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Effect of nutri-cereal intercropping on leaf quality attributes of tree mulberry (*Morus alba* L.)

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ABSTRACT

A field experiment was conducted to evaluate the effect of intercropping with different nutri-cereals on the quality parameters of tree mulberry (*Morus alba* L.) leaves. The quality attributes, viz., leaf moisture content, total chlorophyll, protein and carbohydrate contents, were assessed at 45, 90 and 135 days after pruning (DAP). The pooled results revealed considerable variation among intercropping systems, with sole tree mulberry generally recording the highest values for most quality parameters. At 45 DAP, leaf moisture content was highest in sole tree mulberry (72.5%), followed by tree mulberry + ragi (1:5) (69.2%), while the lowest was recorded with tree mulberry + grain amaranth (1:5) (60.1%). At 135 DAP, moisture content increased to 77.3% in sole tree mulberry, with tree mulberry + ragi (74.6%) and tree mulberry + chia (74.2%) remaining statistically comparable. Total chlorophyll content was highest in sole tree mulberry, increasing from 2.32 mg g⁻¹ at 45 DAP to 2.42 mg g⁻¹ at 135 DAP. Among intercropping systems, tree mulberry + ragi (1:5) recorded the highest chlorophyll content and remained statistically on par with sole tree mulberry. Protein content increased progressively with crop age, reaching 255.2 mg g⁻¹ in sole tree mulberry at 135 DAP, compared with 246.2 mg g⁻¹ under tree mulberry + ragi (1:5). Similarly, carbohydrate content increased from 114.5 mg g⁻¹ at 45 DAP to 116.5 mg g⁻¹ at 135 DAP in sole tree mulberry, while ragi-based intercropping recorded 112.2 mg g⁻¹. Tree mulberry + grain amaranth (1:5) consistently recorded comparatively lower quality attributes. Overall, tree mulberry + ragi (1:5) emerged as the most favourable intercropping system among the nutri-cereal combinations for maintaining superior leaf quality, while chia, quinoa and foxtail millet also showed good compatibility with tree mulberry.

Keywords: Tree mulberry, Nutri-cereal intercropping, Leaf quality, Chlorophyll content, Leaf biochemical constituents

Introduction

Mulberry (*Morus alba* L.) is the primary food plant of the domesticated silkworm, *Bombyx mori* L., and the quality of foliage plays a decisive role in successful sericulture. Leaf characteristics such as moisture content, chlorophyll concentration, protein and carbohydrate contents are important indicators of the nutritional and physiological status of mulberry foliage and have a direct bearing on its suitability as silkworm feed. Adequate moisture contributes to leaf succulence and freshness, while chlorophyll is closely associated with photosynthetic activity and production of assimilates. Protein and carbohydrate constitute important biochemical components of mulberry leaves that contribute to the nutritional requirements of growing silkworm larvae. Hence, improving and maintaining desirable leaf quality is an important component of sustainable mulberry production.

Intercropping of tree mulberry with suitable food and nutri-cereal crops offers an opportunity to diversify production and improve the overall resource-use efficiency of the system. Nutri-cereals such as ragi, chia, grain amaranth, quinoa and foxtail millet are increasingly recognized for their nutritional and economic importance and can provide additional produce from the interspaces of tree mulberry plantations. However, the introduction of companion crops into a mulberry-based system may influence the availability and utilization of soil moisture, nutrients, light and other growth resources. The nature and intensity of such interactions may vary with the companion crop because of differences in root distribution, canopy development, growth duration and resource demand. Therefore, selection of compatible intercrops is essential to ensure that diversification of the mulberry production system does not adversely affect the quality of foliage required for silkworm rearing.

Although intercropping can provide additional economic and nutritional benefits, the compatibility of different nutri-cereals with tree mulberry needs to be evaluated from the perspective of both crop productivity and mulberry leaf quality. Changes in leaf moisture status and biochemical constituents may reflect the degree of competition or complementarity between mulberry and the associated intercrop. Information on the comparative influence of ragi, chia, grain amaranth, quinoa and foxtail millet on the quality characteristics of tree

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mulberry leaves is particularly important for developing suitable intercropping systems for sericulture-based farming. Therefore, the present study was undertaken to assess the effect of different nutri-cereal intercropping systems on leaf moisture content, chlorophyll, protein and carbohydrate contents of tree mulberry at different stages of crop growth.

Materials and methods

Experimental site

The field experiment was conducted at Krishi Vigyan Kendra (KVK), Chintamani, located in the Eastern Dry Zone of Karnataka (Zone-5), India, between 13.3354° N latitude and 78.0824° E longitude, at an altitude of 865 m above mean sea level. The experiment was conducted for two consecutive years, 2024–25 and 2025–26.

Experimental crop

The experiment was conducted in an established five-year-old V-1 mulberry (*Morus alba* L.) garden maintained at a spacing of 2.5 m × 2.5 m. Recommended cultural practices for an irrigated mulberry garden were followed as per Dandin *et al.* (2014) [1]. The existing mulberry shoots were pruned before imposing the treatments. Inter-cultivation was carried out, and the respective treatments were imposed according to the experimental plan.

Experimental design and treatments

The experiment was laid out in a split-split plot design with three replications, comprising 18 treatment combinations. The main plot treatments consisted of three levels of recommended dose of fertilizers (RDF) (M): M₁ – 100% RDF, M₂ – 75% RDF and M₃ – 50% RDF. The sub-plot treatments comprised two levels of liquid formulations applied through fertigation (S): S₁ – Jeevamrutha @ 500 L ha⁻¹ after pruning at 45-day intervals in five splits and S₂ – microbial consortia @ 7.5 L ha⁻¹ after pruning at 45-day intervals in five splits. The sub-sub plot treatments consisted of three foliar spray treatments (F): F₁ – Seriboost Plus @ 0.7% at 20 and 40 days after pruning (DAP), F₂ – Panchagavya @ 5% at 20 and 40 DAP, and F₃ – humic acid + fulvic acid @ 3% at 20 and 40 DAP.

Fertigation of liquid formulations

The liquid microbial formulations were applied through the existing drip irrigation system to ensure uniform application in the active root zone of the mulberry plants. Jeevamrutha was applied at 500 L ha⁻¹, while microbial consortia was applied at 7.5 L ha⁻¹. Both formulations were applied after pruning at 45-day intervals in five split applications.

Total carbohydrate content (%)

Carbohydrate content in the leaves of mulberry was quantitatively measured by Anthrone Reagent method. For assessment of carbohydrates content, 0.2 g of mulberry leaf sample was grinded in pestle and mortar with the help of distilled water. The samples were cen-

$$\text{Protein content (\%)} = \% \text{ N} \times 6.25$$

$$\text{Carbohydrate content (\%)} \times 10 = \text{mg g}^{-1}$$

Results and discussion

Effect of intercropping on quality parameters of mulberry leaves

The data on quality parameters viz., leaf moisture content (%), total chlorophyll content (mg g⁻¹), total protein content (mg g⁻¹) and total carbohydrate content (mg g⁻¹) of leaf as influenced by intercropping

Foliar spray of liquid manures

Foliar applications of Seriboost Plus @ 0.7%, Panchagavya @ 5% and humic acid + fulvic acid @ 3% were made at 20 and 40 DAP. The foliar formulations were applied directly to the foliage during the crop growth period to facilitate nutrient and beneficial compound uptake through the leaves. Foliar application can enhance the immediate availability of nutrients to the plant through absorption by the leaf surface and stomata, thereby supporting plant growth and productivity (Handreck *et al.*, 1994) [2].

Crop management

Apart from the imposition of the respective treatments, all other agromomic practices, including irrigation scheduling, inter-cultivation, weed management and plant protection measures, were followed uniformly in all treatments throughout the experimental period. The crop was managed in accordance with the recommended package of practices for mulberry cultivation (Dandin *et al.*, 2003) [3].

Methodology followed for recording leaf quality parameters

Moisture content (%)

Leaves were harvested from each treatment and preserved in polythene bags of which the fresh weight was taken. The leaves were oven dried at 70 °C for 48 hours and the dry weight recorded.

Moisture percentage of leaves was calculated by using the following formula as

Moisture per cent =	Fresh weight of leaves (g) - Dry weight of leaves (g)	x 100
	Fresh weight of leaves (g)	

Total chlorophyll content

The content of chlorophyll in mulberry leaf was calculated by the following procedure defined by Hiscox *et al.* (1979) [4]. The total leaf chlorophyll content was determined using the formula proposed by Arnon (1949) [5].

mg g ⁻¹ fresh weight	20.2 (O.D.645) + 8.02 (O.D.663)	x volume
=		
	1000 g weight of leaves (g)	

Total protein content

Protein content of the leaves of mulberry was estimated as per cent nitrogen by micro kjeldhal's method (Jackson, 1973) [6]. The protein per cent in the leaves was calculated by multiplying the nitrogen content by a factor of 6.25.

$$\text{Protein content (\%)} \times 10 = \text{mg g}^{-1}$$

trifuged at 5000 rpm for 10 minutes. The supernatant was collected in test tube and 4 ml of anthrone reagent is added to get green colour. The absorbance value of the green colour was noted to evaluate the carbohydrate content using UV spectrophotometer at wavelength of 625 nm. Against standard sugar solution (*Dextrose* L.) the carbohydrate content was calculated and expressed in percentage.

of different nutri-cereals are presented here.

Leaf moisture content (%) (c.f. Table 1)

Leaf moisture content is an important quality attribute of mulberry foliage, as adequate moisture in the leaves is associated with succulence, freshness and suitability of foliage for silkworm feeding.

At 45 DAP, the highest pooled leaf moisture content was recorded in sole tree mulberry (72.5%), followed by tree mulberry + ragi (1:5)

(69.2%), tree mulberry + chia (1:5) (68.4%) and tree mulberry + quinoa (1:5) (67.6%). The lowest value was recorded in tree mulberry + grain amaranth (1:5) (60.1%). The relatively higher moisture content under sole tree mulberry and ragi, chia and quinoa-based intercropping may be attributed to better moisture availability and reduced competition for water during the early growth period.

At 90 DAP, sole tree mulberry recorded the highest pooled leaf moisture content (75.2%), which was statistically on par with tree mulberry + ragi (1:5) (72.2%) and tree mulberry + chia (1:5) (71.1%), whereas tree mulberry + grain amaranth (1:5) recorded the lowest value (62.2%). Intermediate values were observed in tree mulberry + quinoa (1:5) (70.1%) and tree mulberry + foxtail millet (1:5) (68.7%). The comparatively greater moisture retention in sole tree mulberry and selected intercropping treatments indicates better plant water status, possibly due to differences in canopy development, root distribution and soil moisture utilization.

At 135 DAP, the highest pooled leaf moisture content was recorded in sole tree mulberry (77.3%), followed by tree mulberry + ragi (1:5) (74.6%), tree mulberry + chia (1:5) (74.2%) and tree mulberry + quinoa (1:5) (72.8%). The lowest value was observed in tree mulberry + grain amaranth (1:5) (66.8%). Tree mulberry + ragi (1:5) and tree mulberry + chia (1:5) were statistically on par with sole tree mulberry, while tree mulberry + grain amaranth (1:5) recorded the minimum moisture content. The higher moisture content during this stage may be associated with improved vegetative growth and maintenance of leaf hydration, whereas the lower value under grain amaranth intercropping may indicate comparatively greater competition for available soil moisture.

The higher leaf moisture content under sole tree mulberry and selected intercropping combinations could be attributed to better soil moisture availability, efficient root-zone water utilization and reduced interspecific competition for moisture. In contrast, the lower moisture content under tree mulberry + grain amaranth (1:5) may be due to stronger competition between tree mulberry and grain amaranth for soil moisture and nutrients. The gradual increase in leaf moisture content with advancement of pruning stages suggests improved canopy development and plant water status under favourable growing conditions. Overall, intercropping with suitable nutri-cereals, particularly ragi and chia, appeared relatively favourable for maintaining leaf moisture content of tree mulberry, whereas grain amaranth was comparatively less favourable. Similar findings were reported by Arun Kumar (2013) [7].

Chlorophyll content (mg g^{-1}) (c.f. Table 2)

The chlorophyll content of tree mulberry leaves varied among the intercropping treatments at different days after pruning (DAP).

At 45 DAP, the highest chlorophyll content was recorded in sole tree mulberry (2.32 mg g^{-1}), which was statistically on par with tree mulberry + ragi (1:5) (2.22 mg g^{-1}), tree mulberry + chia (1:5) (2.19 mg g^{-1}), tree mulberry + quinoa (1:5) (2.16 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (2.12 mg g^{-1}). The lowest value was recorded in tree mulberry + grain amaranth (1:5) (1.89 mg g^{-1}). The higher chlorophyll content under sole tree mulberry may be attributed to relatively lesser interspecific competition for available nutrients, moisture and light compared with the intercropped systems.

At 90 DAP, chlorophyll content increased slightly in most treatments. Sole tree mulberry recorded the highest pooled chlorophyll content (2.42 mg g^{-1}) and remained statistically on par with tree mulberry + ragi (1:5) (2.32 mg g^{-1}), tree mulberry + chia (1:5) (2.28 mg g^{-1}), tree mulberry + quinoa (1:5) (2.25 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (2.20 mg g^{-1}). Tree mulberry + grain amaranth (1:5) (1.95 mg g^{-1}) recorded the lowest value. The relatively higher chlorophyll content in sole tree mulberry and its comparable values with most intercropping treatments indicate that the presence of nutri-cereals did not markedly impair chlorophyll formation, except under tree mulberry + grain amaranth, where greater competitive effects may have influenced nutrient and moisture availability.

At 135 DAP, sole tree mulberry recorded the highest pooled chlorophyll content (2.42 mg g^{-1}), which was statistically on par with tree mulberry + ragi (1:5) (2.32 mg g^{-1}), tree mulberry + chia (1:5) (2.31 mg g^{-1}), tree mulberry + quinoa (1:5) (2.26 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (2.21 mg g^{-1}). The lowest chlorophyll content was observed in tree mulberry + grain amaranth (1:5) (1.94 mg g^{-1}). The maintenance of relatively higher chlorophyll concentration under sole tree mulberry suggests favourable nutrient availability and reduced competition, whereas the lower value under tree mulberry + grain amaranth could be associated with stronger competition between tree mulberry and grain amaranth for soil resources.

Across the three observation periods, sole tree mulberry consistently recorded the highest chlorophyll content, with pooled values increasing from 2.32 mg g^{-1} at 45 DAP to 2.42 mg g^{-1} at 135 DAP. Among the intercropping treatments, tree mulberry + ragi (1:5) recorded the highest chlorophyll content and remained statistically on par with sole tree mulberry, followed by tree mulberry + chia (1:5) tree mulberry + quinoa (1:5). Tree mulberry + grain amaranth (1:5) consistently recorded the lowest chlorophyll content throughout the observation period. The higher chlorophyll content in treatments maintaining better nutrient and moisture availability may have enhanced chlorophyll synthesis and leaf photosynthetic efficiency. The similar trend across the two years indicates the relative stability of treatment effects on the chlorophyll status of tree mulberry.

The comparatively higher chlorophyll content under sole tree mulberry may be attributed to the absence of interspecific competition for soil moisture, nutrients, light and other growth resources. The statistically comparable chlorophyll content under tree mulberry + ragi (1:5) indicates its relatively lower competitive effect on tree mulberry and better compatibility within the intercropping system. In contrast, the consistently lower chlorophyll content under tree mulberry + grain amaranth (1:5) may be associated with greater competition for moisture and nutrients, which could have restricted chlorophyll synthesis and photosynthetic activity. Overall, tree mulberry + ragi (1:5) emerged as the most favourable intercropping treatment for maintaining chlorophyll status, being statistically comparable with sole tree mulberry. Similar results were reported by Arun Kumar (2013) [7] who reported that the maximum leaf moisture in top leaves (75.23 %), chlorophyll a (1.25 mg g^{-1}) and chlorophyll b (0.45 mg g^{-1}) recorded in middle leaves of mulberry with soybean intercropping situation compared to other intercrops.

Protein content (mg g^{-1}) (c.f. Table 3)

The protein content of tree mulberry leaves was influenced by intercropping with nutri-cereals and exhibited a gradual increase with advancement of crop growth. At 45 DAP, the pooled protein content was highest in sole tree mulberry (228.5 mg g^{-1}), which was statistically on par with tree mulberry + ragi (1:5) (218.2 mg g^{-1}), tree mulberry + chia (1:5) (215.6 mg g^{-1}), tree mulberry + quinoa (1:5) (213.2 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (208.6 mg g^{-1}). The lowest value was recorded in tree mulberry + grain amaranth (1:5) (189.5 mg g^{-1}). A similar trend was observed in both years, with sole tree mulberry maintaining the highest protein content, while grain amaranth intercropping recorded the lowest value.

At 90 DAP, the pooled protein content increased across treatments, with the highest value recorded in sole tree mulberry (247.7 mg g^{-1}), which was statistically on par with tree mulberry + ragi (1:5) (238.0 mg g^{-1}), tree mulberry + chia (1:5) (234.4 mg g^{-1}), tree mulberry + quinoa (1:5) (231.0 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (226.3 mg g^{-1}). Tree mulberry + grain amaranth (1:5) recorded the lowest protein content (204.9 mg g^{-1}) and was significantly lower than sole tree mulberry.

At 135 DAP, protein content further increased, and sole tree mulberry recorded the highest pooled value (255.2 mg g^{-1}). However, it was statistically on par with tree mulberry + ragi (1:5) (246.2 mg g^{-1}), tree mulberry + chia (1:5) (244.7 mg g^{-1}), tree mulberry + quinoa (1:5) (240.2 mg g^{-1}), tree mulberry + foxtail millet (1:5) (235.5 mg g^{-1}) and tree mulberry + grain amaranth (1:5) (220.4 mg g^{-1}).

Overall, protein content increased progressively from 45 to 135 DAP in all the tree-mulberry treatments. Sole tree mulberry consistently recorded the highest numerical protein content, whereas tree mulberry + grain amaranth (1:5) recorded the lowest numerical values throughout the observation period. Among the intercropping systems, tree mulberry + ragi (1:5) maintained the highest protein content, followed by chia- and quinoa-based combinations. The comparatively higher protein content under sole tree mulberry and ragi-based intercropping may be attributed to reduced interspecific competition for nutrients, moisture and other growth resources, favouring nitrogen assimilation and protein synthesis in mulberry leaves. The progressive increase in protein content with crop age may also be associated with improved nutrient accumulation and physiological development of the foliage. Overall, tree mulberry + ragi (1:5) emerged as the most favourable intercropping treatment for maintaining higher protein content among the intercropping systems, while remaining statistically comparable with sole tree mulberry at the observed stages. Similar findings were reported by Shoriful *et al.*, 2023 [8] and Banu Priya, 2021 [9].

Carbohydrate content (mg g^{-1}) (c.f. Table 4)

The carbohydrate content of tree mulberry varied considerably among the different intercropping systems. The carbohydrate content showed a gradual increase with advancement of crop age from 45 to 135 DAP in all the tree mulberry-based treatments.

At 45 DAP, the pooled carbohydrate content was highest in sole tree mulberry (114.5 mg g^{-1}) and lowest in tree mulberry + grain amaranth (1:5) (93.4 mg g^{-1}). Sole tree mulberry was statistically on par with tree mulberry + ragi (1:5) (109.3 mg g^{-1}), tree mulberry + chia (1:5) (108.0 mg g^{-1}), tree mulberry + quinoa (1:5) (106.8 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (104.6 mg g^{-1}).

At 90 DAP, the highest pooled carbohydrate content was recorded in sole tree mulberry (115.4 mg g^{-1}), while the lowest was recorded in tree mulberry + grain amaranth (1:5) (93.4 mg g^{-1}). Sole tree mulberry was statistically on par with tree mulberry + ragi (1:5) (110.8 mg g^{-1}), tree mulberry + chia (1:5) (109.1 mg g^{-1}), tree mulberry + quinoa (1:5) (107.4 mg g^{-1}) and tree mulberry + foxtail millet (1:5) (105.2 mg g^{-1}). The higher carbohydrate content under sole tree mulberry may be attributed to the absence of interspecific competition for moisture, nutrients, light and other growth resources.

At 135 DAP, sole tree mulberry recorded the highest pooled carbohydrate content (116.5 mg g^{-1}), whereas tree mulberry + grain amaranth (1:5) recorded the lowest (95.9 mg g^{-1}). The carbohydrate content under tree mulberry + ragi (1:5) (112.2 mg g^{-1}), tree mulberry + chia (1:5) (111.4 mg g^{-1}), tree mulberry + quinoa (1:5) (109.3 mg g^{-1}) and

tree mulberry + foxtail millet (1:5) (107.0 mg g^{-1}) were statistically on par with sole tree mulberry. The relatively higher carbohydrate accumulation with advancement of crop age could be associated with increased photosynthetic activity and development of a larger photosynthetically active leaf canopy.

Overall, the pooled results revealed a consistent superiority of sole tree mulberry for carbohydrate accumulation, although its values were statistically on par with tree mulberry + ragi (1:5), tree mulberry + chia (1:5), tree mulberry + quinoa (1:5) and tree mulberry + foxtail millet (1:5) at all stages of observation. Tree mulberry + grain amaranth (1:5) consistently recorded the lowest carbohydrate content. The better performance of ragi-, chia-, quinoa- and foxtail millet-based intercropping systems indicates their comparatively greater compatibility with tree mulberry. The progressive increase in carbohydrate content with crop age may be attributed to enhanced photosynthetic efficiency and accumulation of photosynthates, while the lower values under grain amaranth-based intercropping could be due to greater competition for available growth resources. Thus, tree mulberry + ragi (1:5), tree mulberry + chia (1:5), tree mulberry + quinoa (1:5) and tree mulberry + foxtail millet (1:5) were relatively suitable intercropping combinations for maintaining the carbohydrate status of tree mulberry. Similar findings were reported by Vishaka, 2015 [10] and Shoriful *et al.* (2023) [8].

Conclusion

Sole tree mulberry recorded the highest overall leaf quality, as evidenced by the maximum leaf moisture content (77.3 %), total chlorophyll content (2.42 mg g^{-1}), total carbohydrate content (116.5 mg g^{-1}) and total protein content (255.2 mg g^{-1}). The leaf quality parameters of tree mulberry + ragi (1:5) were statistically on par with sole tree mulberry, recording 74.6 per cent leaf moisture, 2.32 mg g^{-1} total chlorophyll, 246.2 mg g^{-1} protein and 112.2 mg g^{-1} carbohydrate.

Declaration of AI use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing interests

Authors have declared that no competing interests exist.

Table 1. Leaf moisture content of tree mulberry as influenced by intercropping of nutri-cereals

Treatments	Leaf moisture content (%)								
	45 DAP			90 DAP			135 DAP		
	2024	2025	Pooled	2024	2025	Pooled	2024	2025	Pooled
T ₁ : Sole tree mulberry	70.6	74.4	72.5	74.0	76.4	75.2	75.3	79.4	77.3
T ₂ : Sole Ragi	—	—	—	—	—	—	—	—	—
T ₃ : Sole Chia	—	—	—	—	—	—	—	—	—
T ₄ : Sole Grain amaranth	—	—	—	—	—	—	—	—	—
T ₅ : Sole Quinoa	—	—	—	—	—	—	—	—	—
T ₆ : Sole Foxtail millet	—	—	—	—	—	—	—	—	—
T ₇ : Tree mulberry + Ragi (1:5)	66.6	71.8	69.2	70.9	73.5	72.2	71.9	77.3	74.6
T ₈ : Tree mulberry + Chia (1:5)	66.4	70.4	68.4	69.4	72.9	71.1	71.1	77.3	74.2
T ₉ : Tree mulberry + Grain amaranth (1:5)	58.1	62.2	60.1	60.4	64.0	62.2	65.3	68.2	66.8
T ₁₀ : Tree mulberry + Quinoa (1:5)	65.4	69.9	67.6	68.2	72.0	70.1	69.5	76.0	72.8
T ₁₁ : Tree mulberry + Foxtail millet (1:5)	63.8	68.6	66.2	66.5	70.9	68.7	67.8	74.9	71.4
SEm ±	3.5	3.8	3.5	4.3	4.4	4.1	4.1	3.8	3.9
CD @ 5%	10.4	11.1	10.3	12.5	13.1	12.0	12.0	11.1	11.4

(continued on next page)

Table 2. Chlorophyll content of tree mulberry as influenced by intercropping of nutri-cereals

Treatments	Chlorophyll content (mg g ⁻¹)								
	45 DAP			90 DAP			135 DAP		
	2024	2025	Pooled	2024	2025	Pooled	2024	2025	Pooled
T ₁ : Sole tree mulberry	2.23	2.42	2.32	2.38	2.45	2.42	2.38	2.46	2.42
T ₂ : Sole Ragi	—	—	—	—	—	—	—	—	—
T ₃ : Sole <i>Chia</i>	—	—	—	—	—	—	—	—	—
T ₄ : Sole Grain amaranth	—	—	—	—	—	—	—	—	—
T ₅ : Sole Quinoa	—	—	—	—	—	—	—	—	—
T ₆ : Sole Foxtail millet	—	—	—	—	—	—	—	—	—
T ₇ : Tree mulberry + Ragi (1:5)	2.11	2.33	2.22	2.29	2.34	2.32	2.26	2.38	2.32
T ₈ : Tree mulberry + <i>Chia</i> (1:5)	2.10	2.27	2.19	2.25	2.31	2.28	2.24	2.38	2.31
T ₉ : Tree mulberry + Grain amaranth (1:5)	1.81	1.96	1.89	1.92	1.97	1.95	1.88	2.01	1.95
T ₁₀ : Tree mulberry + Quinoa (1:5)	2.08	2.25	2.16	2.21	2.28	2.25	2.19	2.33	2.26
T ₁₁ : Tree mulberry + Foxtail millet (1:5)	2.03	2.20	2.12	2.16	2.24	2.20	2.13	2.28	2.21
SEm ±	0.10	0.11	0.10	0.11	0.11	0.11	0.11	0.12	0.11
CD @ 5%	0.28	0.33	0.30	0.33	0.34	0.33	0.34	0.34	0.34

Table 3. Protein content of tree mulberry as influenced by intercropping of nutri-cereals

Treatments	Protein content (mg g ⁻¹)								
	45 DAP			90 DAP			135 DAP		
	2024	2025	Pooled	2024	2025	Pooled	2024	2025	Pooled
T ₁ : Sole tree mulberry	219.0	238.0	228.5	243.3	252.1	247.7	248.5	261.9	255.2
T ₂ : Sole Ragi	—	—	—	—	—	—	—	—	—
T ₃ : Sole <i>Chia</i>	—	—	—	—	—	—	—	—	—
T ₄ : Sole Grain amaranth	—	—	—	—	—	—	—	—	—
T ₅ : Sole Quinoa	—	—	—	—	—	—	—	—	—
T ₆ : Sole Foxtail millet	—	—	—	—	—	—	—	—	—
T ₇ : Tree mulberry + Ragi (1:5)	206.6	229.8	218.2	233.3	242.7	238.0	237.1	255.2	246.2
T ₈ : Tree mulberry + <i>Chia</i> (1:5)	205.8	225.3	215.6	228.5	240.4	234.4	234.5	255.0	244.7
T ₉ : Tree mulberry + Grain amaranth (1:5)	180.0	199.1	189.5	198.6	211.1	204.9	215.6	225.2	220.4
T ₁₀ : Tree mulberry + Quinoa (1:5)	202.8	223.6	213.2	224.4	237.6	231.0	229.5	250.9	240.2
T ₁₁ : Tree mulberry + Foxtail millet (1:5)	197.9	219.4	208.6	218.8	233.9	226.3	223.8	247.2	235.5
SEm ±	11.0	12.1	11.0	14.0	14.6	13.4	13.4	12.4	12.8
CD @ 5%	32.3	35.6	32.4	41.2	43.2	39.6	39.5	36.6	37.7

Table 4. Carbohydrate content of tree mulberry as influenced by intercropping of nutri-cereals

Treatments	Carbohydrate content (mg g ⁻¹)								
	45 DAP			90 DAP			135 DAP		
	2024	2025	Pooled	2024	2025	Pooled	2024	2025	Pooled
T ₁ : Sole tree mulberry	109.4	119.6	114.5	113.8	117.1	115.4	114.2	118.8	116.5
T ₂ : Sole Ragi	—	—	—	—	—	—	—	—	—
T ₃ : Sole <i>Chia</i>	—	—	—	—	—	—	—	—	—
T ₄ : Sole Grain amaranth	—	—	—	—	—	—	—	—	—
T ₅ : Sole Quinoa	—	—	—	—	—	—	—	—	—
T ₆ : Sole Foxtail millet	—	—	—	—	—	—	—	—	—
T ₇ : Tree mulberry + Ragi (1:5)	103.2	115.5	109.3	108.9	112.7	110.8	108.7	115.6	112.2
T ₈ : Tree mulberry + <i>Chia</i> (1:5)	102.9	113.2	108.0	106.6	111.6	109.1	107.4	115.5	111.4
T ₉ : Tree mulberry + Grain amaranth (1:5)	86.8	100.0	93.4	88.8	98.0	93.4	90.2	101.6	95.9
T ₁₀ : Tree mulberry + Quinoa (1:5)	101.3	112.4	106.8	104.6	110.3	107.4	105.0	113.6	109.3
T ₁₁ : Tree mulberry + Foxtail millet (1:5)	98.9	110.2	104.6	101.9	108.6	105.2	102.2	111.9	107.0
SEm ±	4.7	4.7	4.6	6.1	4.5	5.3	5.5	4.4	4.9
CD @ 5%	14.0	13.9	13.7	18.0	13.4	15.7	16.3	12.8	14.5

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