthesis leading to better quality mulberry leaf production (Geetha *et al.*, 2016). Foliar spray of

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micronutrients can influence the growth, quality and yield of mulberry crop (Chikkaswamy *et al*., 2006). As mulberry (*Morus spp.)* is a deep rooted and high biomass producing foliage crop, responds well to foliar nutrition. Foliar application in right time increases level of absorption in specific nutrients to the leaf during growth and development (Narahari *et al*., 1997). Foliar application of micronutrients has improved the yield, quality and micronutrient status of mulberry leaf and the quantitative traits of silkworm, *Bombyx mori* L.in India (Bose and Majumder, 1996).

Our previous studies showed that Mulberry plant production was highest in the liquid fertilizer treated plot followed by urea, basal and control (Ahmed *et al*., 2015: Ahmed *et al*, 2017). Ahmed *et al.*, (2015) demonstrated only the individual impact of control, basal, foliar spray of urea and foliar fertilization treatments on mulberry plant production. Similarly, Ahmed *et al.* (2017) observed the combined effect of foliar applied urea + foliar fertilization along with soil applied basal dose of NPK on mulberry leaf yield and leaf quality excluding silkworm cocoon productivity. However, the present study quantifies the single effect of foliar urea and foliar fertilizer along with soil applied basal dose of NPK on mulberry leaf yield, quality and cocoon productivity. It was hypothesized that the application of liquid fertilizer containing all the plant nutrients particularly micronutrients through foliar spray at regular intervals with basal dose of NPK will enhance rapid absorption of nutrients and will increase quality mulberry leaf production as well as silkworm cocoon production.

MATERIALS AND METHODS

Experimental site and soil

An experiment was conducted on an Typic Endoaquents (Soil series: Sukdebpur) at the experimental field of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh (24˚22′29″ N, 88˚37′84″ E, elevation 23 m above mean sea level) for two consecutive years, 2016 and 2017. The experimental site is classed as high land on a Ganges Floodplain (Arial Beel) soil (FAO/UNDP 1988). The soil (0-15 cm) was loamy textured (400 sand:370 silt:230 clay, in g kg^{-1}) with very low Walkley & Black organic carbon 5.8 g kg^{-1} having a pH (water) 8.5, total N (Kjeldahl N) 0.6 mg g^{-1}, exchangeable K, Ca and Mg 0.33, 13.43 and 1.83 cmol (+) kg^{-1} soil, respectively, available P (Olsen) and S 11.3 and 8.8 µg g^{-1}, respectively, available Zn and B 0.94 and 0.49 µg g^{-1} soil, respectively. The experimental area has subtropical humid climate and is characterized by hot and humid summers and cool winters with an annual maximum mean temperature of 31.02°C and average rainfall of 125 mm (BMD, 2017), 71% of which falls between June to September (Mossammat *et.al*, 2016).

Experimental plant

Mulberry (*Morus spp*) variety BM-9 (BM = Bangladesh Mulberry) was used as test plant. Mulberry plant is small to medium sized shrubs or trees with a thick tan-gray ridged trunk which is perennial, deep rooted and hardy in nature. For its perennial, deep rooted and hardy habit, mulberry is grown in wide range of soil and agro-climatic conditions in Bangladesh.

The high bush plantation system of mulberry garden was used in this study. Silkworm is commercially reared in four seasons of a year. Depending upon the silkworm rearing season, mulberry garden was pruned four times per year namely month of January, April, July and September.

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) having four treatments with three replications. Fertilizer treatments are given below:

(1) Control: No fertilizer was applied.

(2) Basal dose (B): As per recommendation by Bangladesh Sericulture Research and Training Institute (BSRTI) the basal dose used was 305 kg N (Urea=660 kg), 105 kg K (TSP=330kg) and 66 kg P (MoP=210kg)/ha/yr respectively with four split doses each after 3 month intervals in 15-20 days after pruning (DAPr).

(3) Basal + Urea (B+U): 0.3% urea (w/v) water was applied 3 times in a cropping season at 15 day intervals as foliar spray with BSRTI recommended basal dose of NPK. An amount of 500 L was applied/ha in each spraying totaling 18 kg urea ha^{-1} yr^{-1}.

(4) Basal + Foliar fertilizer (FF) (B+FF): 0.3 % FF (w/v) water was applied 3 times in a cropping season at 15 day intervals as foliar spray with BSRTI recommended basal doze of NPK. Foliar fertilizer is a liquid fertilizer containing 13 essential plant nutrients (N, P, K, S, Ca, Mg, Cu, Fe, Zn, B, Mn, Mo and Cl). An amount of 500 L was applied/ha in each spraying totaling 18 L FF ha^{-1} yr^{-1}.

Mass percent (%) composition of Urea, Triple Superphosphate, Muriate of Potash and Foliar fertilizers which were used in these treatments are given in Table 1.

Table 1. Mass percent (%) composition of fertilizer used in this experiment

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

*****Result obtained from the chemical analysis of foliar fertilizer (FF) that done by the Soil Resource Development Institute, Regional Research Station, Dhaka.

In every case, basal fertilizer was applied after 20 days of pruning (DAPr) when the sprouting of mulberry plant started. However, urea and foliar fertilizer (FF) were sprayed as a foliar dose 3 times in a season at 30, 45 and 60 DAPr. Other cultural practices like irrigation, weeding, insect-pest management practices etc. were done as per requirement.

Recorded parameters of mulberry plant

Data were collected for the node per meter, total branch number per plant, leaf number per branch, 10 leaf areas, 10 leaf weight per plant and total weight per plant. Among these parameters specially the 10 leaf areas was measured by leaf area meter on randomly selected 10 leaves for each treatment.

Data were collected at 90 DAPr for each cropping seasons. i.e. four times data was collected in a year. Two years data was collected in the months of April, July, September and December.

Leaf quality analysis

The mulberry leaf samples at different heights of the plant (top, middle and bottom) were collected in paper bags at 70 DAPr and composite leaf samples were made. Then, the prepared leaf samples were shade dried for three days and again dried in hot air oven at 70°C for one hour and were ground into powder forchemo-assay. The moisture (%) was determined following Vijayan *et al*., (1996), total mineral (%) following AOAC (1980), protein (%) following Kjeldahl's method (Wong, 1923), reducing sugar (%) following Miller (1972) and Loomis *et al*., (1937) procedure and soluble carbohydrate (%) following Dubois *et al*., (1956) method.

Silkworm rearing

Silkworm rearing experiment was conducted over 4 seasons in each year. For each treatment one egg lying was reared and three replications were maintained. After III molts, about 100 larvae/replication were maintained. The larvae fed four times daily (6 am, 10 am, 4 pm and 10 pm) with healthy, fresh mulberry leaves. Young age larvae were fed with tender, succulent leaves, while mature and coarse leaves were fed to larvae when they grow till ripening. Cocoons were collected on the 5th day of mounting and were assessed for commercial parameters viz. weight of 10 matured larvae, single cocoon weight, single shell weight, SR%, highest filament length, and yields/100 dfls (Disease free layings). Cocoon quality was assessed following the methods, as described by Sonwalkar (1991).

Statistical analysis

Statistical tests were performed with Genstat 12.1 ed. for Windows (Lawes Agricultural Trust, UK). One-way ANOVA was performed to detect differences for each parameter among the treatments. Mean values of each parameter were compared by DMRT test. In order to investigate the combined effect of foliar fertilizer along with basal dose of NPK on mulberry, leaf quality was analyzed using the Statistical Analysis System (SAS 9.1.3). Sigma Plot 12.5 versions was used for representing the results as a figure form.

RESULTS

Effects of fertilizer management on mulberry plant production

Nodes per meter

The average number of nodes per meter was significantly (*P ≤ 0.05*) influenced by the foliar (FF) fertilizer treatments, but did not statistically differ for the cropping year. However, the average maximum node per meter was found 23.24 in B+FF treatment for the 2nd year crop, which was statistically higher than the basal (B) and control treatments but statistically similar with B+U treatment. The minimum node per meter was recorded in control treatment (Table 2).

Total branches per plant

The maximum total branches per plant were statistically (*P ≤ 0.05*) differ due to fertilizer treatments, but did not significantly vary for the cropping years. The average maximum total branches per plant were 14.94 for the treatment of B+FF which was statistically similar with B+U treatment. The minimum total branches per plant were 8.73 for the treatment of control.

Table 2. Effects of fertilizer management on growth and yield of mulberry plant

Treatments	Nodes per meter		Total branches per plant		Leaves per branch		Ten leaf area (cm^2)		Ten leaf weight (gm)		Total leaf weight per plant (gm)	
	1st yr	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**
Control	19.1c	19.1c	9.1bc	8.7c	34.5c	33.3c	397.9c	392.7c	18.9e	9.1de	401.8b	402.4b
Basal (B)	20.5c	20.4bc	10.7bc	10.8bc	41.1b	43.6ab	445.9bc	447.2bc	20.8cd	20.4c	411.4b	411.6b
B + U	21.7ab	21.7ab	12.2abc	12.6ab.	42.5ab	45.1ab	482.8ab	487.4ab	20.9bc	21.1abc	443.4a	443.6a
B + FF	23.2a	23.2a	14.9a	14.9a	44.3ab	45.8a	542.8a	545.5a	21.8ab	22.9a	469.7a	470.8a

Leaves per branch

The average numbers of leaves per branch were significantly (*P ≤ 0.05*) differed for the fertilizer treatment but did not statistically significant in between 1st and 2nd cropping year. However, the average maximum leaves number per branch was 45.79 in the 2nd year for the treatment of B+FF, which was statistically similar with other treatments except control (Table 2).

Ten leaf area

The average 10 leaf area was similar between control and basal treatment. The maximum 10 leaf area was recorded 545.47 cm^2 in B+FF treated mulberry plot which was statistically higher than the other treatments except B+U treatment. However, the minimum ten leaf area was 392.69 cm^2 for the Control treatment (Table 2).

Ten leaf weight

The leaf weight significantly (*P ≤ 0.05)* differs among treatments. The maximum 10 leaf weight was 22.08 g in the 2nd year crop for the treatment of B+FF which was statistically higher both for the basal and control treatments. The minimum10 leaf weight was recorded 18.86 g for the control treatment (Table 2).

Total leaf weight per plant

The maximum average total leaf weight per plant was 470.80 g in the 2nd year for the B+FF fertilizer treatment which was significantly (*P ≤ 0.05)* higher than the basal and control treatments but statistically similar with B+U fertilizer treatment. However, the minimum total leaf weight per plant was 401.78 g for control treatment (Table 2).

Effect of fertilizer management on leaf quality of mulberry plant

Leaf quality of mulberry plant differed due to different fertilizer managements (Table 3). Among the four fertilizer treatments the average maximum moisture (%) was found 76.2% in the 2nd year for the treatment of B + FF which was significantly higher than that of the other treatments. Similarly, the average maximum crude protein was found 20.2 % in the 2nd year for the treatment of B + FF which was significantly different among other treatments. The average maximum soluble carbohydrate was measured 14.4% in the 2nd year for the treatment of B + FF which was significantly (*P* ≥ 0.05%) the highest among all the treatments. The average reducing sugar % was statistically (*P* ≥ 0.05%) maximum in the 1st year for the treatment of B + FF followed by the other treatments which was 4.15%. Similarly, the average maximum total mineral was 12.2% in the 2nd year for the treatment of B + FF which was also significantly (*P* ≥ 0.05%) higher over the treatments.

Table 3. Effects of fertilizer management on leaf quality of mulberry plant

Treatments	Moisture (%)		Crude protein (%)		Soluble Carbohydrate (%)		Reducing sugar (%)		Total mineral (%)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
Control	60.9f	66.8f	12.8f	12.7g	7.7c	7.7c	1.7e	1.7e	7.6e	7.6e
Basal (B)	72.7e	73.6c	17.4e	17.6d	8.8bc	9.5bc	3.1d	3.1d	10.7c	10.6d
B + U	72.9d	72.9d	17.7c	17.9b.	10.4bc	10.4bc	3.2c	3.2c	10.1b	10.1b
B + FF	75.4ab	76.2a	20.2a	20.2a	11.5ab	14.4a	4.1a	4.1ab	12.2a	12.2a

Means with the same letter are not significantly different at 5% level by DMRT.

Effects of fertilizer management on the silkworm rearing performances

Among the four fertilizer treatments the average weight of 10 mature larvae (g), single cocoon weight (g), single shell weight (g), cocoon shell ratio (SR%), highest filament length (meter) and highest cocoon yield/100 dfls (Disease free laying) (kg) statistically differed due to the different fertilizer treatments. However, the average highest weight of 10 mature larvae (g), single cocoon weight (g), single shell weight (g), cocoon shell ratio (SR%), highest filament length (m) and cocoon yield/100 dfls (kg) were found 35.9, 1.64, 0.28, 18.4, 1006 and 79.2, respectively for the silkworm reared by the B + FF treated mulberry leaf followed by the B + U, Basal and control treated mulberry leaf (Table 4).

Table 4. Economic characters of silkworm rearing under various fertilizers management

Treatments	Weight of 10 mature larve (g)	Single cocoon weight (g)	Single shell weight (g)	Cocoon Shell Ratio (%)	Highest filament length (m)	Cocoon yield/100 dfls
Control	31.9d	1.37d	0.2c	15.2d	856d	51.9d
Basal (B)	32.4c	1.4c	0.2b	15.4c	905c	69.6c
B + U	33.7b	1.5b	0.3a	16.9b	937b	73.8b
B + FF	35.9a	1.6a	0.3a	18.4a	1006a	79.2a

DISCUSSION

Soil condition affecting mulberry plant production

Our soil physical and chemical findings suggest that the existing soil health condition was not congenial to obtain to get reasonable mulberry plant production.

Critical levels of N, P, S, Zn, Fe, Mn, Cu and B in soil were 75 ppm, 12 ppm, 12 ppm, 2 ppm, 20 ppm, 5 ppm, 1 ppm and 0.2 ppm respectively (Portch *et al*., 1984). Initial soil analysis shows that the nutrient content of experimental soil was N (57 ppm), P (8.8 ppm), K (10.3%), organic matter (1.01%), Zn (1.3 ppm), Cu (0.8 ppm), Fe (17.6 ppm), Mn (3.5ppm), S (8.8 ppm), B (0.09 ppm) and soil pH (8.5) respectively. It indicates that in the initial soil macro and micro-nutrients were below the critical level. Due to calcareous soil nature of the experimental field, most of the micronutrients particularly B, Zn, Fe and Mn were not available to plant at optimal level. Similarly, our previous study showed that soil physical and chemical properties like soil pH range 6.2 - 6.8 and high soil organic matter content are suitable for mulberry plant production (Ahmed *et.al*., 2017). When soil pH is above 8.0, P fixation occurs with Ca and Fe forming Ca-P and Fe-P complex and thus, P insolubility arises in the soil solution (CSIRO, 2006). A previous study showed that N, K, Ca, Mg and S were more available within soil pH 6.5 - 8, while B, Cu, Fe, Mn and Zn were more available within soil pH 5 - 7, and P was most available within soil pH 5.5- 7.5 (McCauley *et al*., 2017). Furthermore, soil applied nutrients have a higher tendency to become unavailable to plants due to this high soil pH and calcareousness, even though the rate is increased further. Foliar fertilizer application does not have ability to replace soil-applied fertilizer completely, but it does increase the uptake and hence the efficiency of the nutrients applied to the soil (Tejada & Gonzalez, 2004). That’s why we applied the foliar fertilizer containing 14 macro and micro nutrients with BSRTI recommended basal dose of NPK as an additional supplementary nutrient for improving the quality and quantity mulberry yield. Therefore, it is an effective method for correcting nutrient deficiencies particularly for micronutrients and to overcome soils inability to mobilize nutrients to the plants. Foliar spray was found very effective in improving the leaf yield and quality of mulberry which is an important factor for optimum growth and development of silkworm, *Bombyx mori* (Bose *et al.,* 1995).

Effects of basal, urea and foliar fertilizer application on mulberry plant

Our experimental result showed that among the yield contributing characters of mulberry plant nodes per meter, total branches, leaves per branch, 10-leaf area, 10-leaf weight and leaf weight per plant were significantly ($P \leq 0.001$) influenced by the treatment of B+FF as compared to other treatments (Table 2). However, there were no significant differences were found for the cropping year except leaf number per branch and 10 leaf weight ($P \leq 0.05$) (Table 2). Even the interaction of year × fertilizer treatments were not statistically significant (Table 2). These findings could be due to the presence of most of the macro and micro nutrient in balanced condition in FF (Foliar fertilizer) which was applied additionally as foliar spray with the soil applied basal dose of N, P and K fertilizers (Table 1). This means our fertilizer management practices enhanced the growth, development and yield of mulberry plant. Similarly, an earlier study found that the integrated nutrient management increased mulberry leaf yield and quality (Setua *et al.,* 2005). It was also recognized that supplementary foliar fertilization during crop growth improves the mineral status of plants and increases the crop yield (Moslluh *et al.,* 1978: Kolota *et al.,* 2006**)** which is positively correlated with the present result. Likewise, Malakouti, (2008) reported that the foliar micronutrients spray had a positive influence on the growth parameters for plant.

Foliar fertilization helps to take up nutrients properly through stomatal conductance of mulberry leaf. This could be reason that mulberry plant can utilize both macro and micro nutrients for their growth and development. Regardless of that, foliar fertilization minimizes applied nutrient loss through leaching, denitrification and percolation. Rapid and efficient utilization of foliar applied nutrients by the mulberry plant when sprayed at a regular interval rectifies nutrient deficiencies and plant hidden hunger, avoids canopy closure, reduces nutrient losses, maintains balanced physiological reaction, growth and development. As a consequence, almost all the yield contributing characteristics of mulberry plant positively enhanced through supplementary foliar fertilization with basal NPK application in soil.

Among the all treatments the result of foliar spray of 0.3% urea in water with basal dose of NPK was also good after the treatment of B+0.03% FF. In case of cropping year only, the leaf number per branch and 10 leaf weight were significant differences for the cropping year ($P \leq 0.05$) (Table 2). However, the interaction of year × fertilizer treatments was not statistically significant (Table 2).

This might be due to multiple advantage of foliar applied urea such as rapid absorption, efficient use by plant resulted less urea needed and independence of soil conditions which was in line with the earlier findings (Yildirim *et al*., 2007). This is also in line with the previous finding by Fritz (1978), Mondal & Mamun (2011) and Wojcik (2004) who reported that the absorption of urea by the leaves of most crops are 10 to 20 times higher than the inorganic ions of N.

Effects of fertilizer management on leaf quality of mulberry plant

Foliar fertilizer (FF) with BSRTI recommended basal dose of N, P and K application enhances the nutritive quality of mulberry leaves. Among the various leaf quality characters the moisture (%), crude protein (%), soluble carbohydrate (%), reducing sugar and total mineral (%) were comparatively higher in combined application of B+FF treatment followed by the B+U, BS and control treatment (Table 3). In this study the highest moisture content was 76.1% in the foliar application of FF with the recommended basal doses of NPK followed by the B+U, Basal and control treatments respectively. The higher moisture content in mulberry leaves might be due to the additional supply of nutrition through foliar spray to the leaves and also withstanding the moisture for longer duration. The progressive increase in the leaf protein content by the combined application of recommended basal dose of NPK with foliar spray of FF (foliar fertilizer) might be due to higher absorption of nitrogen, and other nutrients both by roots from soil and leaves, which is more or less similar with the findings of Chela *et al.,* (1999) and Uyanoz (2007). The foliar spray of FF with recommended basal doses of NPK gave the higher percentage of soluble Carbohydrate (11.5%) followed by the other treatments which are in conformity with the previous findings of Gowda *et al.,* (2000). They reported that the soil applied DAP, with foliar application of seriboost increased the total carbohydrates in mulberry leaf. The higher level of reducing sugar content in mulberry leaves was probably due to transportation of soluble sugar from the flowering parts and used by the developing leaves of the crop plants. Our speculation is that the nutrients (NPK) present in the soil were not well absorbed by the deep rooted mulberry plants and translocation of nutrients to shoot was sluggish under adverse soil condition which favor soil fixation of nutrients. However, in the applied foliar fertilizer (FF), most of the nutrients like N, P, K, Ca, S, Mg, Mn, Fe, Zn, B etc (Table 1) were in balanced proportion and available forms.

Effects of fertilizer management on silkworm rearing performance

The rearing performance as well as cocoon productivity of silkworm was significantly increased by the foliar application of foliar fertilize (FF) with soil applied BSRTI recommended basal dose of NPK (Table 4). It is closely related with the findings of Ito *et al.,* (1966) and Horie *et al.,* (1967). They reported that foliar application of potassium, magnesium, iron, manganese and cobalt are essential for the growth of silkworm. Vishwanath *et al*., (1997); Jayaprakshrao *et al*., (1998) and Basit *et al*., (1999) found that mulberry leaves sprayed over with macro and micronutrients were fed to the *Bombyx mori* L all the silkworm growth parameters were improved. However, our speculation was due to the presence of almost all the macro and micro nutrients in applied foliar fertilizer and application method was foliar spray the essential plant nutrients uptake by the mulberry plant through the leaf was higher and thus it improved the leaf quality. This high quality feeding positively influenced the growth of silkworm as well as increased the cocoon productivity of silkworms.

CONCLUSION

This study demonstrated that combined application of foliar fertilizer (FF) with BSRTI recommended basal dose of NPK in calcareous soil is a proactive fertilizer management strategy for mulberry plant production. This strategy improves efficient and available uptake of essential macro and micro nutrients by the plant resulting in improvement of plant growth, leaf yield, quality and silk cocoon parameters Out of the four fertilizer treatments, treatment B + FF followed by treatment B + U showed overall better performances compared to the other treatments. Therefore, this study concluded that foliar spray of liquid fertilizers in combination with recommended basal dose of NPK can be recommended to the sericulture farmers to obtain a higher leaf yield with good nutritive value for the growth and development of silkworm larvae and hence to get good quality cocoons.

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