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Effect of *Tephrosia* mulch doses on guava fruit yield and quality under rainfed ecosystem

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ABSTRACT

Tephrosia candida **(Roxb.) DC. is a perennial shrub well-adapted to withstand drought and acidic soil conditions, exhibits superior biomass production and notably higher concentrations of carbon, nitrogen, phosphorus, potassium, and essential micronutrients. A trial was conducted to standardize the quantity of *Tephrosia candida* biomass for mulching in a guava orchard for 3 years. The treatments comprised of T_1 = 3.0 kg dry biomass m^{-2} of the plant basin, T_2 = 2.0 kg, T_3 = 1.0 kg, and T_4 = control (no mulch). All treatments involving *Tephrosia candida* resulted in significant increment fruit yield and quality. However, application of *Tephrosia candida* @ 3kg m^{-2} and 2 kg m^{-2} was found to be the best. It was found that average mean data over the winter and rainy season crops for fruit yield, titratable acidity and ascorbic acid was highest in the *Tephrosia* mulching @ 3kg m^{-2}. Number of fruits per tree in both winter and rainy season crop, leaf carbohydrate content and fruit length were found to best in *Tephrosia* @ 3kg m^{-2} and 2 kg m^{-2}. All the treatment of *Tephrosia* were equally effective in improving fruit diameter, pericarp thickness, fruit volume and reducing the total phenol content in leaves and fruits. Thus, *Tephrosia* biomass mulching shows as a long-term solution for improving soil fertility and carbon sequestration.**

Key words: Leguminous, productivity, meadow orchard, fruit crops, *Tephrosia candida.*

INTRODUCTION

The word “mulch” comes from the German word “molsch,” which means “soft to decay.” It is referred to gardeners spreading straw and leaves over the ground, to protect the soil from adverse weather conditions and to safeguard the plant roots. In areas with minimal rainfall, mulching is primarily used to reduce erosion and conserve water. Mulching enhances soil ventilation around plants, increases soil productivity, combines soil particles, and facilitates water drainage (Kader *et al*., 14). When organic mulch decomposes, it releases nutrients into the soil and prolongs their availability, modifies soil structure, allows earthworms to travel through the soil, prevents fertilizer leaching by keeping nutrients close to the plant’s roots for optimal uptake, and also prevents weed seeds from germinating by blocking sunlight. Utilizing leguminous species for mulching has been established as an effective way to enhance crop yields. Leguminous plant like *Tephrosia candida* (Roxb.) DC., commonly known as white hoary pea or Himalayan hoary pea, is a perennial shrub native to the Himalayan tropical foothills of India. It is well-adapted to withstand drought conditions and has the unique ability to fix atmospheric nitrogen through synergistic association with Rhizobium. It is known to enhance soil fertility, making it highly valuable for soil improvement and erosion control. Numerous studies have demonstrated the positive effects of *Tephrosia* species on soil organic matter accumulation, nutrient recycling and rehabilitation of degraded land (Das *et al*., 8; Ali *et al*., 3; Ali *et al*., 4). Its adaptability to acidic soil, resistance to consumption by animals, fast-growing nature with high biomass in short period of time and relatively short lifespan (5 to 6 years) makes a sustainable choice for biomass mulching. Therefore it is an effective alternative over subabul and other green manuring species in the eastern platue and hill regions, where there is a scarcity of FYM.

Guavas (*Psidium guajava* L.) are well-known for their nutritional value, sweet, tart flavour, and rich in vitamin C. It is abundant in calcium, phosphorus, and iron. The extracts, traditionally used to treat various diseases, serve as potent antioxidants against hepatic diseases and cancer, boost immunity with their vitamin content, combat conditions such as scurvy and thyroid disorders, and contribute to brain and eye health while aiding in weight management

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(Vijaya *et al.,* 20). It is native to tropical America, and the Portuguese were the first to introduce it to India during the 17th century. India is the world's leading producer of guava, with an area of approximately 0.308 million hectares, a production of 4.58 million tonnes, and an average productivity of 14.88 t ha^{-1} (Ministry of Agriculture & Farmers Welfare, 16). It can grow in a variety of soil conditions, from slightly acidic to alkaline (pH ranges from 5.5 to 7.5) and does quite well in poorly drained soils. The eastern plateau and hill agro climatic provides favourable conditions for the effective production of guava under rain-fed conditions. However, the main challenges are low productivity and poor fruit quality due to the lower organic carbon content. While guava is climate resilient and responds well to manuring and fertilization, like all plants, it is essential to improve the status of soil micronutrients and bio flora for healthy growth and production.

Therefore, substrate dynamics can help the plant achieve quantity and desirable quality, especially in EPHR. The beneficial effects of biomass mulching are mainly attributed to its effects on soil physical, chemical, and biological properties through biomass decomposition. Considering the importance of guava and the beneficial effects of biomass mulching on soil health, this study was undertaken to evaluate the effect of different doses of *Tephrosia candida* (Fig. 1) biomass mulch on the growth, yield, and fruit quality of guava under rainfed conditions of the Eastern Plateau and Hill Region (EPHR). A previous publication from the same long-term experiment demonstrated significant improvements in soil fertility, nutrient status, and tree growth under *Tephrosia* mulching (Ali *et al.,* 3). However, the effects of varying mulch doses on fruit yield and biochemical quality attributes, including titratable acidity, ascorbic acid, and phenolic content, have not yet been reported.

MATERIALS AND METHODS

The study was conducted at ICAR–Research Complex for Eastern Region, Farming System Research Centre for Hill and Plateau Region, Plandu, Ranchi, Jharkhand, India (23°16′50.4″N, 85°24′39.4″E; 620 m above mean sea level). The experimental site is characterized by lateritic sandy loam soil, mean temperature ranging from 19.3 to 30.5°C and average annual rainfall of 1155 mm. The experiment was laid out in a Randomized Block Design with four treatments and five replications (10 fruits per replication) in a 12-year-old rainfed guava orchard cv. Allahabad Safeda planted at a spacing of 1.0 × 2.0 m (5000 plants ha^{-1}). Treatments consisted of dry biomass mulch of *Tephrosia candida* applied at 3.0 kg m^{-2} (T_1), 2.0 kg m^{-2} (T_2) and 1.0 kg m^{-2} (T_3) of basin area along with an unmulched control (T_4). Fresh biomass of 2.5 kg was equivalent to 1.0 kg oven-dried biomass (Fig. 2). The mulch material was collected from the upper 30% portion of *Tephrosia* plants during October and applied uniformly in August each year for three consecutive years (2019–2021) following pruning of all trees to 50% of shoot length (Fig. 1 & 2). Data are presented as pooled means of observations recorded during winter 2021 and rainy 2022. The experiment was maintained under rainfed conditions without application of chemical fertilizers or organic manures, and pooled mean data of three years were used for treatment evaluation.

Fruits were harvested at the colour-break stage during December for physical and biochemical analyses (Fig. 3). Fruit yield (t ha^{-1}) was recorded from the winter crop, whereas the number of fruits per tree was calculated as the average of winter and rainy season crops. Fruit diameter and length were measured using a digital vernier caliper, pericarp thickness was calculated as the difference between fruit diameter and seed core thickness, and fruit volume was determined by the water displacement method using

Fig. 1. *Tephrosia candida* (Roxb.) DC. used as a biomass-producing mulch crop in guava orchards: (a) standing crop of *Tephrosia candida* before harvesting; (b) harvested biomass of *Tephrosia candida* collected for mulching.

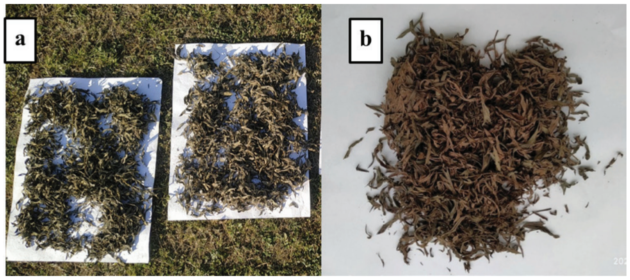

Fig. 2. Visual changes in *Tephrosia candida* litter during decomposition under field conditions: (a) litter after 1 month of decomposition showing partial breakdown of biomass; (b) litter after 6 months of decomposition showing advanced decomposition and fragmentation of litter material.

a Eureka can. Titratable acidity (%) was estimated by NaOH titration and ascorbic acid content (mg 100 g^{-1}) by the 2,6-dichlorophenol indophenol visual titration method (AOAC, 5). Leaf carbohydrate content (%) was estimated from the fifth and sixth leaves of six-month-old shoots using the anthrone method (Hedge and Hofreiter, 11). Total phenol content in leaf and fruit samples was determined by the Folin–Ciocalteu method (Sato *et al.*, 17; Ahamad *et al.,* 2) and expressed as mg gallic acid equivalent (GAE) 100 g^{-1}. Data were subjected to analysis of variance and treatment means were compared using Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$ using OPSTAT software (CCS Haryana Agricultural University, Hisar, India).

RESULTS AND DISCUSSION

The guava cultivar Allahabad Safeda treated with varying concentrations of *Tephrosia* mulch showed significant variation in fruit yield (t ha^{-1}) and number of fruits per tree in both winter and rainy season crops (Table 1). Maximum fruit yield was recorded under *Tephrosia* @ 3.0 kg m^{-2}, with a 42% increment over the control, while *Tephrosia* @ 3.0 kg m^{-2} and 2.0 kg m^{-2} were at par with each other. Treatments at 1.0 kg m^{-2} and 2.0 kg m^{-2} did not differ significantly in either yield or fruit number. The average number of fruits increased from 36.34 in the winter season to 100.80 in the rainy season (a 177% rise) under *Tephrosia* @ 3.0 kg m^{-2}.

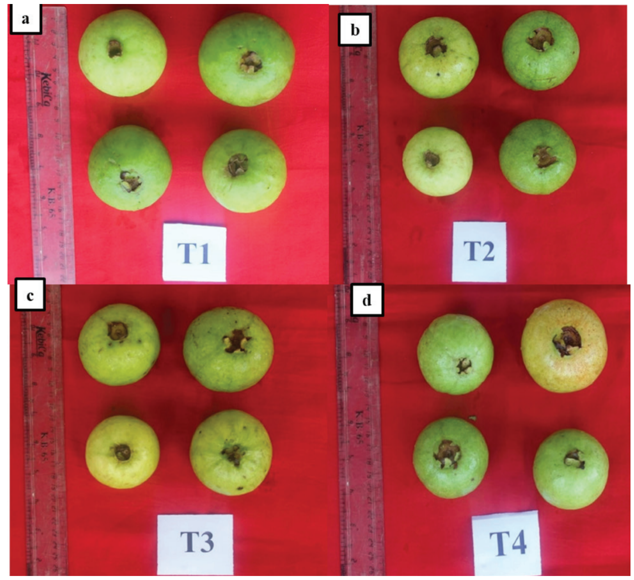

Fig. 3. Representative guava fruits harvested under different *Tephrosia candida* biomass mulch treatments after three years of experimentation: (a) T_1 (3.0 kg dry biomass m^{-2}), (b) T_2 (2.0 kg dry biomass m^{-2}), (c) T_3 (1.0 kg dry biomass m^{-2}), and (d) T_4 (unmulched control).

Similar yield improvements with biomass mulching have been reported in guava by Bhattacharjee *et al.* (6), and in other fruit crops such as bael (Das *et al.* 8). According to Adhikari and Kandel (1), guava in the eastern plateau and hill region bears two crops, a major rainy-season flush and a minor winter crop, and the 177% increase observed here is consistent with this pattern, likely driven by heavy rainfall followed by a prolonged dry winter that intensifies the rainy-season crop load relative to winter. The cumulative effect of three years of mulching, combined with improved soil nutrients and moisture (Das *et al.*, 8; Ali *et al.*, 3) together support the present yield response.

Total leaf carbohydrate and phenol content also varied significantly across treatments over the years (Table 2). Maximum carbohydrate accumulation (12.16%) occurred under *Tephrosia* @ 3.0 kg m^{-2}, at par with 2.0 kg m^{-2}, representing a 20.75%

Table 1: Effect of mulching with Tephrosia biomass on fruit yield and number of fruits per tree yield.

Treatment	Yield per ha (t/ha) (average, winter and rainy crop 2021-2022)	Number of fruits per tree (winter crop 2021)	Number of fruits per tree (rainy crop 2022)
T_1 (3.0 kg dry biomass/m^2)	20.22 ± 0.63^{a}	36.34 ± 0.84^{a}	100.80 ± 6.50^{a}
T_2 (2.0 kg dry biomass/m^2)	15.05 ± 1.02^{b}	28.96 ± 2.45^{ab}	74.80 ± 5.79^{ab}
T_3 (1.0 kg dry biomass/m^2)	14.23 ± 1.43^{bc}	21.10 ± 3.14^{bc}	51.00 ± 10.08^{bc}
T_4(No mulching)	10.92 ± 1.25^{c}	28.73 ± 3.11^{c}	36.20 ± 7.31^{c}

Notes: Means followed by the same letter do not differ significantly at P=0.05 by DMRT.

Table 2: Effect of mulching with *Tephrosia* biomass on leaf parameters.

Treatment	Total phenol (mg GAE/100g)	Carbohydrate (%)
T_1 (3.0 kg dry biomass/m^2)	3,988.25±176.99^b	12.16±0.28^a
T_2 (2.0 kg dry biomass/m^2)	4,363.50±190.78^{ab}	11.22±0.44^{ab}
T_3 (1.0 kg dry biomass/m^2)	3,974.37±164.32^b	10.90±0.43^b
T_4 (No mulching)	4657.10±198.06^a	10.07±0.95^c

Notes: Means followed by the same letter do not differ significantly at P=0.05 by DMRT.

improvement over the control this is likely due to reduced evaporation and oxidation of stored carbohydrates beneath the mulch and the dark mulch surface lowering heat and light reflection from the soil, alongside the enhanced soil fertility and leaf nutrient status associated with *Tephrosia* mulching (Das *et al.*, 8; Ali *et al.*, 3). Total leaf phenol was lowest at 1.0 kg m^{-2} (3,974.37 mg GAE 100 g^{-1}), at par with 3.0 and 2.0 kg m^{-2}, reflecting a 14.56% reduction relative to the control and agreeing with Keawdoung and Boonprakob (15). This decline may result from the favourable soil microclimate created by mulching, which reduces water stress, consistent with the negative correlation reported between leaf phenol and N, K, Fe, Mn and Zn content (Hong *et al.*, 12).

Fruit diameter, length, pericarp thickness and fruit volume also varied significantly across treatments (Table 3), with all *Tephrosia* treatments performing equally well in diameter, volume and pericarp thickness. Maximum fruit diameter (61.48 mm), volume (127.60 ml) and pericarp thickness (1.73 mm) were recorded at 3.0 kg m^{-2}, while maximum fruit length (58.82 mm) at 3.0 kg m^{-2} was at par with 2.0 kg m^{-2}. These improvements amounted to increases of 22.8% in fruit volume, 5.83% in diameter, 7.57% in length and 44.58% in pericarp thickness over the control. Comparable physical improvements have been reported in guava under paddy straw mulch (15.96% and 23.04% increases in fruit length and diameter) (Das *et al.*, 8). The high nutrient content of *Tephrosia* leaf litter 2.94% N, 0.16% P and 1.06% K (Das *et al.*, 9; Ali *et al.,* 3) together with mulching's role in stabilizing soil microclimate and hydrothermal regimes and enhancing root hair and absorptive surface area, likely underlies the improved fruit physical properties observed here.

Titratable acidity, ascorbic acid and total phenol content of the fruit showed significant variation over the years (Table 3). Maximum titratable acidity (0.43%) and ascorbic acid (196.88 mg/100 g) occurred under *Tephrosia* @ 3.0 kg m^{-2}, a 72.00% and 22.05% increase over the control respectively, while 2.0 and 1.0 kg m^{-2} were at par with each other and significantly different from the control. The elevated acidity may stem from the combined effect of planting density and mulching, since a shade effect can leave insufficient sunlight to convert sugars from organic acids (Haque and Sakimin, 10). The ascorbic acid increase aligns with reports in guava (Das *et al.*, 9; Shukla *et al.*, 18), and with the positive correlation Shukla *et al.* (18) found between soil nutrient availability and fruit ascorbic acid content. Total phenol was highest in the control (174.40 mg GAE 100 g^{-1}), with all *Tephrosia* treatments at par with each other, a 47.79% reduction comparable to levels reported by Corrêa *et al.* (7) and, more recently, under mulching in guava cv. VNR Bihi by Jat *et al.* (13). This inverse relationship between mulching

Table 3: Effect of mulching with *Tephrosia* biomass on guava fruit physical and biochemical parameters.

Treatment	Fruit diameter (mm)	Fruit length (mm)	Thickness of the pericarp (mm)	Fruit volume (ml)	Titratable acidity (%)	Ascorbic acid (mg/100g)	Total phenols (mg GAE/100g)
T_1 (3.0 kg dry biomass/m^2)	61.48±0.96^a	58.82±1.11^a	1.73±0.15^a	127.60±3.97^a	0.43±0.02^a	196.88±7.34^a	118.00±8.60^b
T_2 (2.0 kg dry biomass/m^2)	61.38±0.92^a	58.04±0.92^{ab}	1.62±0.08^a	122.80±5.81^{ab}	0.31±0.02^b	182.50±5.64^b	114.86±4.85^b
T_3 (1.0 kg dry biomass/m^2)	60.81±0.88^a	56.73±0.63^b	1.51±0.04^a	118.00±2.82^{ab}	0.33±0.00^b	178.01±4.20^b	134.60±15.06^b
T_4(No mulching)	58.09±0.92^b	54.68±0.79^c	1.20±0.03^b	100.00±1.41^c	0.25±0.01^c	161.31±3.81^c	174.40±20.06^a

Note: Means followed by the same letter do not differ significantly at P=0.05 by DMRT.

and fruit phenol content likely reflects reduced heat stress, since unmulched plants accumulate phenolics as a stress response that blocks oxidation (Singh and kaur, 19). This is consistent with the improved soil nitrogen, phosphorus, and potassium availability previously recorded at this experimental site under the same *Tephrosia* mulching doses (Ali *et al.*, 3), which would support greater nutrient uptake and biosynthesis of organic acids and vitamin C in the fruit. The observed improvements in yield and fruit quality under *Tephrosia* mulching were associated with enhanced soil fertility and nutrient availability reported from the same long-term experiment (Ali *et al.,* 3). *Tephrosia candida* biomass mulching significantly improved guava productivity and fruit quality under rainfed conditions. Among the tested mulch doses, 3.0 kg m^{-2} proved most effective, resulting in the highest fruit yield, enhanced fruit quality attributes, and improved leaf carbohydrate status. Mulch applications of 2.0 and 1.0 kg m^{-2} also produced substantial improvements and were comparable for several growth and quality parameters. Beyond enhancing crop performance, *Tephrosia* biomass mulching contributes to soil moisture conservation, maintenance of soil organic matter, and improved nutrient cycling. These findings demonstrate that *Tephrosia* biomass mulch is a sustainable and practical management strategy for improving guava production in low-fertility, high-leaching rainfed ecosystems while supporting long-term soil health and environmental sustainability.

AUTHOR'S CONTRIBUTION

Conducted the study (AA); Coordinator of the project and conceptualized the study (BD); Execution of research and supervision (BD, SKN, VBP, GPM); Laboratory facilities and analyzed the data (BD, MKD, SKN); Preparation of manuscript (BD, MKD).

DECLARATION OF COMPETING INTEREST

The author(s) declared no potential conflict of interest with respect to research, authorship and/ or publication of this article.

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