



Balanced Fertilization for Improved Nutrient use Efficiency and Mulberry Productivity

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Authors' contributions

This work was carried out in collaboration among all authors. Author MR conceptualized the research idea, facilitated research needs, interpreted the data and drafted the manuscript. Author ML executed the research in field and collected the data. Author SC reviewed the whole manuscript. Author SV critically revised and finally edited the whole manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2021/v33i2030647

Editor(s):

(1) Dr. Ahmed Medhat Mohamed Al-Naggar, Cairo University, Egypt.

Reviewers:

(1) N. Balaji Chowdary, Central Silk Board, India.

(2) Shariful Islam, City University, Bangladesh.

(3) Mohammadreza Momayezi, Islamic Azad University, Iran.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/72981>

Original Research Article

Received 16 June 2021
Accepted 26 August 2021
Published 05 October 2021

ABSTRACT

Aim: To study the effects of balanced fertilization in improving leaf yield, quality and nutrient use efficiency in mulberry.

Study Design: Experiment was conducted in randomized block design (RBD) consisting of 7 treatments in 3 replications.

Place and Duration of Study: The present study was conducted at Central Sericultural Research and Training Institute, Berhampore ((Latitude 24°05'N & Longitude 88°15'E; 18 m > MSL), West Bengal, India in two seasons during 2018 (July-August; September-October).

Methodology: Existing S-1635 mulberry plantation (10year-old; 60 cm × 60 cm spacing; net plot area: 32 m²) was utilized. Experiments were conducted in two seasons (July-August, 2018; September-October, 2018) in randomized block design (RBD) consisting of 7 treatments in 3 replications. The treatments in this study included, T₁: 100% N-P₂O₅-K₂O+S+Zn with Urea-SSP-10:26:26 + Bentonite Sulphur (8 kg ha⁻¹) + Zinc Sulphate (1 kg ha⁻¹) as BF; T₂: 75% BF; T₃: 100%

N-P₂O₅-K₂O alone (Urea-SSP-10:26:26); T₄: 75% N-P₂O₅-K₂O alone (Urea-SSP-10:26:26); T₅: 100% N-P₂O₅-K₂O alone (Urea-DAP-MOP); T₆: 100% N-P₂O₅-K₂O alone (Urea-SSP-MOP) as farmers' practice (FP); T₇: Nutrients omission plot (Control). The recommended fertilizer dose (100%) for irrigated mulberry production in the Eastern region is N-P₂O₅-K₂O=67-36-22 kg ha⁻¹ crop⁻¹. All the fertilizers were applied in two equal splits on 15th and 30th day after pruning.

Results: This study reveals the importance of balanced fertilization of mulberry with N, P, K, S and Zn for sustainable productivity, which is reflected by the maximum values for leaf yield attributes, chlorophyll content and leaf yield. Further, mulberry leaf quality (in terms of total soluble protein and total soluble sugar) significantly improved with balanced fertilization. Higher PFP and AUE were also recorded with fertilization with compound/complex fertilizers than with straight fertilizers; but the balanced fertilization exhibited remarkable enhancement.

Conclusion: The results prove that balanced fertilization of N-P₂O₅-K₂O @ 67-36-22 kg ha⁻¹ (Urea-SSP-10:26:26) with Bentonite sulphur (8 kg ha⁻¹) and zinc sulphate (1 kg ha⁻¹) were effective in improving mulberry productivity through enhanced nutrient use efficiency. This could be useful for realizing maximum productivity in mulberry as an efficient nutrient management strategy in mulberry cultivation.

Keywords: Mulberry; fertilizers; nutrient use efficiency; productivity; leaf yield; quality.

1. INTRODUCTION

Mulberry [*Morus* spp.] is one of the important industrial crops and its leaves are utilized as unique source for feeding silkworms (*Bombyx mori* L.); perennial and cultivated over 20 years as monoculture. The total area under mulberry cultivation in India is about 23.5 lakh ha and contributes directly in producing 25384 MT raw silk annually (Central Silk Board, Annual Report, 2019-20). West Bengal is one of the traditional silk-producing states in India with about 15721 ha plantations (Manjunath et al [1]). S1635 mulberry variety is predominantly cultivated in West Bengal with an average leaf biomass potential of 45 MT ha⁻¹ y⁻¹ in irrigated conditions. However, majority of mulberry farmers do not realize optimal leaf productivity due to varied soil fertility status (Ray et al [2], Liliane and Charles [3]); continuous soil nutrient depletion under intensive cropping system (five crops in a year) leading to decline in soil fertility resulting into lower crop yields (Shashidhar et al [4]). Fertilization has an important role in restoration and maintenance of soil fertility as well sustaining crop productivity (Chen et al [5], Bose and Kar [6]; Rathore and Srinivasulu [7]). Appropriate NPK fertilization can increase mulberry leaf yield by 30-35% and can also improve leaf quality (Ray et al [8], Bose and Majumder [9]). But in reality at the field level, majority of mulberry farmers resort to imbalanced fertilization (*i.e.*, application of only N fertilizer or N & P or N & K or N, P & K with almost no micronutrients). It is well documented that unbalanced availability of nutrients not only lead to lower crop yields (Krishna and Bongale [10], Chen and Lu [11]),

but can also result in mining of soil nutrient reserves which has deleterious effects on soil health (Mahajan and Gupta [12], Xu et al [13]). Besides, improper fertilizer source also leads to nutrient fixation and nutrient loss in the soil ultimately resulting in lower fertilizer use efficiency (Sarkar and Naidu [14], Mahesh et al [15]; Mahesh and Nanda [16]). Mulberry fertilization programmes are often practiced mainly with straight fertilizers (Urea, Single super phosphate, Muriate of potash) in West Bengal. But, several studies suggested that fertilization with either compound or complex fertilizers improve crop productivity and fertilizer use efficiency (Wadas and Dziugiel [17], Kokovic et al [18]).

Micronutrients also play an equally crucial role in maximizing mulberry productivity (Kumar et al [19], Fageria and Brazil [20]). Micronutrients influence qualitative and quantitative growth parameters of mulberry (Bose et al [21], Wani et al [22]). Sulphur and Zinc impart central role for chlorophyll biogenesis and associated enzymatic reactions, improves winter hardiness and immune systems in plants Sharma et al. [23]; Rathore et al [24]; Barker and Pilbeam [25], Mahadeva [26]. Earlier, beneficial effects of S and Zn in mulberry were reported by Roy and Gupta [27]. On the other hand, micronutrients deficiency also becomes one of major limiting factor for productivity, stability and sustainability of soils (Alloway [28], Bell and Dell [29], Bose and Kar [30] reported mulberry leaf yield was adversely affected in sulphur deficient soils. Generally, Indian soils possess negative nutrient balance (Tandon [31] and substantially deficient

in many cationic micronutrients like Zn (49%), Cu (3%), Fe (12%), Mn (5%), B (33%) and Mo (11%) (Singh and Behra [32], Singh [33]. Major deficiencies of S and Zn were recorded predominantly in mulberry growing areas in West Bengal (<https://www.soilhealth.dac.gov.in/>), which are critical in sustaining higher mulberry productivity over the years. Application of balanced nutrients with appropriate fertilizers could sustain mulberry productivity (Lu et al [34], Roy et al [35].

Balanced fertilization is the practice of applying essential nutrients in optimum and adequate amounts. Fertilization utilizing N, P, K, S and Zn nutrients in balanced form has crucial role in realizing growth and enhancing mulberry productivity (Nazar et al [36]. Kar et al [37] reported considerable improvement in mulberry leaf yield (30-36%) with NPK fertilization along with micronutrients spray in West Bengal. Petkov and Greiss [38] reported improved productivity and quality with combined fertilization of mineral fertilizers (N₃₀₀ P₁₅₀ K₁₂₀ kg ha⁻¹), organic fertilizers (15 t ha⁻¹) and micronutrients (Mg, Mn, Fe, Zn, Cu, B, Mo). Moreover, foliar spray of micronutrients has also lead to significant improvement in mulberry productivity in calcareous soils of Bangladesh (Ahmed et al [39]. Several studies suggested balanced fertilization is very effective in improving fertilizer use efficiency as well sustaining crop productivity in various agricultural crops (Lin Bao [40], Sharma and Jain [41], Rene [42], However, most of the research had been focused on N, P & K fertilization only and its response in mulberry (Bose et al [43], Sing et al [44], Mahesh et al [45]). Not much information is available on balanced fertilization in mulberry cultivation especially in West Bengal. The present study evaluates the effects of balanced fertilization in improving leaf yield, quality and nutrient use efficiency in mulberry.

2. MATERIALS AND METHODS

2.1 Location, Soil and Climatic Conditions

The present study was conducted at Central Sericultural Research and Training Institute, Berhampore ((Latitude 24°05'N & Longitude 88°15'E; 18 m > MSL), West Bengal, India during 2018. The experimental soil was clay loam having pH 7.1, electrical conductivity 0.08 dSm⁻¹, soil organic matter 0.81%, available nitrogen (N)

153 kg ha⁻¹, available phosphorus (P₂O₅) 66 kg ha⁻¹, available potassium (K₂O) 462 kg ha⁻¹ and available sulphur 2.45 kg ha⁻¹. Standard analytical procedures for available N by Subbiah and Asija [46], available P₂O₅ by Olsen et al [47], available K₂O by Stanford and English [48], organic carbon by Walkley and Black [49] and pH and electrical conductivity by Jackson [50] were used for soil analysis. The climate of CSRTI-Berhampore is tropical wet and dry climate of Gangetic alluvial plains with an annual average temperature of 27°C; average annual rainfall was 1344 mm (majority of rainfall due to South-West monsoon in June–September). The meteorological data for the crop season (June to October, 2018) was obtained from Meteorological observatory of CSRTI-Berhampore (Fig.1.).

2.2 Experimental Design and Treatments

Existing S-1635 mulberry plantation (10 year-old; 60 cm × 60 cm spacing; net plot area: 32 m²) was utilized. Experiments were conducted in two seasons (July-August, 2018; September-October, 2018) in randomized block design (RBD) consisting of 7 treatments in 3 replications. The treatments in this study included, T₁: 100% N-P₂O₅-K₂O+S+Zn with Urea-SSP-10:26:26 + Bentonite Sulphur (8 kg ha⁻¹)+ Zinc Sulphate (1 kg ha⁻¹) as BF; T₂: 75% BF; T₃: 100% N-P₂O₅-K₂O alone (Urea-SSP-10:26:26); T₄: 75% N-P₂O₅-K₂O alone (Urea-SSP-10:26:26); T₅: 100% N-P₂O₅-K₂O alone (Urea-DAP-MOP); T₆: 100% N-P₂O₅-K₂O alone (Urea-SSP-MOP) as farmers' practice (FP); T₇: Nutrients omission plot (Control). The recommended fertilizer dose (100%) for irrigated mulberry production in the Eastern region is N-P₂O₅-K₂O=67-36-22 kg ha⁻¹ crop⁻¹. All the fertilizers were applied in two equal splits on 15th and 30th day after pruning through localized placement method.

2.3 Crop Husbandry

Bottom pruning was adopted, followed by weeding and digging as per recommended practices for Eastern India (Setua [51]). The recommended Farm Yard Manure (FYM) @ 4 MT ha⁻¹) was applied before digging and properly incorporated into the soil. Flood irrigation was undertaken immediately after fertilizer and FYM application followed by irrigation at regular intervals (once in ten days with 4.5 cm water ha⁻¹). No pests and diseases were recorded in the experimental mulberry plantation.

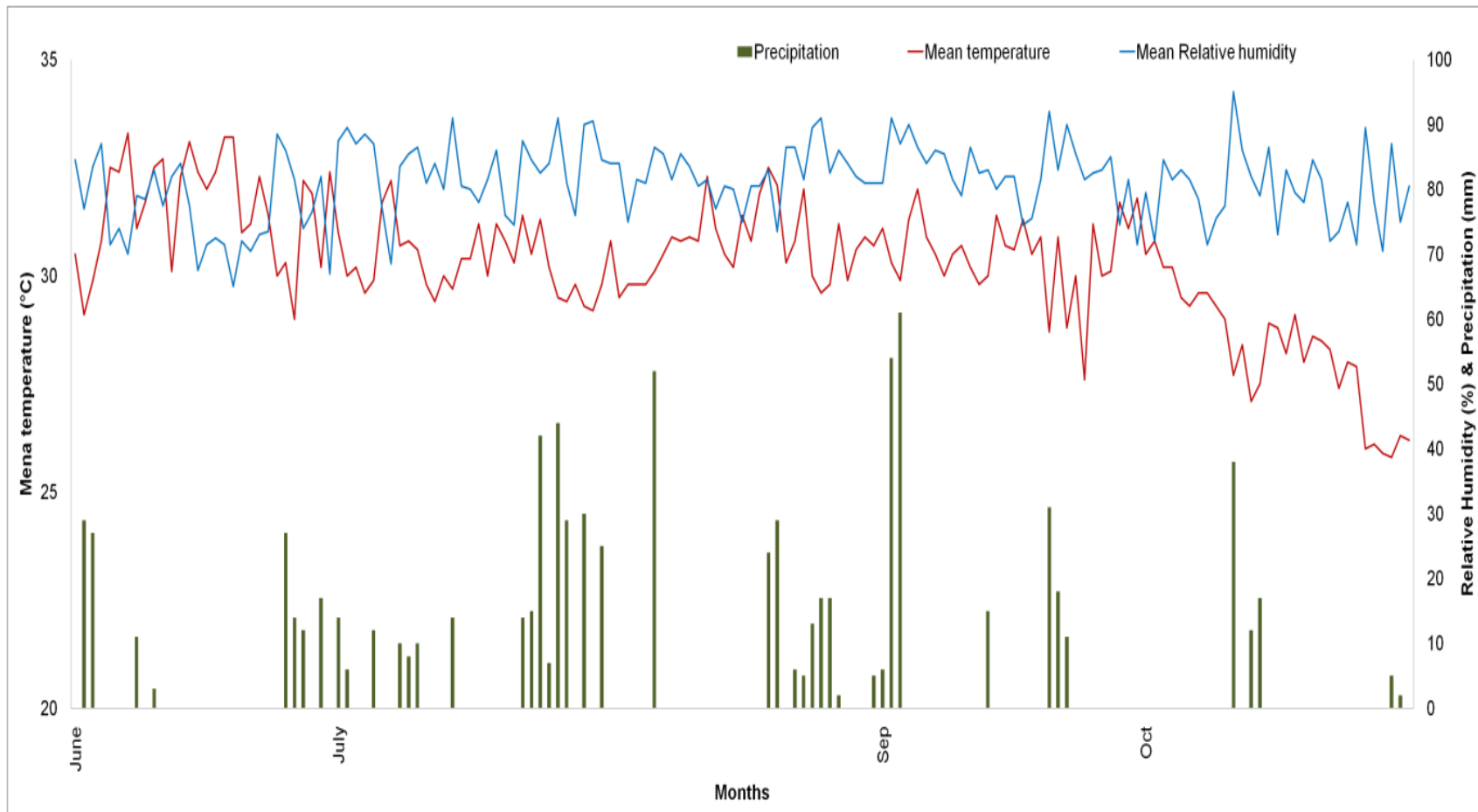


Fig. 1. Meteorological parameters of mean temperature, mean relative humidity and precipitation during mulberry experimentation period in Berhampore, West Bengal, India during 2018

2.4 Data Collection

Leaf yield and quality attributes were recorded from ten randomly selected plants in each replication on 60th day after pruning. Numbers of shoots, number of leaves, maximum shoot length and leaf yield per plant were assessed following the method of Dandin and Jolly [52]. Leaf yield per hectare was obtained by multiplying leaf weight per plant and number of plants per hectare and expressed in t ha⁻¹. Leaf moisture content (LMC) was estimated on 3rd, 5th & 6th leaves from the top of the plant by dry weight basis as $LMC (\%) = \frac{[Fresh\ weight\ (g) - Dry\ weight\ (g)]}{[Dry\ weight\ (g)]} \times 100$. Leaf chlorophyll index (LAI) was measured on the fifth fully expanded leaf from the top of each plant by using a SPAD meter (Peng et al [53]). Leaf total soluble protein (Lowry et al [54]) and leaf total soluble sugar (Morris et al [55]) were estimated and expressed on fresh weight basis.

NUE was estimated in terms of Partial Factor Productivity (PFP) and Agronomic Use Efficiency (AUE) of applied nutrients (Dobermann [56]; PFP: leaf yield produced per unit of nutrient applied; AUE: leaf yield increased per unit of N, P₂O₅ K₂O applied). $PFP\ (kg\ leaf\ kg^{-1}\ N\ P_2O_5\ K_2O) = \frac{leaf\ yield\ (kg\ ha^{-1})}{Total\ N\ P_2O_5\ K_2O\ applied\ (kg\ ha^{-1})}$; $AUE\ (kg\ leaf\ kg^{-1}\ N\ P_2O_5\ K_2O) = \frac{[leaf\ yield\ in\ N,\ P_2O_5\ K_2O\ applied\ plot\ (kg\ ha^{-1}) - leaf\ yield\ in\ N,\ P_2O_5\ K_2O\ omission\ plot]}{Total\ N\ P_2O_5\ K_2O\ applied\ (kg\ ha^{-1})}$.

2.5 Statistical Analysis

The mean of two crops data was processed for analysis of variance by Fishers F-test at 0.05 level of significance (Gomez and Gomez [57]). When treatment interaction was significant, it was compared with least significant differences (LSD) at 5% level.

3. RESULT AND DISCUSSION

3.1 Leaf Yield Attributes and Leaf Yield

Sustained mulberry productivity relies on regular replenishment of essential nutrients which could be achieved by application of chemical fertilizers (Ahmed et al [58]). However, unsuitable or imbalanced fertilizer application generally leads to poor crop yields as well as low nutrient use efficiency and can cause environmental problems (Yousaf et al [59]). Mulberry leaf yield is totally dependent on the growth attributing characters. The significant ($p \leq 0.05$) productive

effects of balanced fertilization was reflected in increased number of leaves, shoot length, number of shoots of mulberry over to that of farmers practice (Table 1.). Compared to farmers practice, combined fertilization (100% N-P₂O₅-K₂O + S and Zn) improved mulberry leaf yield attributes by 16.6% (number of leaves), 11% (shoot length) and 14% (number of shoots). This could be attributed to the combined application of various nutrients (N-P₂O₅-K₂O-S-Zn) provided requisite nutrient supply to mulberry as result of enhanced nutrient uptake. Significant improvement in mulberry growth and yield attributes, yield and nutrient uptake with balanced fertilization of N-P₂O₅-K₂O-S than NPK alone was reported (Shilpashree and Subbarayappa [60]). On the other hand, improper and imbalanced fertilization was observed in the farmers' practice which not only limits the availability of essential nutrients, but also reduces the nutrient use (Lobell et al [61]).

In the present study (Table 1.), leaf yield of mulberry responded significantly ($p \leq 0.05$) with the application of different sources of N, P₂O₅, K₂O nutrients over control (nutrient omission plot). Among the various source of fertilizers, leaf yield improved significantly with 100% fertilization of N-P₂O₅-K₂O in combination with Urea-SSP-10:26:26 (10742 kg ha⁻¹), but not differed significantly with Urea-DAP-MOP (10838 kg ha⁻¹). Leaf yield (9940 kg ha⁻¹) was least in farmers' practice (100% N-P₂O₅-K₂O with Urea-SSP-MOP combination). These results show that compound/complex fertilizers combination increased the mulberry leaf biomass production by 8-9% over straight fertilizers. Plausibly compound/complex fertilizers supplied different forms of mineral nutrients like ammonical-N, neutral ammonium citrate soluble-P₂O₅, water soluble-K₂O for longer cropping period resulting in better nutrient uptake and enhanced mulberry leaf productivity. The present study results are supported by the findings of Tripolskaja et al [62], where enhanced yields of potato and barley (1.8-11.6%) by fertilization with complex fertilizers as compared to straight fertilizers. Similarly, Tian et al [63] reported that compound fertilizers improved the chestnut yield by 68%. However, highest leaf yield was recorded with balance fertilization of N P₂O₅ K₂O along with S and Zn (Table 1.). Chen et al [5] reported that balanced N P₂O₅ K₂O fertilization along with S improved the mulberry productivity. Similar observations were reported on the impact of balanced fertilization of N P₂O₅ K₂O and Zn on grain yields in Rice and Wheat (Panwar et al [64]). Present

study shows that improvement in mulberry leaf yield was 19% with balanced fertilization of 100% N-P₂O₅-K₂O (Urea-SSP-10:26:26) along with Bentonite Sulphur (8 kg ha⁻¹) and Zinc Sulphate (1 kg ha⁻¹) as compared to that of farmers' practice; which is in consonance with the findings of Bose et al [65] and Kar et al [66] in improving mulberry leaf yield by 9-15%. Nithin Kumar et al [67] also reported improvement in mulberry leaf yield by 126% with balanced fertilization (NPK+FYM+ZnSO₄) than NPK+FYM application. Significant improvement in mulberry leaf yield due to right sources of nutrition with balanced nutrients supply *i.e.*, N-P₂O₅-K₂O-S-Zn might have accelerated the nutrient uptake leading to positive effects on chlorophyll content, photosynthetic activity, cell division, cell elongation and growth-regulating substances, ultimately enhancing the leaf biomass production. Similar line of results also were documented in other crops by Kumar et al [68] in Baby corn (15-16%) and Yousaf et al [59] in Rice (19-41%).

3.2 Relative Leaf Chlorophyll Content

SPAD values indirectly reflect the relative leaf chlorophyll content per unit leaf surface area (Zhang et al [69]). Chlorophyll is the most important pigment needed for the photosynthesis (Baker [70] and is greatly influenced by fertilization Nazar et al [71]). In the present study (Table 2.), no significant differences ($p \leq 0.05$) were observed between the treatments; however, SPAD value under 100% BF (N-P₂O₅-K₂O-S-Zn) was significantly higher than those under farmers practice and nutrient omission plot. The drastic improvement in SPAD value suggests that synergistic interaction of balanced plant nutrients could be the reason for accelerated nitrogen uptake which in turn resulted in higher chlorophyll content. The chlorophyll content was highest in 100% BF representing 17% improvement relative to farmers practice. Similar line of results were reported by Tian et al [72] in Rice (balanced application of N-P-K-S-Bo) improved leaf chlorophyll content. Leaf contents of chlorophyll increased significantly by applying balanced NPK through customized fertilizers in mulberry (Shyla et al [73]).

3.3 Leaf Quality Attributes

The quality of mulberry leaves play a significant role in the successful silkworm rearing and cocoon production (Das and Vijayaraghavan

[74]). The nutritional status of mulberry leaves can be improved by efficient fertilizer management (Ahmed et al [39]). The leaf quality attributes were greatly influenced by fertilization in the present study (Table 2). The balanced fertilization (100%: N-P₂O₅-K₂O-S-Zn) had the highest TSP (24.5 mg g⁻¹) and TSS (39.0 mg g⁻¹) among all the treatments evaluated. Leaf quality was reduced by 24.5 to 22.2 mg g⁻¹ (TSP) and by 39.0 to 37.0 mg g⁻¹ (TSS) when 75% of the BF application rate was applied. More consistently, the leaf quality of NPK fertilization through Urea-SSP:10:26:26 (TSP:23.5 & TSS:38.2 mg g⁻¹) was similar to Urea-SSP:10:26:26 (TSP:23.1 & TSS:34.0 mg g⁻¹), but lesser than BF. Farmers practice had the lowest leaf quality (TSP: 19.7; TSS: 33.2 mg g⁻¹) among all the treatments. Leaf quality improvement was 24.3% (TSP) and 17.4% (TSS) with balanced fertilization of N-P₂O₅-K₂O-S-Zn; Urea-SSP-10:26:26-Bentonite sulphur-zinc sulphate combination) as compared to farmers practice. This might be due to greater balanced absorption and translocation of nutrients helping better metabolic processes, enzymatic reactions, protein synthesis, carbohydrates metabolism and translocation of sugars in plants. Furthermore, sulphur application could reduce the soil pH, which may have indirectly influenced the availability of other micronutrients (Zn, Fe, Mn, and Cu) and their uptake (Jensen and Thomas [75], Neina [76]). This result is in agreement with findings of Chen et al [5] who noticed improvement in leaf sugar, essential and total amino acid concentrations in mulberry with application of 375 kg N ha⁻¹, 66 kg P ha⁻¹, and 125 kg K ha⁻¹ along with Mg, S, and B in mulberry than N-P-K alone. Similarly, Kumar et al [77] reported application of 100% NPK along with ZnSO₄ @ 25 kg ha⁻¹ significantly enhanced protein content and reducing sugar in baby corn over RDF. Kumar et al [68] also reported the improvement in baby corn protein content (16%) in balanced fertilization of N-P-K-S-Zn in comparison to N-P-K. Sing et al [78] reported that application of N-P-K along with Zn increased the baby corn protein content by 11% over N-P-K.

Leaf quality attributes were greatly reduced with reduced fertilizer doses. 100% N-P₂O₅-K₂O consistently produced higher leaf quality (TSP and TSS) over to that of 75% (Table 2.). The increase in protein & sugar content may be due to the availability of sufficient quantity of essential nitrogen for accelerated synthesis of leaf biochemical compounds. Similarly, these results are in close conformity with the findings of

Table 1. Effect of fertilizer sources on growth attributes in Mulberry

Treatments	Number of Shoots Plant ⁻¹			Number of Leaves Plant ⁻¹			Maximum Shoot Length (cm)			Leaf Yield (kg ha ⁻¹)		
	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean
T ₁ : 100% BF (N-P ₂ O ₅ -K ₂ O+S+Zn)	12.1 ^a	13.29 ^a	12.7 ^a	19.9 ^a	20.9 ^a	20.4 ^a	156.3 ^a	159.4 ^{ab}	157.9 ^{ab}	11389 ^a	12300 ^a	11844 ^a
T ₂ : 75% BF (N-P ₂ O ₅ -K ₂ O+S+ Zn)	11.1 ^{ab}	12.17 ^{bc}	11.6 ^{bc}	17.6 ^{bc}	18.4 ^{bc}	18.0 ^{bc}	148.7 ^a	157.6 ^{ab}	153.2 ^{ab}	9305 ^b	9385 ^c	9345 ^c
T ₃ : 100% N-P ₂ O ₅ -K ₂ O (Urea-SSP-10:26:26)	11.7 ^{ab}	12.88 ^{ab}	12.3 ^{ab}	18.5 ^{abc}	19.6 ^{ab}	19.1 ^{abc}	153.3 ^a	164.3 ^a	158.8 ^a	10250 ^{ab}	11234 ^{ab}	10742 ^{ab}
T ₄ : 75% N-P ₂ O ₅ -K ₂ O (Urea-SSP-10:26:26)	11.1 ^{ab}	12.22 ^{abc}	11.7 ^{bc}	17.1 ^c	18.1 ^{bc}	17.6 ^c	146.7 ^{ab}	156.2 ^{ab}	151.5 ^{ab}	9805 ^b	10482 ^{bc}	10144 ^{bc}
T ₅ : 100% N-P ₂ O ₅ -K ₂ O (Urea-DAP-MOP)	11.8 ^{ab}	12.93 ^{ab}	12.4 ^{ab}	18.8 ^{ab}	20.2 ^a	19.5 ^{ab}	152.7 ^a	153.5 ^{ab}	153.1 ^{ab}	10472 ^{ab}	11205 ^{ab}	10838 ^{ab}
T ₆ : 100% N-P ₂ O ₅ -K ₂ O (Urea-SSP-MOP) as FP	10.6 ^b	11.58 ^c	11.1 ^c	17.5 ^{bc}	17.6 ^c	17.5 ^c	136.2 ^b	147.9 ^b	142.1 ^b	9500 ^b	10379 ^{bc}	9940 ^{bc}
T ₇ : Fertilizer Omission Plot	6.8 ^c	7.47 ^d	7.1 ^d	10.6 ^d	11.9 ^d	11.2 ^d	95.3 ^c	100.1 ^c	97.7 ^c	4583 ^c	4767 ^d	4675 ^d
CD (p≤0.05)*	1.35	1.08	1.03	1.45	1.62	1.59	11.85	13.78	16.70	11.80	12.62	12.21

Notes: CD (p≤0.05)*: Critical Difference at probability of ≤0.05. Means with distinct letter statistically differ and same letters not statistically differ between the values.

Abbreviations: N, Nitrogen; P₂O₅, Phosphorus; K₂O, Potash; S, Sulphur; Zn, Zinc; SSP, Single Super Phosphate; DAP, Di-Ammonium Phosphate; Complex Fertilizer (N-P₂O₅-K₂O): 10:26:26; MOP, Muriate of Potash; FP, Farmers' Practice; BF, Balanced Fertilization [N-P₂O₅-K₂O (Urea-SSP-10:26:26) + Bentonite Sulphur + Zinc Sulphate].

Table 2. Effects of fertilizer sources on leaf quality attributes in Mulberry

Treatments	Leaf Moisture Content (%)			Relative Leaf Chlorophyll Content (SPAD value)			TSP (mg g ⁻¹ fresh leaf)			TSS (mg g ⁻¹ fresh leaf)		
	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean
T ₁ : 100% BF (N-P ₂ O ₅ -K ₂ O+S+Zn)	17.2 ^a	19.8 ^a	18.5 ^a	80.4	81.1	80.8	23.2 ^a	25.8 ^a	24.5 ^a	38.6 ^a	39.3 ^a	39.0 ^a
T ₂ : 75% BF (N-P ₂ O ₅ -K ₂ O+S+ Zn)	16.5 ^{ab}	18.0 ^{bc}	17.3 ^{abc}	78.1	82.8	80.5	21.1 ^{bc}	23.2 ^b	22.2 ^{ab}	36.3 ^{ab}	37.7 ^{ab}	37.0 ^{ab}
T ₃ : 100% N-P ₂ O ₅ -K ₂ O (Urea-SSP-10:26:26)	17.1 ^a	18.9 ^{ab}	18.0 ^{ab}	78.1	79.5	78.8	22.6 ^{ab}	24.4 ^{ab}	23.5 ^{ab}	37.9 ^a	38.6 ^a	38.2 ^a

Treatments	Leaf Moisture Content (%)			Relative Leaf Chlorophyll Content (SPAD value)			TSP (mg g ⁻¹ fresh leaf)			TSS (mg g ⁻¹ fresh leaf)		
	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean	Jul-Aug	Sep-Oct	Mean
T ₄ : 75% N-P ₂ O ₅ -K ₂ O (Urea-SSP-10:26:26)	16.1 ^{ab}	17.3 ^{cd}	16.7 ^{bc}	77.5	78.3	77.9	21.1 ^{bc}	22.3 ^b	21.7 ^{bc}	35.4 ^{abc}	36.4 ^{ab}	35.9 ^{abc}
T ₅ : 100% N-P ₂ O ₅ -K ₂ O (Urea-DAP-MOP)	17.0 ^a	18.5 ^{abc}	17.7 ^{ab}	78.9	80.1	79.5	22.7 ^{ab}	23.4 ^{ab}	23.1 ^{ab}	33.7 ^{bc}	34.3 ^b	34.0 ^{bc}
T ₆ : 100% N-P ₂ O ₅ -K ₂ O (Urea-SSP-MOP) as FP	15.4 ^b	16.2 ^d	15.8 ^c	78.1	78.8	78.5	19.8 ^c	19.5 ^c	19.7 ^c	32.8 ^c	33.7 ^b	33.2 ^c
T ₇ : Fertilizer Omission Plot	12.7 ^c	13.1 ^e	12.9 ^d	78.0	78.3	78.1	15.7 ^d	16.0 ^d	15.8 ^d	25.3 ^d	24.9 ^c	25.1 ^d
CD (p≤0.05)*	1.32	1.44	1.51	NS	NS	NS	1.88	2.35	2.46	3.16	4.08	3.21

Notes: CD (p≤0.05)*: Critical Difference at probability of ≤0.05. Means with distinct letter statistically differ and same letters not statistically differ between the values.

Abbreviations: TSP, Total Soluble Protein; TSS, Total Soluble Sugar

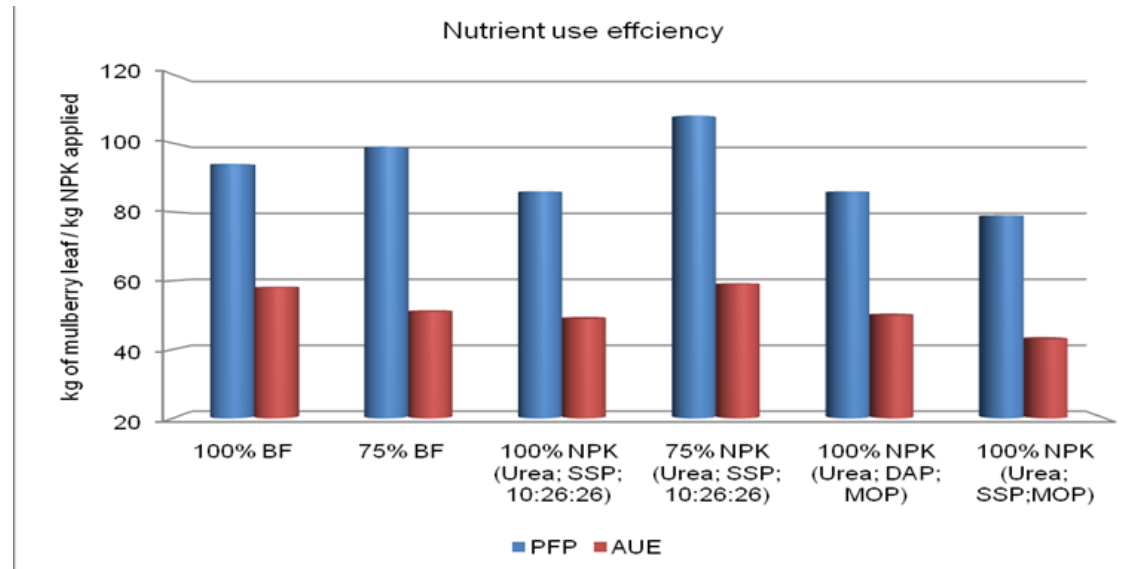


Fig 2. Effects of fertilizer sources on partial factor productivity and agronomic use efficiency in Mulber

Mahesh et al [79] that inorganic fertilizers application improved leaf quality in terms of total soluble protein and sugars. Leaf moisture is one of the most important quality attribute for the success of silkworm growth and development (Shivashankar [80]). No significant differences between treatments were found for leaf moisture content (78.0-80.4%; highest in 100% BF and followed by 75% BF; Table 2.).

3.4 Nutrient use Efficiency

Nutrient use efficiency (NUE) is a most essential measure to assess the crop production systems and can greatly be altered by fertilizer management (Singh et al [81]) with PFP and AUE being major indicators of NUE (Yadav [82]). In present study, three different combinations of fertilizer sources were used. Mulberry plot fertilized with combination of complex/compound fertilizers demonstrated higher use applied nutrients resulting in enhanced PFP and AUE (Fig. 2). Similar results have been reported in sugarcane (Mahesh et al [18]). However, PFP and AUE were further improved by addition of S and Zn along with N-P₂O₅-K₂O in the present study. This could be plausibly attributed to the synergistic effect of macro and micro nutrients on plant growth (Aulakh and Malhi [83]; Rene et al [42]). Appropriate and balanced use of N-P₂O₅-K₂O-S-Zn facilitates plant for better use of native and applied nutrients in plant growth and increased nutrient use efficiency (Fixen [84]). Considering the efficiency of applied nutrients, a consistent order of NUE was BF: Urea-SSP-10:26:26-bentonite sulphur-zinc sulphate > Urea-SSP-10:26:26 > Urea-DAP-MOP > Urea-SSP-MOP, however, better utilization of nutrients was found reduced dose (75% RD) than 100% RD. In the present study, fertilization of 1-kg of N-P₂O₅-K₂O along with S and Zn nutrients produced 94 kg mulberry leaf, which was 19% higher than that of farmers practice (79 kg leaf kg⁻¹ of NPK). Similarly, 1-kg of N-P₂O₅-K₂O along with S and Zn application increased leaf yield by 58 kg over nutrient omission plot indicating that mulberry responded well to the balanced fertilization (N-P₂O₅-K₂O-S-Zn).

4. CONCLUSIONS

This study reveals the importance of balanced fertilization of mulberry with N, P, K, S and Zn for sustainable productivity, which is reflected by the maximum values for leaf yield attributes, chlorophyll content and leaf yield. Further, mulberry leaf quality (in terms of total soluble

protein and total soluble sugar) significantly improved with balanced fertilization. Higher PFP and AUE were also recorded with fertilization with compound/complex fertilizers than with straight fertilizers; but the balanced fertilization exhibited remarkable enhancement. Overall, the results prove that balanced fertilization of N-P₂O₅-K₂O @ 67-36-22 kg ha⁻¹ (Urea-SSP-10:26:26) with Bentonite sulphur (8 kg ha⁻¹) and zinc sulphate (1 kg ha⁻¹) were effective in improving mulberry productivity through enhanced nutrient use efficiency. This could be useful for realizing maximum productivity in mulberry as an efficient nutrient management strategy in mulberry cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Manjunath M, Narayanaswamy KC, Savithamma SHB, Harishkumar HV. Scenario of mulberry and cocoon production in major silk producing States of India-Application of exponential growth function. Indian. J. Economic Develop. 2015;3(8):1-8.
2. Ray P, Gogoi SN, Bandyopadhyay S, Padua S, Jena RK, Deb Roy P, Ramachandran S, Sharma GK, Sah K, Trivedy K, Singh SK, Ray SK. Fertility status of mulberry (*Morus indica* L.) growing soils of upper Brahmaputra valley region of north Eastern India. Range Manag. & Agrofor. 2018;39 (2):147-155.
3. Liliane TN, Charles MS. Factors affecting yield of crops. 2020; 90672. Available:https://doi. 10.5772/ intechopen.
4. Shashidhar KR, Narayanaswamy TK, Bhaskar RN, Jagadish BR, Mahesh M, Krishna KS. Influence of organic based nutrients on soil health and mulberry (*Morus indica*) Production. EJ. Biol. Sci. 2009;1(1):94-100.
5. Chen F, Lu J, Zhang M, Wan K, Liu D. Mulberry nutrient management for silk production in Hubei Province of China. J. Plant. Nutr. Soil Sci. 2009;172(2): 245-253. Available:https://doi.org/10.1002/jpln. 200800093.
6. Bose PC, Kar R. Soil characteristics and nutritional management of mulberry in Eastern & North-Eastern India. Central

- Sericultural Research and Training Institute, Central Silk Board, Govt. of India, Berhampore, West Bengal, India. 2010;76.
7. Rathore MS, Srinivasulu Y, Kour R, Darzi GM, Dhar A, Khan MA. Integrated soil nutrient management in mulberry under temperate conditions. *Eur. J. Biol. Sci.* 2011;3(4):105-111.
 8. Ray D, Mandal LN, Pain AK, Mondal SK. Effect of NPK and FYM on the yield and nutritive value of mulberry leaf. *Indian J. of Seric.* 1973;12(1):7-12.
 9. Bose PC, Majumder SK. Nitrogen fertilizer recommendation of mulberry (*Morus alba* L.) based on the Mitscherlich-Bray Concept. *Sericologia*, 1999;35(2):331-336.
 10. Krishna M, Bongale UD. Role of organic manures on growth and quality of mulberry leaf and cocoons. *Indian silk*, 2001; 40 (2):11-12.
 11. Chen F, Lu J. Identifying gaps in mulberry fertilization in Hubei Province. *Better Crops* (4). 2006; 29-30.
 12. Mahajan A, Gupta RD. Balanced use of plant nutrients. In: (eds) Integrated Nutrient Management (INM) in a Sustainable Rice-Wheat Cropping System. Springer, Dordrecht; 2009. Available: <https://doi.org/10.1007/978-1-4020-9875-8-8>.
 13. Xu X, Liu X, He P, Johnston AM, Zhao S, Qiu S, Zhou W. Yield gap, indigenous nutrient supply and nutrient use efficiency for maize in China. *PLOS ONE*. 2015;10(10):e0140767. Available:<https://doi.10.1371/journal.pone.0140767>.
 14. Sarkar B, Naidu R. Nutrient and water use efficiency in soil: The influence of geological mineral amendments. A. Rakshit, B.H. Singh, A. Sen (Eds.), *Nutrient Use Efficiency: From basics to advances*, Springer, New Delhi, India. 2015;29-44.
 15. Mahesh R, Patil B, Archana HA. Subsurface Drip Fertigation: A Tool for Practicing 4R Nutrient Stewardship in Sugarcane. *Better Crops with Plant Food*, 2018;102(2):17-20.
 16. Mahesh R, Nandaln G. 4R Nutrient management in sugarcane-an overview. *J. Curr. Microbiol. App. Sci.* 2020a;9(10): 2423-2431.
 17. Wadas W, Dziugiel T. Effect of multi-nutrient complex fertilizers on growth and tuber yield of very early potato (*Solanum tuberosum* L.) cultivars. *Acta Agrobotanica*. 2012;66(3):55-66. Available:<https://doi.10.5586/aa.2013.038>.
 18. Kokovic N, Kresovic M, Mrvic V, Sikiric B, Jaramaz D, Saljnikov E. The effect of the application of complex and mixed fertilizers on wheat yield and soil fertility. *Soil and Plant*. 2015;64(1).
 19. Kumar RV, Kumar D, Prasad S. Efficacy of bio foliar spray on plant nutrients of different mulberry varieties. *J. Biopestic.* 2012;5(2):113-119.
 20. Fageria NK, Brazil NB. Micronutrients in crop production. *Adv. Agron. Academic press*. 2001;39-50.
 21. Bose PC, Singhvi NR, Dutta RK. Effect of micronutrients on yield and yield attributes of mulberry (*Morus alba* L.). *Indian J. Agron.* 1994;39:97-99.
 22. Wani MY, Mir MR, Baqual MF, Mehraj K. Role of micronutrients in mulberry crop improvement. *Indian Hort. J.* 2016;6: 92-97.
 23. Sharma PN, Parma KP, Tewari KR. Morphology and physiology of zinc stressed mulberry plants. *J. Plant Nutr. Soil Sci.* 2008;171:286-294.
 24. Rathore, Srinivasulu Y. Management of soil fertility for sustaining quality mulberry leaf production in North India. *Int. J. Sci. Res. in Biolog. Sci.* 2018;5(5):58-62.
 25. Barker AV, Pilbeam DJ. *Handbook of plant nutrition*. 2nd ed. CRC Press, Taylor and Francis Group, New York, USA; 2015.
 26. Mahadeva A. Nutritive elemental status in mulberry (*Morus sp.*) foliage under Jassids (*Empoasca flavescens* F.) infestation. *Indian J. Nat. Sci.* 2016;7(38): 11537-11544.
 27. Roy D, Gupta BK. Effect of micronutrients on the yield and chemical composition of mulberry leaf. *Annual Report, Central Sericultural Research and Training Institute, Berhampore*. 1974;81-82.
 28. Alloway BJ. Micronutrients and crop production: An introduction. In: Alloway B.J., (eds) *Micronutrient deficiencies in Global Crop production*. Springer, Dordrecht; 2008. Available:<https://doi.org/10.1007/978-1-4020-6860-7-1>.
 29. Bell RW, Dell B. *Micronutrients for sustainable food, feed, fiber and bioenergy production*, 1st edn. IFA, Paris; 2008.
 30. Bose PC, Kar R. Triple role of sulphur in mulberry garden. *Indian Silk*. 2007;46: 10-12.

31. Tandon, HLS. Soil nutrient balance sheets in India: Importance, status, issues, and concerns. Better Crops- India. 2007; (1):15-19.
32. Singh MV, Behra SK. Micro-and secondary-nutrient deficiencies problems in Indian soils and their amelioration through balanced fertilization. Extended Summaries: National Seminar on micro and secondary nutrients for balanced fertilization and food security. Indian Institute of Soil Science, Bhopal, India. 2008;3-10.
33. Singh MV. Micronutrient deficiencies in crops and soils in India. In: Alloway B.J. (eds) Micronutrient Deficiencies in Global Crop Production. Springer, Dordrecht; 2008. Available:https://doi.org/10.1007/978-1-4020-6860-7_4.
34. Lu JW, Xiong JP, Chen F. Hubei Agricultural Sciences, 2004;(1):59-62.
35. Roy RN, Finck A, Blair GJ, Tandon HLS. Plant nutrition for food security. A Guide for Integrated Nutrient Management. FAO Fertilizer and Plant Nutrition Bulletin 16. Rome, Italy: FAO; 2006.
36. Nazar A, Kalarani MK, Jeyakumar P, Kalaiselvi T, Arulmozhiselvan K, Manimekalai, S. Combined effect of biofertilizers and micronutrients on growth and yield attributes of mulberry (*Morus indica L.*). Int. J. Pure App. Biosci. 2019a;7(1):346-352.
37. Kar R, Ram RL, Ghosh MK, Trivedi K. Response of mulberry (*Morus alba L.*) to foliar supplementation of nutrient-composite. Int. J. Agric. Innov. Res. 2017;6(3):2319-1473.
38. Petkov N, Greiss H. Effect of balanced NPK and micronutrient fertilization of mulberry plantations on the development and productivity of silkworm (*Bombyx mori L.*). Bulg. J. Agric. Sci. 2001; 7:81-85.
39. Ahmed F, Abdul Kader M, Sultana R, Ahmed O, Begum SA, Iqbal MT. Combined application of foliar fertilizer with basal NPK enhances mulberry leaf yield and silkworm cocoon productivity in calcareous soil. J. South Pacific Agric. 2018;21.
40. Lin Bao. Significance of balanced fertilization based on long-term fertilizer experiments. Better Crops International. 1997;11(1).
41. Sharma SK, Jain NK. Effect of balanced fertilization on productivity and soil fertility status of clusterbean. Legume Res. Int. J. 2012;35:32-35.
42. Rene PJJR, Heinen M, Dimkpa COP, Bindraban S. Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. Commun. Soil Sci. Plant Anal. 2017; 48(16):1895-1920. Available:<https://doi.10.1080/00103624.2017.1407429>.
43. Bose PC, Bindroo BB. Effect of micronutrients on yield of mulberry in sub-tropical region. J. Crop and Weed. 2009;5(2):142-143.
44. Singh GS, Ram RL, Alam M, Nirmal Kumar S. Soil testbased fertilizers recommendation of NPK for mulberry (*Morus alba L.*) farming in acid soils of Lohardaga, Jharkhand, India. Int. J. Curr. Microbiol. App. Sci. 2016;5(6):392-398.
45. Mahesh R, Pappachan A, Chakravarty D, Sivaprasad V. Improved mulberry productivity and resource efficiency through low-cost drip fertigation. Arch. Agron. Soil Sci. 2020a;1-5. Available:<https://doi.org/10.1080/03650340.2020.1852552>.
46. Subbiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Curr. Sci. 1956;25:259-260.
47. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus of soil extraction with sodium carbonate. In: U.S. Dept. Agric. Cir. p. 939, Washington, D.C; 1954.
48. Stanford S, English L. Use of flame photometer in rapid soil tests for K and Ca. Agron J. 1949; 41:446-447. DOI:10.2134/ agronj1949. 00021962004 100090 01 2x.
49. Walkley A, Black IA. An examination of the Degtjareff method for determining organic carbon in soils: effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 1934;63:251-263. DOI:10.1097/ 00010694-194704000-00001.
50. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd; 1973.
51. Setua GC. Mulberry cultivation and its management with reference to eastern and north eastern regions. In Sarkar A, editor. CSRTI 2006. Proceedings of the appropriate technologies for mulberry sericulture in eastern and north eastern India. Jan 17-18; Kolkata, Berhampore: Central Sericultural Research and Training Institute. 2006;6-10.

52. Dandin SB, Jolly MS, Mulberry descriptor. *Sericologia*. 1986;26(4):465-475.
53. Peng S, Garcia F, Laza R, Cassman KG. Leaf thickness affects the estimation of leaf N using a chlorophyll meter. *Int. Rice Res. News Letter*. 1992;17(6):19-20.
54. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with Folin-phenol reagent. *J. Biol. Chem.* 1951;193:265-275.
55. Morris DI. Quantitative determination of carbohydrate with drey woods anthrone reagent. *Science*. 1948;107:254-255.
56. Dobermann A. Nutrient use efficiency-measurement and management. In IFA International Workshop on Fertilizer Best Management Practices, Brussels, Belgium. 2007;1-28.
57. Gomez KA, Gomez A. Statistical procedure for agricultural research-Hand Book. 2nd ed. New York (NY): A wiley Interscience; 1984.
58. Ahmed F, Ahmed O, Iqbal, MT. Advanced fertilizer management practices for mulberry (*Morus spp.*) plant production. *J. Basic App. Res. Int.* 2015;9(2):111-122. Available:<https://www.ikpress.org/index.php/JOBARI/article/view/2816>.
59. Yousaf M, Li J, Lu J, Ren T, Cong R, Fahad S, Li X. Effects of fertilization on crop production and nutrient-supplying capacity under rice-oilseed rape rotation system. *Sci. Rep.* 2017;7:1270. Available:<https://doi.org/10.1038/s41598-017-01412-0>.
60. Shilpashree KG, Subbarayappa CT. Effect of soil application of micronutrients on quality of mulberry and cocoon production. *Res. J. Agric. Sci.* 2015;6(4):830-833.
61. Lobell DB, Cassman KG, Field CB. Crop yield gaps: Their importance, magnitudes, and causes. *Annu. Rev. Environ. Resour.* 2009;34:179-204.
62. Tripolskaja L, Razukas A, Sidlauskas G, Verbyliene I. Effect of fertilizers with different chemical composition on crop yield, nitrogen uptake and leaching in a sandy loam Luvisol. *Zemdirbyste-Agriculture*, 2017;104(3):203-208. Available:<https://doi.10.13080/z-a.2017.104.026>.
63. Tian C, Ahmed XZ, Fahmy E, Ding Z, Zhran MA, QiangLiu, Peng J, Zhang Z, Song, H, Guan C, Kheir AMS, Eissa MA. Balanced fertilization under different plant densities for winter oilseed rape (*Brassica napus* L.) grown on paddy soils in Southern China. *Ind. Crops Prod.* 2020;151.
64. Panwar AS, Shamim M, Babu S, Ravishankar N, Prusty AK, Alam NM, Singh DK, Bindhu JS, Kaur J, Dashora LN, Latheef Pasha MD, Chaterjee S, Sanjay MT, Desai LJ. Enhancement in productivity, nutrients use efficiency, and economics of rice-wheat cropping systems in India through farmers participatory approach. *Sustainability*, 2019;11:122. Available:<https://doi.10.3390/su11010122>.
65. Bose PC, Singhvi NR, Dutta RK. Effect of micronutrients on yield and yield attributes of mulberry (*Morus alba* L.), *Indian J. Agron.* 1994;39:97-99.
66. Kar R, Bindroo BB, Ghosh MK, Majumder SK, Bose PC. Impact of residual sulphur on mulberry (*Morus alba* L.) nutrition and soil reaction. *J. Crop Weed.* 2013;9(1):214-215.
67. Nithin Kumar DM, Doreswamy C, Deepa KB, Divyashri HJ. Effect of soil and foliar application of Zinc and Boron on growth and yield parameters of mulberry leaf. *J. Pharmacognosy Phytochem.* 2020;9(4):1396-1399.
68. Kumar R, Bohra JS, Kumawat N, Upadhyay PK, Singh AK. Effect of balanced fertilization on production, quality, energy use efficiency of baby corn (*Zea mays*) and soil health. *Indian. J. Agric. Sci.* 2017; 88(1):28-34.
69. Zhang K, Yuan Z, Yang T, Lu Z, Cao Q, Tian Y, Zhu Y, Cao W, Liu X. Chlorophyll meter-based nitrogen fertilizer optimization algorithm and nitrogen nutrition index for in-season fertilization of paddy rice. *Agron. J.* 2020;1-13. Available:<https://doi.10.1002/agj2.20036>.
70. Baker NR. Chlorophyll fluorescence: a probe of photosynthesis *in vivo*. *Annu. Rev. Plant Biol.* 2008;59:89-113. Available:<https://doi.10.1146/annurev.arplant.59.032607.092759>.
71. Nazar A, Kalarani MK, Jeyakumar P, Kalaiselvi T, Arulmozhiselvan K, Manimekalai. S. Physiological and biochemical changes in mulberry (*Morus alba* L.) as influenced by nutrients. *Madras Agric. J.* 2019b;106(4-6):297-302. Available:<https://doi.10.29321/MAJ2019.000263>.
72. Tian SL, Sun XL, Shen GN, Xu L. Effects of compound fertilizer of (NH₂)₂CO and KH₂PO₄ on the chestnut photosynthesis characteristics, growth and fruiting. *Ying*

- Yong Sheng Tai Xue Bao. 2015;26(3):747-54. Chinese. PMID: 26211055.
73. Shyla PN, Sadatulla F, Prabhakar V, Pallavi Rashmi S, Harish Babu S, Raksha Sharma C. Influence of customized fertilizers on bio-chemical composition of V1 Mulberry. *Int. J. Adv. Res. Biol. Sci.* 2016;3(3):261-264.
74. Das PK, Vijayaraghavan K. Studies on the effect of different mulberry varieties and seasons on the larval development and cocoon characters of silkworm (*Bombyx mori* L). *Indian J. Seric.*, 1990; 29(1):44-53.
75. Jensen Thomas L. Soil pH and the availability of plant nutrients. *IPNI Plant Nutrition Today*, No. 2. www.ipni.net/pnt. 2010.
76. Neina D. The role of soil ph in plant nutrition and soil remediation. *Appl. Environ. Soil.* 2019;1-9. Available:<https://doi.org/10.1155/2019/5794869>.
77. Kumar R, Kumawat N, Kumar S, Singh AK, Bohra JS. Effect of NPKS and Zn fertilization on, growth, yield and quality of baby corn-A review. *Int. J. Curr. Microbiol. App. Sci.* 2017a;6(3):1392-1428.
78. Singh MK, Singh RN, Singh SP, Yadav MK, Singh VK. Integrated nutrient management for higher yield, quality and profitability of baby corn (*Zea mays*). *Indian J. Agron.* 2010;55:100-104.
79. Mahesh R, Meitei HP, Chakravarty D, Sivaprasad V. Effect of fertilizer dose and split application of fertilizer on growth, yield and nutrient use efficiency in mulberry. *Innovative Farming*, 2020b;5(2):92-97.
80. Shivashankar M. Study on leaf moisture status of some mulberry varieties as influenced by foliar spray of Paras (Mulberry garden). *Int. J. Curr. Microbiol. App. Sci.* 2015;4(6):1200-1206.
81. Singh A, Kumar A, Jaswal A, Singh M, Gaikwad DS. Nutrient use efficiency concept and interventions for improving nitrogen use efficiency. *Plant Arch.* 2018;18(1):1015-1023.
82. Yadav RL. Assessing on-farm efficiency and economics of fertilizer N, P and K in rice wheat systems of India. *F. Crops Res.* 2003;18:39-51.
83. Aulakh MS, Malhi SS. Interactions of nitrogen with other nutrients and water: Effect on crop yield and quality, nutrient use efficiency, carbon sequestration, and environmental pollution. *Adv. Agron.* 2005;86:341-409.
84. Fixen PE. Understanding and improving nutrient use efficiency as an application of information technology. In: *Proceedings of the symposium on information technology in soil fertility and fertilizer management, a satellite symposium at the XV International Plant Nutrient Colloquium, Beijing, China.* 2005:14-16.

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