SVU-IJAS SVU-International Journal of Agricultural Science
Volume 7 Issue (2) pp.: 10-21, 2025
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2025.371531.1456
RESEARCH ARTICLE

Foliar fertilization of NPK as a stimulator to boost silkworm (*Bombyx mori L.*) productivity and cocoon quality

Safaa I. A. Hassan*

Plant Protection Department, Faculty of Agriculture, South Valley University, Qena, Egypt

Abstract

This study aimed to investigated the optimal nutrient combination of NPK foliar application on mulberry trees on the silkworm performance. Two silkworm hybrids were fed mulberry leaves from trees with NPK fertilizers at two different ratios (19:19:19 and 20:20:20). The local silkworm hybrid showed a significant increase in final larval weight (2.97 ± 0.14 g) when it fed leaves from trees treated with NPK (19:19:19) compared to the control (2.37 ± 0.18 g). Applying NPK fertilizers also led to a highly significant ($p \leq 0.01$) increased in the total haemolymph solids (T.H.S.) in the larval heamolymph of the imported hybrid. Furthermore, cocoon characteristics significantly improved in both silkworm hybrids with NPK fertilization. The local hybrid exhibited the highest cocoon weight (1.19 ± 0.05 g) with NPK ration of 20:20:20, a 36.62% increase compared to the control (0.87 ± 0.05 g). The imported hybrid also showed similar improvements in cocoon weight with NPK ratio 20:20:20. While the shell percentage, silk conversion index (SCI %) and Renditta showed positive trends, particularly with NPK (20:20:20) in both hybrids. It could be concluded that applying NPK fertilizer directly to mulberry leaves significantly enhanced silkworm growth, cocoon quality, and the efficiency of silk production in both hybrids, with a more response from the local hybrid. While NPK at ratio of 19:19:19 resulted in a greater increase in larval growth, while NPK at ration of 20:20:20 generally yielded better outcomes in terms of improving cocoon quality and economic parameters.

***Keywords*:** Silkworm, NPK, Foliar Fertilization, Sericulture sustainability, Silk productivity.

1. *Introduction*

Mulberry (*Morus alba*), a dioeciously plant belonging to the Moraceae family, is the sole food source for silkworms. The quality of mulberry foliage significantly influences silkworm growth, development, and silk production due to its high nutritional value (Zhang *et al.*, 2018; Borah and Boro, 2020; Bharath *et al*., 2024). Mulberry leaves provide essential amino acids, carbohydrates, and minerals for silkworm larvae to metamorphose into pupae and subsequently spin cocoons. Actually, 70% of the silk proteins produced by silkworms are directly derived from mulberry leaves (Islam *et al*., 2023; Riaz *et al*., 2020). However, variations in fertility, climatic conditions, and cultural practices can significantly impact the nutritional value and quality of mulberry leaves (Rashmi *et al*., 2009; Rahmathulla, 2012). Foliar fertilization, the application of nutrients directly onto the leaves of mulberry trees, has emerged as a promising strategy to enhance leaf nutritional quality by increasing the levels of essential nutrients and hormonal regulation, which can subsequently affect the nutritional composition of the leaves and also, increased nutrient availability, particularly nitrogen, stimulates photosynthesis, resulting in increased leaf biomass and improved nutrient content in trees (Žinete, 2023; Chawla and Kumar, 2024; Rani *et al*., 2024; Kaya and Ashraf, 2024). Compared to soil-applied fertilizers, foliar applications are more readily absorbed by leaves, minimizing nutrient losses due to leaching or fixation in the soil. Furthermore, foliar fertilization can be targeted to specific nutrient deficiencies identified through leaf tissue analysis, allowing for a more precise and efficient use of fertilizers (Sathyanarayana *et al*., 2017; Patil, 2018; Ray and Sairam 2024). NPK fertilizers provide essential macronutrients, nitrogen (N), phosphorus (P), and

***Corresponding author:** Safaa I. A. Hassan,
Email: s.ismail@agr.svu.edu.eg
Received: March 26, 2025; Accepted: June 14, 2025; Published online : June 20, 2025.

potassium (K) and resulted in increased leaf area, higher chlorophyll content, and improved photosynthetic. These effects can be translated into an increase of leaf biomass and an improved of nutrients content in trees leaves. Several studies have investigated the impact of NPK fertilization on mulberry trees and it's reflected on silkworm performance. These studies have reported various positive outcomes, including, improved larval growth, cocoon yield, cocoon quality and silkworm health (Abdelmegeed, 2021; Rajegowda and Dhamodhar, 2022; Dhole *et al*., 2023; Diniță *et al*., 2023). This study hypothesis that foliar fertilization with NPK would significantly enhance mulberry leaf nutritional quality, leading to improved silkworm growth, increased cocoon yield, and superior cocoon characteristics. Thus the objective of this study was to investigate the impact of foliar fertilization with different NPK ratio (20:20:20 and 19:19:19) on the performance of two silkworm hybrids (Local and Bulgarian).

2. Materials and Methods

2.1 Experimental site and mulberry cultivar

The experiment was conducted at Sericulture Research Laboratory - Research Farm, Plant Protection Department, Faculty of Agriculture, South Valley University, Qena, Egypt. Mulberry cultivar [*Morus alba* - var, Kanva-2] was used. The mulberry trees were cultivated in traditional cultivation conditions, a research farm, following standard agricultural practices. Healthy, disease-free mulberry leaves of uniform maturity fully expanded were selected for the feeding experiments.

2.2 Fertilization schedule

Foliar applications were conducted 3 times for (one week before the rearing, after the second instar, and after the fourth instar) during the silkworm rearing season. About 2 g L^{-1} – 5L $tree^{-1}$ of each fertilizer solution was prepared and sprayed evenly on the leaves using a gasoline engine back sprayer. Mulberry trees were sprayed early in the morning at 8 am.

2.3. Experimental design

A randomized complete design (RCD) with three replicates were employed. Three treatments were designed; each treatment has 3 trees, as the following:

- **Control:** No foliar fertilization. (normal water only)
- **T_1:** Foliar application of NPK fertilizer at ratio of 19:19:19.
- **T_2:** Foliar application of NPK fertilizer at ration of 20:20:20.

2.4. Silkworm rearing

The disease-free (DF) eggs of Local and Bulgarian hybrids silkworm were obtained from The Sericulture Research Department, Plant Protection Research Institute (A.R.C) at Giza, Egypt. Newly hatched larvae from each hybrid of mulberry silkworm were divided into three groups; each group consisted of 300 larvae (100 larvae / replicate). Silkworms were reared under standard rearing conditions [27±2 °C], relative humidity: (70± 5%), and light (14 h light 10 h^{-1} dark). Fresh and tender mulberry leaves from treated and control trees were provided to the silkworms [4 times daily] according to their instar-wise requirements. Growth and cocoon quality by recorded Larval weight, Silk gland weight (g), Gland / Body Tissue Ratio (%), Total haemolymph solids (T.H.S.), Effective rate of rearing (ERR) (%), Cocoon weight, Pupa weight, Shell weight, Shell ratio (%), Silk conversion index (%) and Renditta.

2.5. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using statistical software (SPSS). Data were presented as mean ± standard deviation to ensure clarity and reproducibility. $P<0.05$ was considered as significant value.

3. Results

3.1. Growth Performance of Silkworm (Bombyx mori L.)

3.1.1. Larval weight

Larval weight significantly increased when silkworm larvae fed leaves from NPK-fertilized trees compared to the control (Table 1 and Fig. 1). The Local hybrid exhibited the highest final larval weight (2.97±0.14 g) with NPK ration of 19:19:19, a significant increase of 25.32% (Fig.1) compared to the control 2.37±0.18 g, ($p \leq .018$). The Bulgarian hybrid also showed a positive increase in larval weight (11.88%) with NPK (19:19:19), 2.79 ± 0.12 g. compared to the control 2.49 ± 0.51 g. Although, treatment with NPK (20:20:20) showed remarkable increased in larvae weight compared to the control, but this increase less than those of NPK at ration of (19:19:19) in both hybrids.

3.1.2. Silk gland weight

In the local hybrid, silk gland weight increased by 30.62% (Fig.1) with the NPK at 19:19:19 ratio (0.60±0.11 g) compared to the control (0.46±0.07 g. Similarly, in the Bulgarian hybrid, NPK (19:19:19) also resulted in increased silk gland weights by 21.09 % from the control. Consistent with the observed increased in larval weight, silk gland weight was significantly higher in both hybrids when fed on leaves from fertilized trees than those of the control. While the NPK (19:19:19) formulation generally showed a slight trend towards increase silk gland weights. The differences between the two NPK ratios were not significant. This increase in silk gland weight is crucial for silk production, as it directly correlates with the amount of silk produced by the silkworm.

3.1.3. Gland / body tissue (G/B Ratio)

The G/B ratio, an indicator of silk gland development relative to overall body mass, was generally higher in silkworms fed on leaves from fertilized trees. In the local hybrid, G/B ratio increased in the NPK (19:19:19) treatment (20.06±2.94 g) compared to the control (19.42±3.45 g), while, in the Bulgarian hybrid, NPK (20:20:20) resulted in increased G/B ratio more than those of NPK (19:19:19) treatment and control. The Bulgarian hybrid consistently exhibited a significantly higher G/B ratio compared to the local hybrid, irrespective of the fertilization treatment. indicating a higher inherent growth potential in this hybrid.

3.1.4. *Total Haemolymph Solids (THS)*

In both the local and Bulgarian hybrids, foliar application of NPK of 19:19:19 ratio was increased the total haemolymph solids (THS) compared to the control. The Local hybrid exhibited THS of 15.13±0.51 with NPK (19:19:19), which is higher than those the control (12.47 ± 2.26). Similarly, the Bulgarian hybrid showed a high positive increase ($p \leq .0.01$) in THS to 15.73±0.6 with NPK (19:19:19) compared to the control 13.37± 0.32. This elevation in silkworm haemolymph THS, resulting from NPK foliar fertilization, likely enhanced nutrient uptake by the silkworms, consequently stimulating their physiological metabolism and contributing to improved growth and development of silkworm.

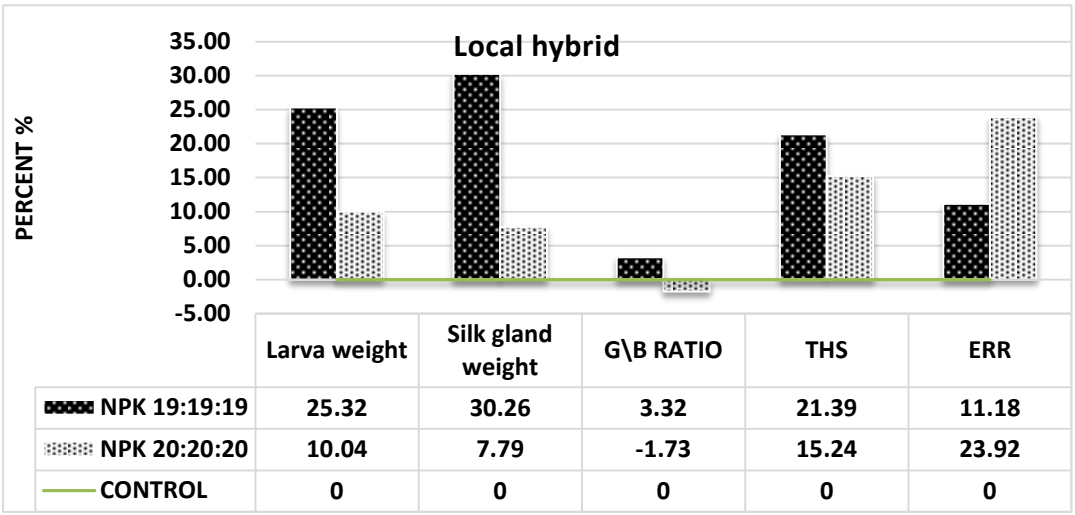
3.1.5. Effective Rate of Rearing (ERR)

The effective rate of rearing (ERR) was enhanced in both hybrids, when it was fed leaves from fertilized trees with NPK at ratio of 20:20:20. Generally it exhibited the most pronounced effects. In the local hybrid, the ERR increased by 23.92% with NPK (20:20:20) compared to the control. Similarly, in the Bulgarian Hybrid, the ERR showed a significant increase of 23.28% with NPK (20:20:20), compared to the control. (Fig.1).

Table 1. Impact of foliar fertilization on larvae growth of silkworm, *B. mori*

Item \ Hybrids	Local hybrid				Bulgarian hybrid			
	Control	NPK (19:19:19)	NPK (20:20:20)	P value	Control	NPK (19:19:19)	NPK (20:20:20)	*P*-value
Final larval weight, g	2.37±0.18	2.97±0.14	2.61±0.21	0.018	2.49±0.51	2.79±0.12	2.60±0.04	0.521
Silk gland weight, g	0.46±0.07	0.60±0.11	0.49±0.07	0.189	0.49±0.09	0.59±0.04	0.59±0.08	0.208
Gland / Body ratio	19.42±3.45	20.06±2.94	19.08±3.31	0.932	20.23±5.82	21.22±3.15	22.71±1.74	0.752
Total Haemolymph Solids (THS)	12.47±2.26	15.13±.51	14.37±0.32	0.119	13.37±0.32	15.73±0.6	15±0.72	0.006
Effective rate of rearing (ERR)	68.06±19.05	75.67±2	84.33±2	0.321	71.11±17.13	73.33±2.34	87.67±1.68	0.16

Values are the mean of the observations ± standard deviation (SD) and p value for probability.



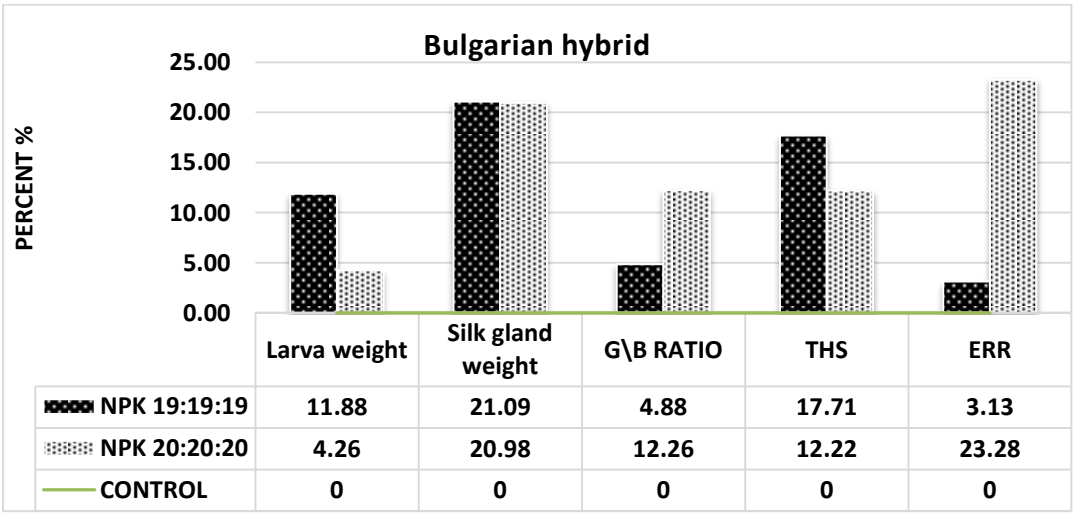


Figure 1. *The Overall Percentage Changes from control (OPC %) for NPK-Fertilization treatments from the control group on some growth parameters of silkworm Local and Bulgarian hybrids*

3.2. Economic Performance and Cocoon Quality of Silkworm (Bombyx mori L.).

3.2.1.Cocoon weight

Cocoon weight, a critical economic parameter, exhibited an enhancement (P≤ 0.01) in both hybrids when fed with leaves from NPK-fertilized trees. The Local hybrid demonstrated the highest cocoon weight (1.19 ± 0.05 g) with NPK (20:20:20), reflecting a 36.7% increase compared to the control (0.87 ± 0.05 g). Similarly, the Bulgarian hybrid exhibited a substantial increase in cocoon weight by 29.66% with NPK at 20:20:20 ratio compared to the control. (Fig.2).

3.2.2. Pupal weight

Pupal weight, a direct indicator of silkworm growth and development, was augmented positively (P≤ 0.01) in both hybrids when fed with NPK-enriched leaves. The Local hybrid exhibited the highest pupal weight representing a significantly increased by 33.57% with NPK (19:19:19). Similarly, the Bulgarian hybrid displayed a high significant increase in pupal weight by 29.27% with NPK (19:19:19). These results suggest that NPK fertilization positively influences silkworm growth and development, leading to heavier pupae.

3.2.3. Shell weight

An enhancement in shell weight (P =.026) was observed in both hybrids, when it was fed leaves from NPK-fertilized trees. The Local hybrid demonstrated the most substantial significant increased by 66.59% (from 0.15 ± 0.01 g to 0.25 ± 0.05 g) with NPK ratio of 20:20:20 (Fig.2). The Bulgarian hybrid significantly increased by 31.46% with NPK (20:20:20).

3.2.4. Shell ratio

The shell ratio, an indicator of silk protein deposition, exhibited an increasing trend in both hybrids under NPK fertilization. While a general increase was observed, statistically significant differences between treatments were not detected. Conspicuously, feeding larvae with mulberry leaves treated with NPK (20:20:20) tended to result in higher shell ratios in both hybrids compared to NPK (19:19:19) and control group. In general, cocoon traits, including cocoon weight and shell weight, demonstrated a trend towards superiority in silkworms fed with mulberry leaves treated with NPK (20:20:20) compared to those fed with NPK (19:19:19) and the control group in both hybrids**.**

3.3.5. Renditta (Silk Yield)

Renditta, a critical parameter reflecting silk yield efficiency, exhibited some variation among treatments. While not consistently significant across hybrids, a trend towards higher Renditta (kg of cocoons required to produce 1 kg of raw silk) was observed in silkworms fed on leaves from NPK-fertilized trees. Remarkably, silkworms fed with mulberry leaves treated with NPK (20:20:20) demonstrated the most favorable results. This resulted in a -15.58%, (Fig.2) reduction in the required cocoon weight per kilogram of raw silk in the Local hybrid and a -0.48% reduction in the Bulgarian hybrid, suggesting that NPK fertilization can potentially improve silk yield efficiency.

3.2.6. Silk conversion index (SCI)

The Silk conversion index, an indicator of silk production efficiency, varied between treatments and hybrids. It is a common method used to assess silk production efficiency in silkworms. The highest silk conversion index (51.31 ± 16.83%) was observed in the local hybrid treated with NPK (20:20:20), suggesting improved silk production efficiency in terms of silk yield in relation to larval weight. The SCI exhibited variability across treatments and hybrids. The Bulgarian hybrid fed with NPK (20:20:20) displayed the highest SCI (36.88±3.12%), indicating efficient conversion of larval biomass into silk.

Table2. Impact of Foliar Fertilization on cocoon characteristics of silkworm, *B. mori*

Hybrids / Item	Local hybrid				Bulgarian hybrid			
	Control	NPK (19:19:19)	NPK (20:20:20)	P value	Control	NPK (19:19:19)	NPK (20:20:20)	*P*-value
cocoon weight, g	0.87±0.05	1.19±0.05	1.19±0.05	0.01	0.93±0.04	1.18±0.03	1.21±0.05	0.01
pupa weight, g	0.73±0.05	0.97±0.03	0.95±0.03	0.01	0.77±0.04	0.97±0.03	0.99±0.03	0.01
shell weight, g	0.15±0.01	0.22±0.02	0.25±0.05	0.026	0.17±0.01	0.21±0.002	0.22±0.02	0.002
shell ratio, %	17±0.42	18.64±0.78	20.48±3.47	0.20	17.89±0.84	17.88±0.6	17.97±0.73	0.986
Renditta, kg.	7.83±0.19	7.43±0.21	6.61±1.02	0.12	7.44±0.35	7.44±0.25	7.41±0.30	0.986
Silk conversion index, %	32.72±3.63	37.62±3.59	51.31±16.83	0.146	34.53±5.99	36.07±5.04	36.88±3.12	0.839

Values are the mean of the observations ± standard deviation (SD) and p value for probability.

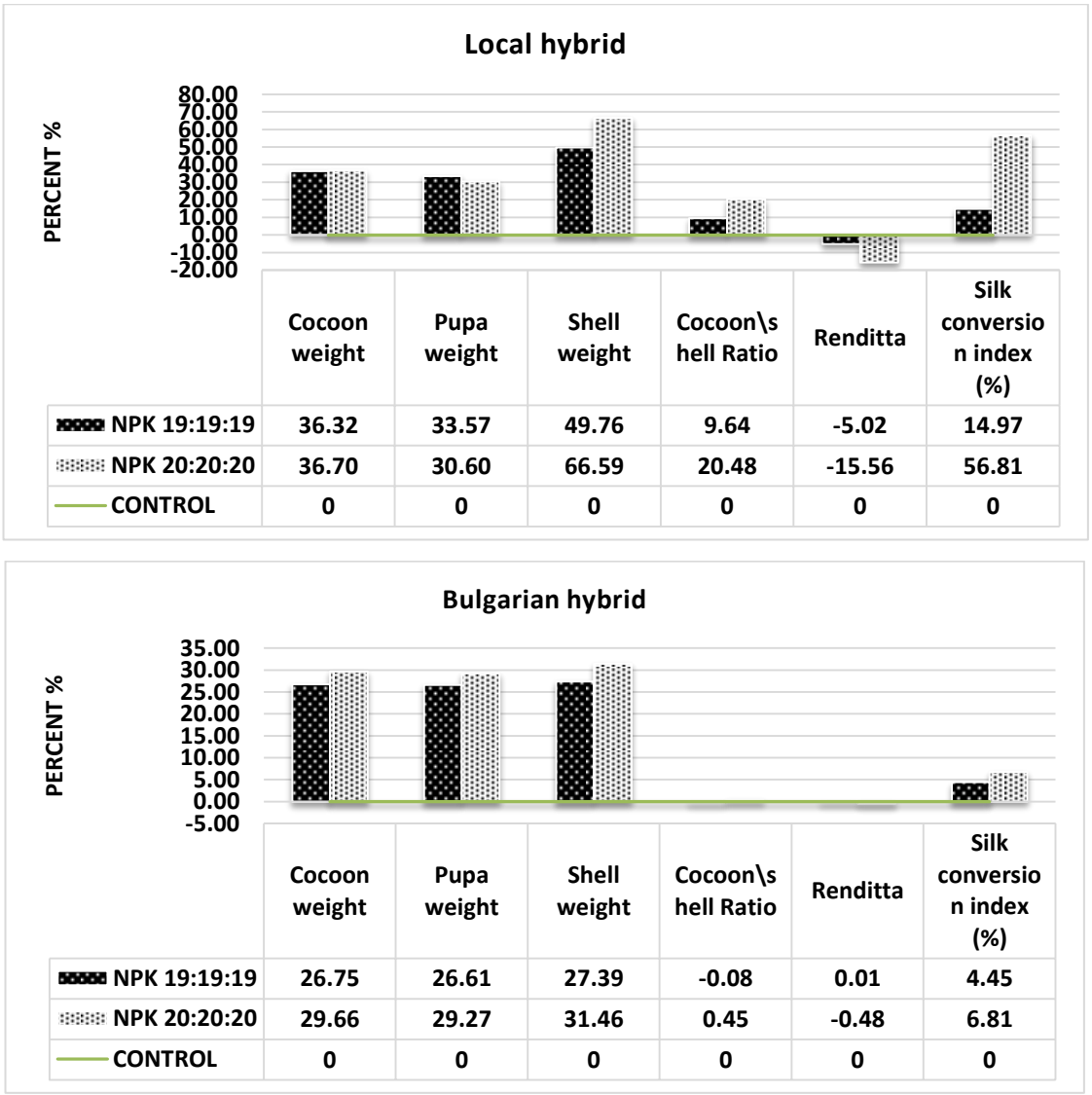


Figure 2. *The Overall Percent Changes from control (OPC %) for NPK-Fertilization treatments from the control group trees on some cocoon parameters of silkworm Local and Bulgarian hybrids.*

4. Discussion.

The findings indicate that NPK Foliar fertilization significantly improved both growth and cocoon quality of silkworms compared to the control, with NPK (20:20:20) demonstrating the most favorable results. These results not only align with previous research but also provide valuable new insights into the optimal use of NPK Foliar fertilization as a promising strategy in sericulture. The higher final larval weight and silk gland weight in fertilized treatments suggest that NPK fertilization promoted efficient nutrients utilization by the silkworms, leading to increased biomass and silk production. The improved G/B ratio indicates faster growth rates in silkworms fed on leaves from fertilized trees, which can contribute to heaver silk gland weight and increased productivity. These findings suggest that foliar fertilization with NPK enhanced larval growth, likely through improved mulberry leaf nutritional quality and enhanced nutrient assimilation by the silkworms. Consistent with our findings Pooja *et al.* (2022) reported that mulberry leaves serve as an ideal food and provide various nutrients to carry out the physiological activities in silkworm. Our study observed that a significant increase in larval weight with the addition of NPK foliar fertilization. Similarly, Ahmed *et al*. (2018) demonstrated that foliar NPK application directly delivers micronutrients essential (NPK) for mulberry leaves growth. These nutrients are crucial for plant growth and metabolism, leading to higher levels of amino acids, vitamins, and minerals in the leaves. Hence the good quality of leaves could be substantially enhanced the growth parameters of silkworm larvae. Similarly, Kannihalli *et al.* (2023) reported that NPK foliar fertilization led to an increase in larval weight. The high essential nutrients content in NPK foliar fertilization leaves likely contribute to this enhancement by providing the necessary nutrients for rapid growth and development of silkworm (Kumar *et al*., 2024). Moreover, Soliman (2024) highlighted the positive impact of NPK foliar fertilization, on silkworm growth and enzyme activity. Our study extends these findings by demonstrating that NPK foliar fertilization improved growth rates, and they also improved some physiological parameters such as silk gland weight and THS. Wani *et al*. (2018); Mir *et al*. (2024) reported that foliar fertilization positively affected lipid metabolism and enzyme activity in the silk glands of silkworms, which aligns with our observation that silk gland weight increased when used NPK foliar fertilization especially, with NPK ratio of 19:19:19. It is clear that the influence of mulberry treated by NPK fertilization on full-grown larval weight was better than the control; these results may be due to existence of higher amounts of essential nutrients from NPK fertilization than untreated treatment. These obtained results are in similar with those of Rashid *et al.* (2002); Sannappa *et al.* (2003); Kamel (2014), who reported that the fertilization of mulberry tree with different methods has more effects on silkworm larval body weight than untreated treatment; and it is important for biological aspects. The observed increase in ERR in fertilized treatments, indicate a higher proportion of larvae successfully completing their development and forming cocoons, signifying improved rearing efficiency and reduced mortality. This could be attributed to the improved nutritional status of the silkworms, which may have strengthened their immune systems and increased their resistance to diseases. This align with Pavithra *et al*. (2024) who found the positive effects of foliar application of Nano nitrogen on growth and development of silkworm and also in managing the disease BmNPV infection. Significant enhancements in silkworm economic traits, such as cocoon weight, pupal weight, shell weight, and shell ratio, were observed with NPK foliar fertilization. Notably, a 20:20:20 NPK formulation led to a substantial increase in cocoon weight, with a 36.7% improvement in local silkworms and a 29.66% increase in Bulgarian hybrids. These findings are consistent with previous research of Ahmed *et al.* (2018) who reported that NPK foliar fertilization positively affected mulberry leaf biochemical composition, leaf yield, silkworm growth, and cocoon parameters. Similarly, Fouad and Ahmed (2020) concluded that this fertilization practice enhanced

mulberry leaf quality by increasing moisture content, crude protein, soluble carbohydrates, reducing sugars, and total mineral content, ultimately impacting silkworm growth and cocoon parameters. Both Local and Bulgarian hybrids exhibited significantly higher cocoon and pupal weights when fed on mulberry leaves from trees fertilized with NPK compared to the control. This indicates that NPK fertilization promotes better growth and development of the silkworms, resulting in larger and heavier cocoons and pupae. Also, the positive effects of foliar fertilized NPK (20:20:20) and NPK (19:19:19) on the shell weight and ratio highlight the nuanced roles these NPK-fertilized play in resource allocation within the silkworm larvae. The observed increase in shell ratio in silkworm hybrids suggests a redirection of metabolic resources towards filamentous silk production. This physiological shift, potentially driven by NPK-mediated up regulation of silk protein synthesis pathways, may enhance silk quality and quantity while maintaining a robust cocoon structure critical for pupal protection and development. These findings have significant implications for optimizing silkworm nutrition and maximizing silk yield (Qian *et al*., 2023; Gathumbi, 2008). The observed improvements in silkworm growth, development, and cocoon parameters can be attributed to the enhanced nutritional quality of mulberry leaves obtained from trees treated with NPK fertilizers. Foliar fertilization likely increased the availability of essential nutrients such as N, P. K in the leaves, which are crucial for various physiological processes in silkworms, including protein synthesis, energy metabolism, and immune function. The observed improvements in cocoon weight, pupal weight, and silk yield have significant implications for increasing silk production and improving the economic viability of sericulture, this reported by (Kerenhap *et al*., 2007). The reduction in Renditta observed in our study with NPK foliar fertilization is particularly noteworthy. NPK foliar fertilization silkworms fed with mulberry leaves treated with NPK (20:20:20) demonstrated the most favorable results. This resulted in a 15.56% reduction in the required cocoon weight per kilogram of raw silk in the local hybrid and a 0.48% reduction in the Bulgarian hybrid, thereby increasing sericulture efficiency by reducing kilograms of cocoons required for produce one kilogram of silk. Similar to our results NPK foliar fertilization (20:20:20) resulted in a noticeable decrease in Renditta. This reduction in Renditta can lead to higher turnover rates in sericulture operations, enhancing overall productivity and economic viability. The observed increase in silk conversion index (%) with NPK-fertilized is particularly significant for sericulture, as silk conversion index (%) directly correlates with silk quality. Karkos *et al*. (2011) emphasized the role of NPK-fertilized rich nutritional profile in mulberry leaves in enhancing silk protein synthesis. Enhanced silk conversion index (%) not only improved the economic value of the silk produced but also reflected better larval health and metabolic efficiency. This aligns with the findings of Jiang (2019), who reported that the physiological mechanisms underpinning these improvements are multifaceted. Also, Pooja *et al*. (2022) emphasizes the critical role of foliar nutrition in enhancing mulberry leaf quality, which leading to improved silk production and corroborating the positive impact of NPK fertilization on silkworm development. These nutrients facilitate enhanced metabolic processes, enzyme activities, and cellular functions that contribute to increased larval weight and silk production. NPK-enriched leaves, provides not only proteins but also phytonutrients and bioactive compounds that may enhance immune functions and metabolic efficiencies in silkworms (Soliman, 2024). Also, El-Khayat *et al*. (2013) reported that the synergistic effects observed with NPK-enriched leaves which suggest complementary nutritional and physiological roles, where NPK-enriched leaves boosts growth and silk production, enhance overall health and resilience. The two NPK formulations, 19:19:19 and 20:20:20, elicited differential responses across measured silkworm parameters. Specifically, 19:19:19 resulted in higher larval weight, silk gland weight, and total haemolymph solids total haemolymph solids (T.H.S.) (THS), whereas 20:20:20 significantly enhanced effective rate of rearing (ERR), cocoon weight, shell weight, shell ratio, Renditta, and silk

conversion index. These findings corroborate observations by Ashish *et al*. (2024), emphasizing the importance of balanced fertilization in silkworm productivity. Also, Ahmed *et al*. (2022) concluded that elevated nitrogen enhances mulberry leaf yield, quality, silk cocoon productivity as well as suppresses the foliar diseases incidence of mulberry plant. Hybrid-specific responses to NPK were also evident, with both local and Bulgarian hybrids showing improvements. Ultimately, this study successfully demonstrated the potential of NPK fertilization (19:19:19 and 20:20:20) to optimize silkworm growth and productivity, contributing to sustainable sericulture practices. By identifying optimal formulations, the research provides practical recommendations for enhancing silk yield and quality, aligning with broader goals of eco-friendly and economically sustainable agriculture, as supported by Wani *et al*. (2017).

5. Conclusion

This study comprehensively demonstrates the significant positive impact of NPK foliar fertilization on silkworm performance and silk production. Both the Local and Bulgarian hybrids exhibited substantial improvements in larval growth and cocoon characteristics when fed mulberry leaves from NPK-treated trees. Specifically, NPK (19:19:19) proved most effective for enhancing larval and silk gland growth, while NPK (20:20:20) yielded superior results for cocoon-related traits, including cocoon weight, pupal weight, and shell weight, as well as improving the effective rate of rearing (ERR) and reducing Renditta. The observed increases in total soluble solids (THS) and the silk conversion index (SCI) further underscore the enhanced nutrient assimilation and silk production efficiency resulting from NPK fertilization. Hybrid-specific responses were evident, with showing a stronger affinity for NPK (19:19:19) in terms of larval weight, silk gland weight and THS. In contrast, the two hybrids exhibited a stronger response to NPK (20:20:20) in terms of ERR, shell weight and ratio, silk conversion index, and Renditta. These findings collectively suggest that NPK foliar fertilization, particularly with the appropriate formulation, represents a promising and practical approach to optimize mulberry leaf quality, improve silkworm rearing efficiency, and enhance silk production, contributing to the economic sustainability of sericulture.

Declarations

Authors' Contributions
All authors are contributed in this research
Funding
There is no funding for this research.
Institutional Review Board Statement
All Institutional Review Board Statements are confirmed and approved.
Data Availability Statement
Data presented in this study are available on fair request from the respective author.
Ethics Approval and Consent to Participate
Not applicable
Consent for Publication
Not applicable.
Conflicts of Interest
The authors disclosed no conflict of interest.

References

Abdelmegeed, S. (2021). Foliar fertilization of different species of mulberry trees and its impact on silkworm Bombyx mori productivity from cocoons and eggs. Arab universities journal of agricultural sciences, 29(2), 787-793. DOI: 10.21608/ajs.2021.82532.1397

Ahmed, F., Hossain, M. S., Uddin, M. A., and Ahmed, O. (2022). Prominent Doses of Nitrogen Enhance Mulberry and Silk Cocoon Productivity. European Journal of Agriculture and Food Sciences, 4(1), 10-19. https://doi.org/10.24018/ejfood.2022.4.1.415

Ahmed, F., Kader, M. Abdul, D., Sultana, R., Ahmed, O., Begum, S.A. and Iqbal, M.T. (2018). Combined application of foliar fertilizer with basal NPK enhances mulberry leaf yield and silkworm cocoon productivity in calcareous soil. Journal of South Pacific Agriculture, 21: 18-25. https://repository.usp.ac.fj/id/eprint/11351

Ashish, S., Karur, D. C., Naveenchandra R., Basangouda, J. and Bharath K. B.M. (2024). Effect of graded level of nutrients on tree mulberry and its influence on cocoon parameters of FC1 and FC2 breeds of silkworm Bombyx mori L. International Journal Advanced Biochemical. Researches 8(8):520-524.
DOI: 10.33545/26174693.2024.v8.i8g.1786

Bharath, K.B., Vinoda, K.S., Banuprakash, K.G., Hariwal, P. (2024): Assessment of the performance of silkworm (Bombyx mori L.) on feeding with mulberry raised using different bioagents. Journal of Entomol Zool Stud,12(4):32-36.
DOI: 10.22271/j.ento.2024.v12.i4a.9346

Borah, S. D., and Boro, P. (2020). A review of nutrition and its impact on silkworm. Journal of Entomology and Zoology Studies, 8(3), 1921-1925.

Chawla, R., and Kumar S. (2024). Nitrogen fertilization of stone fruits: a comprehensive review. Journal of Plant Nutrition, 1-41. https://doi.org/10.1080/01904167.2024.2405990

Dhole, J. S., Shinde, K. S., and Shinde, V. D. (2023). Effect of NPK fertilizers on the growth and yield components of two high yielding mulberry (Morus alba L.) varieties in irrigated conditions". International Journal of Life Sciences, 11(1), 113-118. http://www.ijlsci.in

Diniță, G., Doliș, M. G., Gheorghe, A., Hăbeanu, M., and Mihalcea, T. (2023). Research on the use of biofertilizers in mulberry culture and silkworm rearing. Scientific Papers. Series D. Animal Science. Vol. LXVI, No. 1, https://repository.iuls.ro/xmlui/handle/20.500.12811/3971

El-Khayat, E. F., Gaaboub, I. A., Omer, R. E. M., Ghazey, U. M., and El-Shewy, A. M. (2013). Impact of bio and inorganic fertilizer treatments on economic traits of mulberry silkworm (Bombyx mori L.). Academic Journal of entomology, 6(1), 01-06. DOI: 10.5829/idosi.aje.2013.6.1.310

Etebari, K. and Fazilati, M. (2003). Effects of feeding on mulberry's supplementary leaves with multi-mineral on some biological and biochemical characteristics of silkworm (Bombyx mori). Isfahan University of Technology-Journal of Crop Production and Processing, 7(1), 233-244. http://jcpp.iut.ac.ir/article-1-398-en.html

Fouad, T. A., & Ahmed, G. M. (2020). Biochemical analysis for mulberry silkworm Bombyx mori L. fed with treated leaves by some foliage fertilizers. International Journal of Entomology Research, 5(1), 122-126.

Gathumbi, M. N. (2008). The effects of fertilizers and mulberry (Morus alba l.) variety on cocoon and silk quality in Kenya (Doctoral dissertation). Thesis.122. http://erepository.uonbi.ac.ke:8080/xmlui/handle/123456789/20367

Greiss, H. F., G. Dinita, and D. B. Tanase, (2001). Study on the addition of balanced secondary and micronutrients to mulberry Plantation under Egyptian conditions. Archiva Zootechnica.6:151- 159.

Greiss, H. and Petkov, N. (2001). Effects of balanced NPK and micronutrients fertilization of mulberry Plantations on the development and productivity of silkworm. Bulgarian Journal of Agricultural Science.7 (1):81-85.

Hassan, E., and Morsy, G. (2013). Effect of enriching mulberry leaves with certain foliar fertilizers on some physiological aspects of mulberry silkworm, Bombyx mori L. Journal of Productivity and Development, 18(3), 389-403.

Islam, T., Bhat, S. A., Malik, F. A., Wani, S. A., Khan, F. A., Mir, S. A., and Nazir, N. (2023). Feeding of different Mulberry Varieties and its Impact on Silk Gland of Silkworm, Bombyx mori L. Biological Forum–An International Journal.15(1): 488-492.

Kamel, H. M. (2014). The Effect of fertilized mulberry leaves with balanced NPK on the biological, quantitative and technological parameters of silkworm, Bombyx mori L. Middle East Journal of Agriculture Research, 3(4), 988-993.

Kannihalli, S., Rayar, S. G., Mallapur, C. P., Patil, P. V., and Ravikumar, H. (2023). Foliar application of Nano fertilizers to enhance growth and cocoon yield of mulberry silkworm, Bombyx mori. Agriculture Association of Textile Chemical and Critical Reviews Journal. 11(4):322-326.

https://doi.org/10.58321/AATCCReview.2023.11.04.322

Kaya, C. and Ashraf, M. (2023). Foliar Fertilization: A Potential Strategy for Improving Plant Salt Tolerance. Critical Reviews in Plant Sciences, 43(2), 94–115. https://doi.org/10.1080/07352689.2023.2270253

Kerenhap, W., Thiagarajan, V., and Kumar, V. (2007). Biochemical and bioassay studies on the influence of different organic manures on the growth of Mulberry Variety V1 and silkworm, Bombyx mori Linn. Caspian J. Env. Sci. 2 5(1): 51-56

Kumar, B. B., Banuprakash, K. G., Reddy, R. N., and Gowda, M. (2024). Performance of silkworm, Bombyx mori L. (FC1 X FC2) reared on mulberry raised with foliar applied different volumes of Nano nitrogen. Environment and Ecology, 42(3), 961-967. DOI: https://doi.org/10.60151/envec/UMKR9316

Mir, A. H., Mir, M. R., Haq, S. A., Sharma, R. K., and Baqual, M. F. (2024). Efficacy of multinutrient foliar spray on mulberry leaf yield, quality and commercial characters of silkworm (Bombyx mori L.). International Journal of Veterinary Sciences and Animal Husbandry,9(3): 424-428

Patil, B. and Chetan H.T. (2018). Foliar fertilization of nutrients. Marumegh. 3:49–53.

Pavithra, M., Reddy, R. N., Vinoda, K., and Banuprakash, K. (2024). Impact of Nano Nitrogen Sprayed Mulberry Leaves on BmNPV Infected Larval and Cocoon Traits of Silkworm, Bombyx mori L. Mysore Journal of Agricultural Sciences, 58 (2): 203-213.

Pooja, L., Banuprakash, K. G., Gowda, M., Reddy, R. N., and Satish, A. (2022). Effect of Nano Nitrogen Fertilizer on Mulberry and its Influence on Larval and Cocoon Traits of Silkworm, Bombyx mori L. (FC 1 x FC 2). Mysore Journal of Agricultural Sciences, 56 (2): 240-248.

Potdar, M. P., V.C. Patil and R.R. Patil, (1997). Effects of balanced NPK and micronutrient fertilization of mulberry plantations on the development and productivity of silkworm. Bulgarian Journal of Agricultural. Science.7: 81-85.

Qian, W., Li, H., Zhang, X., Tang, Y., Yuan, D., Huang, Z., and Cheng, D. (2023). Fzr regulates silk gland growth by promoting endoreplication and protein synthesis in the silkworm. PLoS Genetics, 19(1), e1010602: 10.1371/journal.pgen.1010602

Rahmathulla, V. K. (2012). Management of climatic factors for successful silkworm (Bombyx mori L.) crop and higher silk production: a review. Psyche: A Journal of Entomology, 2012(1), 121234. https://doi.org/10.1155/2012/121234

Rajegowda, B. N. and Dhamodhar, G. N. (2022). Effect of soil and foliar application of micronutrients on growth and yield of mulberry (Morus alba L.) and silkworm (Bombyx mori L.). Environment and Ecology 40 (1): 24-27.

Rani, S., Sheikh, N., Baqual, M.F., Rufaie Z.H., Baba Z.A., Maqbool, S., and Akhter, F. (2024). Impact of foliar spray of micronutrients on mulberry (Var. Goshoerami) growth parameters. International Journal of Research in Agronomy, SP-7(1): 89-100. DOI: https://doi.org/10.33545/2618060X.2024.v7.i1Sb.242

Rashid, M. Muhammad T. J. and M. K. Idrees, (2002). Effects of nitrogen (Farm Yard Manure + Urea) treated mulberry trees on the larval development and cocoon weight of silkworm, (Bombyx mori L.). Asian Journal of Plant Sciences, 1(2): 93-94. 10.3923/ajps.2002.93.94

Rashmi, K., Shankar, M.A., Shashidhar, K.R., Narayanaswamy, T.K., (2009). Growth and foliar constituents of mulberry (M5) cultivated under organic-based nutrient management. International Journal of Industrial Entomology. 19(1):165-169.

Ray, S., and Sairam, M. (2024). Foliar Fertilizer–An Approach Towards Micronutrient Optimization and Biofortification of Micronutrients in Cereals. Advances in Modern Agricultural Practices, New Delhi Publishers, India, 223-244.

Riaz, M., Bukhari, R., and Sudan, K. (2020). Growth rate pattern and economic traits of

silkworm, (Bombyx mori L) under the influence of inorganic and organic supplementation diet. Int J Fauna Biol Stud, 8, 5-7. https://doi.org/10.22271/23940522.2021.v8.i1a.783

Sathyanarayana, E., Sudha P., and Chawla S.L. (2017). Impact of integrated nutrient management on growth and flowering of gladiolus (Gladiolus grandiflorus L.) cv. American beauty. Int. J. Chem. Stud. 5:317–319

Shankar, M. A.; Devaiah, M. C.; Peter, A. and Rangaswamy, B.T. (2000). Effects of graded levels of organic manure on growth, yield and quality of mulberry in relation to silkworm growth and cocoon production. Crop Research, 19(1): 128-132.

Shankar, M. A., P.A. Nagaraju, and B. T. Rangasw, (1999). Response of mulberry to application of micronutrients and their impact on cocoon production and grainage parameters. The proceeding of the XVIIth international sericulture commission congress, Cairo- Egypt, 12-16 October

Soliman, N. H. (2024). Nitrogen Fertilizer on Mulberry Leaves and Effect on Larval and Cocoon Characteristics of Silkworm, Bombyx mori L. Egyptian Academic Journal of Biological Sciences. A, Entomology, 17(4), 119-125. DOI: 10.21608/eajbsa.2024.400290

Wani, M. Y., Mir, M. R., Baqual, M. F., Mehraj, K., Bhat, T. A., and Rani, S. (2017). Role of foliar sprays in sericulture industry. Journal of Pharmacognosy and Phytochemistry, 6(4), 1803-1806.

Wani, M. Y., Rather, R. A., Bashir, M., Shafi, S., and Rani, S. (2018). Effect of zinc on the larval growth and quality cocoon parameters of silkworm (Bombyx mori L.): a review. Int. J. Fauna and Biol. Stud, 5(4), 31-36.

Zhang, Q., Zhang, F., Thakur, K., Wang, J., Wang, H., Hu, F., and Wei, Z. J. (2018). Molecular mechanism of anti-cancerous potential of morin extracted from mulberry in Hela cells. Food and Chemical Toxicology, 112, 466-475. https://doi.org/10.1016/j.fct.2017.07.002

Žinete, J. (2023): The role of NPK fertilizers in modern agriculture: Fuelling crop growth and maximizing yields. International Journal of Manures and Fertilizers, ISSN 2756-3863, Vol. 11 (2):1-2.