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Application of Foliar Nutrients to Increase Productivity in Sericulture

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ABSTRACT

It is a well acknowledged fact that foliar nutrients provide instant nourishment to the plants which not only enhance the growth rate of plants but also boost their productivity. Present review focuses on bringing in a nutshell, diverse information about different foliar formulations (natural, synthetic and commercially available) which can play a significant role in sustainable improvement of mulberry plants and silkworms, *Bombyx mori* L. (Lepidoptera: Bombycidae). Furthermore, it reveals that foliar sprays on mulberry plants help in disease management, enhance biochemical constituents in mulberry plants, silkworm growth as well as cocoon parameters. Thus, foliar sprays have a wider impact on sericulture productivity.

Key words: Mulberry, silkworm, foliar nutrients, quality, productivity, disease

INTRODUCTION

It is a well established fact that, synthetic chemicals, fertilizers, pesticides, herbicides, growth promoters and other inputs though enhance productivity but adversely affect the eco-system and increase prices of agricultural inputs (Patil *et al*., 2006). Due to excessive use of insecticides and fungicides for improving productivity of mulberry cultivars, these chemicals pose a serious threat not only to mulberry crop but also the environment. So an alternative approach is necessary for the purpose of enhancing mulberry production without causing substantial damage to the ecosystem. Foliar spray in liquid form with plurality of strains is generally used as spray for augmentation of crop yield and leaf quality.

The main aim of applying foliar nutrients to mulberry plants is to enhance essential nutrients and biochemical content in a readily available form. These sprays are not only cost effective but also have a longer life as compared to solid biofertilizers and chemical fertilizers (Katiyar *et al*., 1995). It is easy to apply and has been found to be highly effective for the growth and development of mulberry crop. Due to presence of antioxidants, essential amino acids, macro and micronutrients in foliar spray, it directly influences the growth of mulberry and is also capable of enhancing the productivity of mulberry.

Biological organisms play very important role and can be used as constituents in foliar spray. Nitrogen fixing algae i.e., *Nostoc* and *Anabaena* have been used to evaluate different combinations of nutrients both in indoor and outdoor cultures used as foliar sprays for mulberry cultivation (Bongale, 1989). Plant growth promoting bacterium applied as foliar spray on *Lycopersicon esculentum* and *Cucumis sativus* increased biochemical contents and growth parameters of plants (Dursun *et al*., 2010).

Application of sodium chloride at one per cent concentration imposed through roots by irrigation during the growth period of mulberry (S-1 variety) decreased the leaf yield, photosynthetic rate and water use efficiency. Sodium chloride treatment drastically reduced the soluble protein content but the opposite trend was also noticed in the case of soluble sugar and proline content of mulberry. Foliar spray of kinetin (Lee, 1985) and spermidine with different concentrations increased the leaf yield and photosynthetic rate under normal condition (Das *et al.*, 2000). Hosny *et al.* (1996) showed that 'ethrel' can be used as an effective foliar spray on *Morus alba* and *Baladi* trees. It was also seen that the quality and percentage of dropped leaves were found more in untreated plants. The total nitrogen content increased in dropped leaves while the sugar content decreased.

Gowda *et al.* (2000) studied the efficacy of foliar spray 'seriboost' on mulberry and its impact on cocoon production. Foliar spray on M-5 mulberry variety significantly increased the number of shoots, shoot height, number of leaves and total leaf yield. In addition, to that increased N, P, K, Ca, Mg, S and level of soluble sugars, protein and total chlorophyll.

IMPORTANCE OF FOLIAR SPRAY

Nutrients 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 favour soil fixation of nutrients. Mulberry (*Morus* spp.) as a deep rooted 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).

Effects of foliar spray of urea (Gooding and Davies, 1992; Readman *et al.*, 1997) along with different doses of NPK fertilizers significantly increase leaf yield and nutrients like moisture content, protein, sugar, reducing sugar and starch in both tender and matured leaves (Quader *et al.*, 1989). Commercially available foliar formulations namely Plantoflex, Microflex, Multizyme and Harith used on M-5 mulberry variety under irrigated condition increased yield, quality, total chlorophyll, sugar and protein contents of mulberry (Narahari *et al.*, 2001).

Plant nutrients like magnesium, manganese, iron, zinc and boron are also used as foliar spray on mulberry crop for enhanced growth, yield, quality (Loknath and Shivasankar, 1986), cocoon weight and cocoon yield (Vishwanathan and Krishnamurthy, 1982). The influence of micronutrients was studied by assessing the quality of leaves offered to bivoltine race Kalimpong-A (Kasivishwanathan, 1986) on larval development and cocoon characters of silkworm (*Bombyx mori* L.).

Das *et al.* (2002) found that, foliar spray of kinetin based plant growth regulator (Biozyme) spray to mulberry plant before onset of water logging, showed that biozyme partially compensated the water logging effect and increased the leaf yield by 30% and improved the chlorophyll, sugar content and photosynthetic rate significantly. Foliar spray of Indol Acetic Acid (IAA) and Gibberellic Acid (also called Gibberellin A3, GA and GA_3) as plant growth regulators significantly improved leaf lobation and sex expression of Kajli and Mysore Local cultivars of mulberry (Govinda and Basavaiah, 2006).

Previous studies have shown that, liquid fertilizers significantly improve crop productivity and it has also been reported that, foliar application of urea increased the protein content of wheat grain (Abod *et al.*, 2004). The effects of foliar spray of CCC (2-Chloroethyl-trimethyl-ammonium chloride) on growth and metabolic activities of mulberry were calculated. Leaf area, fresh and dry weight of leaves and height of shoot was not found effective but it was effective in enhancing diameter of shoot and chlorophyll content (Lee, 1980). The activities of hydrolytic reducing sugar in mulberry leaves of infiltrated sucrose were lower than those of the control in all treated leaves

but the activities of synthetic non-reducing sugar in the mulberry leaves infiltrated glucose were higher. Growth regulators especially 'Cytokinin' modify morphological and physiological characteristics of plant and also induce better adaptation of the plant to environment which improves the growth and yield. Such compounds induce cell division and organogenesis in plant cell cultures and affect many other physiological and developmental processes in plants (Ibrahim *et al*., 2001). Different types of foliar spray (Table 1) can be used effectively to enhance nutritive quality of mulberry leaves and their use will help to reduce the extensive usage of chemicals and insecticides.

Table 1: Commonly used foliar nutrients in mulberry production

Foliar nutrients	Improvement in plant	Source of information	Natural product	Synthetic product	Commercially available product
Botanicals	Chlorophyll-a, b, total chlorophyll, total soluble sugar, total soluble protein and total soluble phenol	CSR and TI, Berhampore, India.	+	-	-
B-nine	Leaf moisture and chlorophyll	RSRS, Dehradun, India.	+	-	-
Phalda	Leaf yield	RTRS, Bhandara, India.	+	-	-
Tracel, Navaras, Mircon 'S20' Amruth, Paras, Plantovit	Growth, quality and yield of mulberry leaves	DOS, Bangalore University, India.	+	-	-
Azotobacter chroococcum	Atmospheric nitrogen	CSR and TI, Mysore, India.	+	-	-
Seri-Azo and Seri-Phos	Mulberry leaf yield and quality	DOS, UAS, Dharwad, India.	-	+	-
Di-ammonium phosphate	Total chlorophyll, crude protein, total carbohydrates, nitrogen phosphorus, potassium, calcium, magnesium and sulphur.	DOS, GKVK, Bangalore, India.	-	+	+
Daman Penshibao	Amino acids, citric acid and humic acid, photosynthesis	DOS, GKVK, Bangalore, India	+	-	+
Biozyme	Chlorophyll, sugar content and photosynthetic rate an water logging effect	CSR and TI, Berhampore, India.	+	-	-
VAM	Leaf quality and quantity	RSRS, Chamarajanagar, India.	+	-	+
Green Leaf	Shoot height, number of shoots, leaves per plant, fresh leaf yield, dry leaf yield, moisture content	DOS, Bangalore University, India.	+	-	-
Seriboost	N, P and K constituents of the leaf	SDTCL, Bangalore, India.	+	-	+
Sodium chloride	Soluble sugar and proline	CSR and TI, Berhampore, West Bengal, India.	-	+	+
Ethrel	Nitrogen content increased in dropped leaves	PPRI, DOS, Dokki-Giza, Egypt.	-	+	+
Plantonik	Chlorophylls, proteins, sugar and amino acid	RSRS, Jorhat, Assam, India.	+	-	-
Urea and NPK	Nitrogen in plants	BAAS, Dhaka, Bangladesh.	-	+	+
Plantoflex, Microflex	Growth, quality and yield of mulberry leaves	KSSR and DI, Bangalore, India.	+	-	-
Multizyme	Leaf moisture and chlorophyll	KSSR and DI, Bangalore, India.	+	-	-
Nostoc, Anabaena	Leaf yield	KSSR and DI, Bangalore, India.	+	-	-
2Chloroethyl-trimethyl-ammonium chloride	Metabolic activities	CACNU, Kwangju, Korea Republic.	-	+	+
Harith	Leaf yield and quantity	KSSR and DI, Bangalore, India.	+	-	+
Tracel-2	Leaf spot disease	Rallis India, Ltd., Bangalore.	-	+	+
PGPR	Leaf rust disease	RSRS, Chamarajanagar, India.	+	-	-

+: Yes, -: No

FOLIAR SPRAY AND PLANT RELATIONSHIP

The uptake of plant nutrients varies according to the plant species, variety and agro-climatic conditions which ultimately determine factors such as leaf morphology, structure and the rate of physiological processes. Several investigators have been reported on the penetrability of the lower epidermis vs. the upper epidermis which will be governed chiefly by stomatal and cuticular variations between the two leaf surfaces (Currier and Dybing, 1959; Wojick, 2004). The structure and composition of the cuticle as well as the morphology, distribution and sizes of the stomata and leaf hairs differ between plant species and influence foliar uptake processes. Variations in cuticular structure and composition resulted into differences in leaf wettability, retention and penetration of substances.

Selective permeability of the cuticular edges of guard cells has been reported (Eichert and Burkhardt, 2001; Schlegel *et al*., 2006; Schonherr, 2001). Tender and partially-expanded leaves are more penetrable than fully expanded leaves (Sargent and Blackman, 1962). The stomata present in old leaves may fail to open and penetrability of foliar spray suffers adversely (Turner and Begg, 1973).

MICRO ORGANISMS AS FOLIAR SPRAY

Continuous use of chemicals, insecticides, fungicides and antibiotics lead to evolution of resistant pathogen strains, a major constraint in enhancing productivity. Various investigators determined that Plant Growth Promoting Rhizobacteria (PGPR) can stimulate growth and increase yield in sugar beet (Cakmakc *et al*., 2006), in spring barley (Salantur *et al*., 2005), in apricot (Esitken *et al*., 2003; Altindag *et al*., 2006), in raspberry (Orhan *et al*., 2006) and in apple (Aslantas *et al*., 2007). Maximum grain yield were produced from inoculation of blue green algae alone or in combination with *Azospirillum* in different seasons (Sharief *et al*., 2006). Arbuscular Mycorrhizal Fungi (AMF) also well known for phosphorus solubilization, increased plant nutrients uptake and in control of root diseases in mulberry (Bharadwaj and Satyawati, 2006).

Several studies have also shown that, liquid biofertilizer formulations i.e., *Azotobacter*, phosphate solubilizing microorganisms and potash mobilizing bacteria, carrier based biofertilizers formulation (Seri-Azo, Seri-Phos and Potash Mobilizing Bacteria) and foliar application in rhizosphere have significantly enhanced leaf yield of mulberry, quality and soil health under irrigated condition. However, the role of potash mobilizing bacteria *Frateuria aurentia* belonging to the family Pseudomonaceae in liquid or carrier based forms was found to be quite promising when applied in the rhizosphere of mulberry (Saha *et al*., 2006). Application of Vesicular Arbuscular Mycorrhiza (VAM) and *Azotobacter* has shown a way of saving on expensive fertilizers like Nitrogen and Phosphorus thereby improving leaf yield and quality. Unlike chemical fertilizers, VAM and Biofertilizer enrich the soil fertility and are eco-friendly (Srikantaswamy *et al*., 2001). Kumar *et al*. (2009) studied the efficacy of blue green algae (*Spirulina*) as a foliar spray drastically enhanced pupal weight, cocoon weight, shell weight and silk filament length.

EFFICACY OF FOLIAR NUTRIENTS IN ENHANCING BIOCHEMICAL CONSTITUENTS IN MULBERRY

Biochemical analysis revealed that, foliar spray of botanicals increased Chlorophyll-a, b, total chlorophyll, total soluble sugar, total soluble protein and total soluble phenolic content. Kumar *et al*. (2010a, b) evaluated the best mulberry variety from the locally available for silkworm feeding based on the nutritional composition, physiological and biochemical parameters.

The effect of B-nine on growth modification of mulberry viz. moisture and chlorophyll contents in the leaf as major component and also produced thicker and darker leaves with high nutritive values (Mohan *et al.*, 2006). 'Navaras' a proprietary commercial nutrient used as foliar spray on Kanva-2 mulberry variety significantly increased the growth and number of leaves per plant along with other biochemical parameter (Chikkaswamy *et al.*, 2006). He also reported that, effect of 'Vipul' as foliar spray on mulberry under irrigated conditions increased leaf yield, leaf moisture, number of shoots and number of leaves. Plant growth promoter 'Phalda' is used as foliar spray which increases the growth and leaf yield of mulberry and its application produced variety specific results.

Response of mulberry varieties like K-2, S-13 and S-34 was positive on growth parameters, except plant height, leaf yield and biomass production (Singhvi *et al.*, 2006). Daman Penshibao is a multifunctional organic acids (amino acids, citric acid and humic acid) with the necessary major nutrients, micro elements and vitamins (Jyothi *et al.*, 2002). It is known to promote the uptake of nutrients, stimulate photosynthesis, protein synthesis and activate enzyme action. Foliar application of Daman Penshibao has significantly increased the chlorophyll-a, chlorophyll-b, total chlorophyll and soluble protein while crude protein was higher. Plantonik a micronutrient formulation was found to be effective for improvement in leaf yield of mulberry over control through foliar spray. The leaf biomass was also improved significantly in 'Plantonik' sprayed plants (Phukan *et al.*, 1995).

Raj *et al.* (2003) investigated the effect of different doses/forms of phosphatic fertilizer and methods of application on improving the quality of mulberry leaf of M-5 variety and elemental composition under irrigated condition. Foliar application of phosphorus through Single Super Phosphate (SSP) and Di-ammonium Phosphate (DAP) recorded significantly results. It enhance leaf moisture percentage, total chlorophyll, crude protein, total carbohydrates and plant nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulphur content (Trivedy *et al.*, 2003). Foliar treatment with different concentrations of potassium chloride (KCl) to mulberry plants resulted in higher level of total chlorophyll, total sugars and soluble protein (Das *et al.*, 2003). Biochemical factors such as sugar, protein, moisture content and leaf yield significantly increased by application of 'green leaf' as foliar spray (Chikkaswamy *et al.*, 2001).

ROLE OF FOLIAR SPRAYS ON MULBERRY DISEASE MANAGEMENT

Many diseases of mulberry affect the leaf yield and nutritive quality. Therefore, Maji *et al.* (2006) developed eco-friendly control of different mulberry diseases using two botanicals viz., botanical-I and botanical-II and one biocontrol agent. Botanical-II and biocontrol agent reduced powdery mildew disease which is caused by *Phyllactinia corylea*. The findings indicated that foliar spray of botanicals is safe and eco-friendly for management of major foliar diseases of mulberry. Further, foliar spray of medicinal plant extract of neem, parthenium and bulb extract of garlic were tested to assess their effect on conidial germination of *Phyllactinia corylea* and powdery mildew disease development on mulberry leaves and these were found to drastically reduce the Percent Disease Index (PDI) (Vidyasagar and Rajasab, 2001).

Leaf spot disease of mulberry is very common, causes substantial yield loss caused by *Cercospora moricola* which is controlled by Tracel, Navaras, Mircon 'S20' Amruth, Paras, Plantovit, Micromixture (Chikkaswamy, 2006) and Tracel-2 (Teotia *et al.*, 1994). As a result, disease resistant mulberry varieties viz, BM-4 and BM-5 (Ghosh *et al.*, 2003) were evaluated to decrease the substantial crop loss. Srikantaswamy and Subramaniam (2005) have reported *Azotobacter*

chrococcum as growth promoter and its role in resistance against leaf rust disease. The aqueous leaf extracts prepared from *Azadirachta indica, Rhizophora apiculata, Adathoda vasica, Parthenium hysterophorus, Lantana camara* and *Prosopis juliflora* were directly used as foliar spray in the control of tukra disease of mulberry (Babu *et al*., 1994).

FOLIAR SPRAYS AS SILKWORM GROWTH ENHANCER

Ito and Niminura (1966) and Horie *et al*. (1967) suggested that potassium, magnesium, iron, manganese and cobalt are essential for the growth of silkworm. Therefore, mulberry leaves sprayed over with macro and micronutrients were fed to the *Bombyx mori* L. and observed that all silkworm growth parameters were found to be improved (Vishwanath *et al*., 1997; Jayaprakshrao *et al*., 1998; Basit and Ashfaq, 1999). Foliar application of 'seriboost' significantly improved larval weight of silkworms (Singhvi *et al*., 2002). Further, Bose *et al*. (1994) also observed the enhanced total larval duration and larval weight. Ankalgi and Ansari (1992) developed foliar spray of triacontonal and fasal which is effectively used in silkworm disease management. Islam *et al*. (2004) resulted that nickel chloride can be used at low concentrations for enhancing the economic character of silkworm, *Bombyx mori* L.

The nutritional supplement of soluble protein aqueous extracts from waste pupae on larval instars of *Antheraea assama* in different concentrations has an impact on the larval growth and cocoon parameters. The increased rate of food absorption in silkworms is evident with the enrichment of mulberry leaves by leaf extracts of *Coffea arabica* (Jeyapaul *et al*., 2003). The protein extract of muga pupa can be utilized as a supplement on the muga food plant as a growth stimulator in silkworm (Saikia and Das, 2005).

Effects of *Tridax procumbens, Tribulus terrestris* and *Parthenium hysterophorus* recorded significantly higher mature larval weight and found to be superior over controls and bringing down the larval mortality (Murugesh and Bhaskar, 2007). The silkworms fed with foliar spray of Green Leaf have improved cocoon weight, shell weight, pupal weight and filament length significantly enhanced when cocoons spun by worms fed with foliar treated leaves (Chikkaswamy *et al*., 2001).

ROLE OF FOLIAR SPRAYS ON SILKWORM DISEASE MANAGEMENT

The most commonly used methods of preventing diseases in silkworm are through application of chemicals. In nature, a number of plants have been found to harbor antiviral substances. Srivastava and Kumar (2009) studied the effect of antibiotics on reduction of mortality rate in mulberry silkworm (*Bombyx mori* L.). Phytochemicals like flavanoids has anti-microbial activity (Bernabas and Nagarajan, 1988) and their possible role in defense mechanism of silkworms (Chandrakala *et al*., 2007). Adminstration of seed extract of *Plectranthes corylifolia* and leaf extract of *P. ambonicus* to third instar silkworms resulted into reduction in mortality due to grasserie disease (Manimegalai and Chandramohan, 2006; Ranganatha *et al*., 2004). It is also noticed that higher doses of vitamin C, lowered the silk yield and caused decline in growth of silkworm larvae (Hussain and Javed, 2002). Some fungicides and chemicals were evaluated to control Muscardine disease in the silkworm *Bombyx mori* L. (Chikkaswamy *et al*., 2007).

Antifungal activity of certain botanicals in which the highest growth inhibition and lowest sporulation of *Beauveri bassiana* were observed with *Phyllantus niruri* (Savitha and Bhaskar, 2005). Extract of algae (*Turbinaria conoides*) were found effective against *Beauveria bassiana* infected silkworm larvae for antifungal activity (Kumari *et al*., 2011). According to Shuba and Bhaskar (2006), the leaf extracts of *Adhathoda vasica, P. niruri, P. corylifolia, Tribulus*

terrestris and *Withania somniferum* when supplemented through mulberry leaf to BmNPV infected larvae, were able to inhibit multiplication of BmNPV.

EFFECT OF FOLIAR SPRAYS ON COCOON PARAMETERS

Silk protein synthesis starts in fourth and fifth instar of silkworm, there is a huge demand for protein rich food in late instars. Dietary supplementation of the leaf, flower and pod extract of *Moringa oleifera* elicited varied responses in the final instar larvae of the mulberry silkworm, *Bombyx mori* L. (Rajeswari and Isaiarasu, 2004). Various minerals viz. N, P, K, Ca, Mg and Cu, respectively in various combinations were enhanced silk production of *Bombyx mori* L. (Ashfaq *et al*., 2000).

Amaranthus grain powder is very rich in carbohydrates, protein, iron and a-carotene and it is found to be effective in increasing silk yield coupled with increased cocoon and shell weights (Gururaja and Patil, 1997). The application of leaf extract of *Acacia indica* and *Vitex negundo* at different concentrations on silkworm has significantly improved the shell weight and silk filament length (Sujatha and Rao, 2004). *Parthenium* root extract induced silkworms to feed more resulting in higher cocoon and pupal weight and better survival (Patil *et al*., 2005). The conversion of ingested dry matter into shell was increased by 20% in silkworms due to the application of *Spirulina* solution (Kamalakannani *et al*., 2005).

FUTURE PERSPECTIVE OF FOLIAR SPRAY

Foliar sprays influence the performance of mulberry varieties in terms of physiological parameters of plants viz., protein, carbohydrate, chlorophyll, carotenoids etc. Further research is needed to know the potential interactions between formulation components using modern analytical techniques. Efforts are to be made to understand the relevance of the biochemical properties of bio-foliar sprays of blue green algae, medicinal plants and vermiwash extracts containing formulations and its significance in the changes of leaf surface in relation to the foliar uptake of nutrients. The process of penetration of biological organism containing solutions is increasing growth, quality and quantity of mulberry. The role of physiological processes and environmental factors in foliar uptake and distribution are required to be investigated further using intact leaves. In a nutshell, more information relating to biological organism based foliar spray and plants relationship. Eco-friendly and holistic approach is required to develop effective foliar spray formulations to correct widespread deficiency of mulberry and to sustain sericulture.

CONCLUSION

Foliar feeding is a technique of feeding plants by applying nutrients directly to their leaves. Foliar spray has been used as supplemental doses of minor and major nutrients, plant hormones, botanicals, stimulants and other beneficial substances. It has been known for many years that plants are able to absorb essential nutrients through their leaves and develop defense mechanisms to resist several mulberry and silkworm diseases. Study concluded that foliar nutrients improved drought tolerance, increases crop quality and yield of mulberry, enhanced silkworm growth and cocoon productivity without harming flora and fauna.

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