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Effect of levels of mulberry shoots biochar, farm yard manure and NPK fertilizer on nutrient uptake by mulberry leaf

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Abstract
A field experiment was conducted during 2022, at Krishi Vigyan Kendra, Hassan, to know the effect of biochar, Farm Yard Manure (FYM)and NPK fertilizer on nutrient uptake by mulberry leaf. The experiment was planned in Randomized Complete Block Design (RCBD) with 10 treatments T_1: Absolute Control (without biochar and FYM), T_2: 100 per cent NPK, T_3: FYM @ 20 t $ha^{-1}y^{-1}$, T_4: 100 per cent NPK + FYM@ 20 t ha^{-1} (Package of practice), T_5: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$, T_6: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$, T_7: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$ and T_8: 75 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$, T_9: 75 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$, T_{10}: 75 per cent NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t $ha^{-1}y^{-1}$ replicated trice. The result revealed that significantly increased the higher uptake of nitrogen (61.29 kg ha^{-1}), phosphorus (6.89 kg ha^{-1}), potassium (32.03 kg ha^{-1}), calcium (18.84 kg ha^{-1}), magnesium (6.40 kg ha^{-1}), sulphur (7.75 kg ha^{-1}), total uptake of micronutrients *viz*., Zn (52.18 g ha^{-1}), Mn (90 g ha^{-1}) and Cu (13.25 g ha^{-1}) by mulberry leaf was observed in treatment T_7 which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$. over treatment T_4 (100% NPK + FYM 20 t ha^{-1}) Package of practise.

Keywords: Mulberry shoots biochar, nutrient uptake, nitrogen, micronutrients

1. Introduction
Mulberry is one of the most important commercial crop grown extensively as a food plant for silkworm. It is a perennial and high biomass producing plant. The mulberry leaf quality plays a vital role in healthy growth of silkworm and the economic traits such as larval, cocoon and grainage parameters which are influenced largely by the nutritional status of the leaves fed to silkworm (Krishnaswami *et al*., 1971) [9]. When foliage has been used as food for silkworm, shoots is left wasted. These shoots often take a long time to decompose in soil. Keeping in this view mulberry shoots can be used as a feedstock for biochar production.
Biochar is a carbon-rich substance, produced by thermal decomposition of organic compounds at a relatively higher temperature (<700 °C) under limited supply of oxygen called pyrolysis. It contains more than 60 per cent carbon and is rich in various nutrients essential for crop growth. Retuning biochar to the field can quickly improve soil carbon storage and improve crop yields. Biochar has a great, stable, and a long term potential in carbon sequestration.
In recent years, biochar has emerged as an organic amendment with mineral nutrient elements and hold a promise to improve the soil quality and yield of crops. The biochar is found to have a positive impact on soil fertility, resulting in an increase in crop yield without causing a hazard to soil and water environment.
Biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar makes it to adsorb or retain nutrients and hold moisture and in addition to this labile fraction of C in biochar provides C and energy to heterotrophic beneficial microorganisms to flourish and the ash fraction may supply some of the mineral nutrient requirements for crops (Glaser *et al*. 2002, and Warnock *et al*.

2007) [6, 16].

Addition of biochar to soils has attracted widespread attention as a method to sequester carbon in the soil. Increased soil carbon sequestration can improve soil quality because of the vital role that carbon plays in chemical, biological and physical soil processes and many interfacial interactions. Biochar application to soil may thus improve the physical properties of soil because of retardation of native stable organic matter decomposition. It persists for a longer time in soil. Therefore, the studies on effects of biochar application on soil properties especially in mulberry garden and its potentiality as a nutrient source are very scanty and it deserves detailed investigation

2. Materials and Methods

A field experiment was conducted during 2022, at the Krishi Vigyan Kendra, Kandali, Hassan. The experimental site is geographically located in Southern Transition Zone (Zone-7) of Karnataka and lies between12º 58ˈ57ˈˈ North latitude, 76º 2ˈ32ˈˈ East longitude at an altitude of 940 m above the mean sea level and it receives an average rainfall of 839 mm annually.

The soil of experimental plot was sandy loam in texture and prior to the laying out of the experiment, the soil samples were collected randomly drawn from 0 to 30 cm depth. The samples were mixed thoroughly and made into one composite sample. The composite sample of around 500 g was taken, air dried and grounded it and then passed through a 2 mm sieve and analysed for physical and chemical properties as per the standard procedures.

2.1 Experiment details

Crop	Tree mulberry
Variety	Victory-1
Spacing	10 x 10 feet
Design	RCBD
No. of treatment	10
No. of replications	3
RDF	350:140:140 kg NPK ha^{-1}y^{-1}

RDF: Recommended dose of fertilizer

2.2 Treatment details

Treatments	Description
T_1	Absolute Control
T_2	100% NPK
T_3	FYM @ 20 t ha^{-1}y^{-1}
T_4	100% NPK + FYM@ 20 t ha^{-1} (Package of practice)
T_5	100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}
T_6	100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}
T_7	100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}
T_8	75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}
T_9	75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}
T_{10}	75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t ha^{-1}y^{-1}

Note:

1. FYM and mulberry shoots biochar were applied as basal application on the day of pruning.
2. Split quantity of NPK fertilizers was applied 15 days after pruning.
3. All other practices of mulberry cultivation were followed as per standard package of practices (Dandin and Giridhar 2014) [4].

2.3 Observations recorded

Uptake of Nutrients (kg ha^{-1}) by mulberry leaves

The uptake of macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Mn, Zn and Cu) by mulberry leaf was calculated after the analysis of nutrients concentrations in mulberry leaf. For the calculation of the uptake the concentration of each nutrient in leaf was multiplied with their respective dry biomass. The formula below are used to measure the nutrient uptake for macro and micro nutrients.

$$\text{Macronutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)} \times \text{Dry Biomass (kg ha}^{-1})}{100}$$

$$\text{Micronutrient uptake (g ha}^{-1}) = \frac{\text{Nutrient concentration (mg kg)} \times \text{Dry Biomass (kg ha}^{-1})}{1000}$$

3. Results and Discussion

Effect of levels of mulberry shoots biochar, Farm Yard manure and NPK fertilizer on nutrient uptake by mulberry leaf

3.1 Nitrogen uptake (kg ha^{-1}) by mulberry leaf

The perusal of the data in Table 1 showed that the uptake of nitrogen by mulberry leaf was varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of nitrogen (61.29 kg ha^{-1}) was observed followed by T_5 (56.29 kg ha^{-1}) which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (50.81 kg ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of nitrogen was recorded in absolute control (30.06 kg ha^{-1})

The uptake of primary nutrients (NPK) increased with the increased levels of mulberry shoots biochar. This might be due to the higher release of nutrients in the soil by the effect of biochar and it also avoided the loss of fertilizer by runoff and leaching losses by providing good physical environment hence, more nutrient retention in soil subsequently higher uptake of nutrients by plant. As nutrient uptake is a product of concentration and yield, due to increase in yield of mulberry by biochar addition, nutrient uptake also increased. Biochar also enhanced root development which contributed to improved nutrient uptake by crop. The higher uptake of nitrogen under high doses of biochar may be attributed to the positive effects of biochar on crop growth, as well as positive effects on uptake of nutrients (P, K, Ca and Mg) by crop plants and P, K, Ca and Mg availability of soil. The rise in acidic soil pH can decrease the activity of Aluminum, thereby improving root growth and in turn expected more nutrient uptake. Chan *et al.* (2007) [3] and Zhao *et al.* (2014) [20] noted a rise in N uptake at higher biochar levels. Angst and Sohi (2013) [1] and Yao *et al.* (2013) [19] reported that primary nutrient bioavailability and plant uptake increased in response to biochar application, especially when combination with agricultural lime and chemical fertilizers. Deluca *et al.* (2015) [5] stated that biochar added with an organic N source to the soil yielded an increase in net nitrification and improved plant availability of nitrogen.

3.2 Phosphorous uptake (kg ha^{-1}) by mulberry leaf

The perusal of the data in Table 1 showed that the uptake of phosphorous by mulberry leaf was varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of phosphorous (6.89 kg ha^{-1}) in leaf was observed followed by T_6 (6.04 kg ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1} when compared to T_4 (5.37 kg ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of phosphorous was recorded in absolute control (3.13 kg ha^{-1}).

The uptake of nutrients is a function of the nutrient content and the production of biomass. Higher biochar application rate improved biomass output and inevitably increased nutrient uptake. The addition of biochar neutralized the soil pH, thereby releasing the fixed Fe-P and Al-P increased the available phosphorus. This is in line with the reports of Varela *et al.* (2013) [15]. Muhammad *et al.* (2017) [12] indicated that the increased availability of P can also be induced healthy root development by reduced Al toxicity which causes root damage. Similarly, with the introduction of biochar, Uzoma *et al.* (2011) [14] and Yamato *et al.* (2006) [19] recorded an improvement of the available plant P in soil. Xu *et al.* (2012) [17] recorded a substantial increase in plant uptake of P, K, Ca, Zn and Cu, bioavailability and chilli plant uptake of primary nutrients, especially in the presence of added fertilizer, in biochar uses.

3.3 Potassium uptake (kg ha^{-1}) by mulberry leaf

The data in Table 1 shows that the uptake of potassium by mulberry leaf was varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of potassium in (32.03 kg ha^{-1}) leaf was reported followed by T_5 (30.79 kg ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (26.45 kg ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of potassium was recorded in T_1 absolute control (15.77 kg ha^{-1}).

Table 1: Effect of mulberry shoots biochar on primary and secondary nutrients uptake of mulberry leaves

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Calcium (kg ha^{-1})	Magnesium (kg ha^{-1})	Sulphur (kg ha^{-1})
T_1: Absolute Control	30.06	3.13	15.77	8.85	2.72	2.28
T_2: 100% NPK	51.94	4.93	27.53	11.47	4.38	3.80
T_3: FYM @ 20 t ha^{-1}y^{-1}	49.62	3.89	25.06	9.76	3.73	3.36
T_4: 100% NPK + FYM@ 20 t ha^{-1} (Package of practice)	50.81	5.37	26.45	16.01	4.39	4.39
T_5: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	56.29	5.51	30.79	18.34	6.07	6.45
T_6: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	55.05	6.04	28.49	17.19	5.77	6.37
T_7: 100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}	61.29	6.89	32.03	18.84	6.40	7.75
T_8: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	47.46	5.01	25.76	15.17	4.54	4.85
T_9: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	39.09	4.31	20.97	12.82	3.92	4.48
T_{10}: 75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t ha^{-1}y^{-1}	38.93	4.60	21.52	12.88	4.09	4.42
F- Test	*	*	*	*	*	*
S.Em ±	5.86	0.61	2.98	1.88	0.60	0.53
CD @ 5%	18.42	1.81	9.42	5.60	1.80	1.59

* - significant at 5%

The increase in K concentration and uptake may be due to biochar ash content which helps to release occluded mineral nutrients such as K for crop use immediately. Most of the uptake of nutrients (N and K) will increase as the biochar influences the increased availability of water. In addition, biochar has the capacity to increase the soil's CEC, thereby increasing soil's ability to hold K and make it available for plant uptake. The availability of K increased as the soil pH increased by applying biochar (Manolikaki and Diamadopoulos, 2017) [11]. Rondon *et al.* (2007) [13] also reported increased K uptake by plants when biochar applied to soil. Lehmann *et al.* (2003) [10] studied experiments with Lysimeter and reported that by adding charcoal to soil, uptake to leaching ratio (uptake: leaching) increased for all nutrients because the nutrients might have retained on the electrostatic adsorption complexes created by charcoal addition to soil.

3.4 Calcium uptake (kg ha^{-1}) by mulberry leaf

The data in Table 1 showed that the uptake of calcium by mulberry leaf varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of calcium in (18.84 kg ha^{-1}) leaf was reported followed by T_5 (18.34 kg ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1} when compared to T_4 (16.01 kg ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of calcium was recorded in T_1 absolute control (8.85 kg ha^{-1}).

3.5 Magnesium uptake (kg ha^{-1}) by mulberry leaf

The data in Table 1 showed that the uptake of magnesium by mulberry leaf varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of magnesium in (6.40 kg ha^{-1}) leaf was reported followed by T_5 (6.07 kg ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (4.39 kg ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of magnesium was recorded in T_1 absolute control (2.72 kg ha^{-1}).

3.6 Sulphur uptake (kg ha^{-1}) by mulberry leaf

The data in Table 1 showed that the uptake of sulphur by mulberry leaf varied significantly due to biochar application. The treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially recorded higher uptake of sulphur (7.75 kg ha^{-1}) in leaf was observed, followed by T_5 (6.45 kg ha^{-1}) which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (4.39 kg ha^{-1}) Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of sulphur was recorded in absolute control (2.28 kg ha^{-1}).

The presence of both anionic exchange sites along with cationic exchange sites (CEC) on the biochar surface, helps in the retention of sulphate ions on biochar surfaces and make it available to plant roots, and also reduces the leaching losses, hence increase the sulphur uptake by mulberry leaf. The biomass increased with biochar addition may be attributed to increase in nutrient uptake of sulphur. The results are in line with that Haque *et al.* (2019) [8].

3.7 Micronutrients (Fe, Mn, Zn, Cu and B) uptake by mulberry leaf

3.7.1 Iron uptake (g ha^{-1}) by mulberry leaf

The data in Table 2 showed that the uptake of iron by mulberry leaf not varied significantly due to biochar application. However numerically in treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, higher uptake of iron (317.58 g ha^{-1}) in leaf was observed, followed by T_5 (317.07 g ha^{-1}) which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (291.79 g ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Lower uptake of iron was recorded in T_1 absolute control (176.42 g ha^{-1}).

Table 2: Effect of mulberry shoots biochar on micronutrients content uptake of mulberry leaves

Treatments	Iron (g ha^{-1})	Zinc (g ha^{-1})	Manganese (g ha^{-1})	Copper (g ha^{-1})
T_1: Absolute Control	176.42	21.18	44.86	6.15
T_2: 100% NPK	183.33	42.26	80.03	11.32
T_3: FYM @ 20 t ha^{-1}y^{-1}	179.16	32.49	74.86	10.11
T_4: 100% NPK + FYM@ 20 t ha^{-1} (Package of practice)	291.79	41.21	74.56	10.55
T_5: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	317.07	51.20	85.73	12.65
T_6: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	294.57	47.23	80.46	11.71
T_7: 100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}	317.58	52.18	90.00	13.25
T_8: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	272.27	39.59	70.59	10.00
T_9: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	232.89	33.84	57.07	8.23
T_{10}: 75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t ha^{-1}y^{-1}	235.48	34.84	59.16	8.82
F- Test	NS	*	*	*
S.Em ±	35.17	4.82	8.67	1.30
CD @ 5%		14.63	25.78	3.86

* - significant at 5%, NS- Non significant

3.7.2 Zinc uptake (g ha^{-1}) by mulberry leaf

The data in Table 2 showed that the uptake of zinc by mulberry leaf varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, recorded substantially higher uptake of zinc in (52.18 g ha^{-1}) leaf, followed by T_5 (51.20 g ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (41.21 g ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of zinc was recorded in T_1 absolute control (21.18 g ha^{-1}).

3.7.3 Manganese uptake (g ha^{-1}) by mulberry leaf

The data in Table 2 showed that the uptake of manganese by mulberry leaf varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of manganese in (90 g ha^{-1}) leaf was reported followed by T_5 (85.73 g ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (74.56 g ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of manganese was recorded in T_1 absolute control (44.86 g ha^{-1}) where no external nutrient and biochar source was applied.

3.7.4 Copper uptake (g ha^{-1}) by mulberry leaf

The data in Table 2 showed that the uptake of copper by mulberry leaf varied significantly due to biochar application. In treatment T_7, which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}, substantially higher uptake of copper in (13.25 g ha^{-1}) leaf was reported followed by T_5 (12.65 g ha^{-1}) which obtained 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1} when compared to T_4 (10.55 g ha^{-1}) which was Package of Practice (100% NPK + FYM@ 20 t ha^{-1}). Significantly lower uptake of copper was recorded in T_1 absolute control (6.15g ha^{-1}).

Higher uptake of these micronutrients was due to higher biomass production which was recorded due to higher doses of biochar application. Application of biochar is accompanied by increase in soil pH and reduced mobility of micronutrients. But in presence of plant, which actively releases organic compounds in rhizosphere may mobilize the micronutrients. Lehmann *et al*. (2003) [10] noticed higher uptake of Zn and Cu by the plants with increased levels of biochar due to reduced leaching losses and increased fertilizer use efficiency. Similar findings were also reported by Carmeis *et al*. (2016) [2] and Gwenzi *et al*. (2016) [7].

4. Conclusion

The present study showed that, the Higher uptake of nitrogen (61.29 kg ha^{-1}), phosphorus (6.89 kg ha^{-1}), potassium (32.03 kg ha^{-1}), calcium (18.84 kg ha^{-1}), magnesium (6.40 kg ha^{-1}), sulphur (7.75 kg ha^{-1}), total uptake of micronutrients *viz*., Zn (52.18 g ha^{-1}), Mn (90 g ha^{-1}) and Cu (13.25 g ha^{-1}) by mulberry leaf was recorded higher in treatment (T_7) received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1} .This increased uptake of N, P and K might be due to higher leaf yield in that treatment (T_7). Application of mulberry shoots biochar at varied levels significantly improved nutrient content and nutrient uptake by mulberry leaf.

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