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Effect of different phytomulches on soil and plant nutrients

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Abstract

The current study, "Effect of Different Phytomulches on Soil and Plant Nutrients," was conducted at the College of Temperate Sericulture, Mirgund (SKUAST-K) in the spring and fall of 2022 and 2023 to assess the impact of seven phytomulches on the biochemical composition of mulberry leaves and the status of soil nutrients. Paddy straw, dried weeds, wood chaff, dried leaves, aquatic weeds, Typha, and sawdust were among the phytomulches; an unmulched control was used for comparison. Typha mulch increased soil fertility and leaf nutritional quality, outperforming all other treatments. Typha mulch significantly improved soil nutrient availability, as evidenced by the greatest levels of soil organic carbon (1.823% in spring and 1.947% in autumn), nitrogen (338.74 and 273.59 kg/ha), phosphorus (22.36 and 18.39 kg/ha), and potassium (187.56 and 150.41 kg/ha). Accordingly, throughout the seasons, mulberry leaves from Typha-mulched plots showed the highest quantities of total chlorophyll (3.913 and 3.213 mg/g fw), protein content (24.45% and 21.94%), carbs (9.189% and 8.307%), and leaf NPK. The use of phytomulches decreased the crude fiber content of mulberry leaves (13.773-15.063%). Overall, results show that Typha is an effective, environmentally friendly phytomulch that, in temperate climates, can significantly improve the primary macronutrient status of the soil, plant nutrient uptake, and the biochemical quality of mulberry leaves, providing a sustainable method of increasing crop productivity.

Keywords: Phytomulches, soil, typha, fibre, eco-friendly

Introduction

The mulberry (*Morus* spp.) leaf is a perennial plant with deep roots that is the only food source for the silkworm *Bombyx mori* L. The grade of silk produced is directly correlated with leaf quality. Additionally, the quality of mulberry leaves alone accounts for roughly 38.2% of the silkworm crop's success (Miyashita, 1986)^[16]. However, the general condition of the soil also affects leaf yield and quality. Mulberry plantations in rainfed temperate locations frequently experience moisture stress, variable nutrient availability, and low soil organic matter. These limitations affect not only the nutrient status of the soil but also key biochemical traits of the leaf such as chlorophyll, protein, carbohydrates and fibre content. Since these parameters influence feeding efficiency, digestion and cocoon formation, improving both soil conditions and leaf composition remains a central requirement in mulberry cultivation.

Mulching with plant-based materials has emerged as a simple and sustainable method to enhance soil fertility and leaf quality. Plant based/phyto-mulches help to conserve moisture, moderate soil temperature, reduce weed competition and gradually enrich the soil as they decompose. These changes can influence important soil parameters such as organic carbon, available nitrogen, phosphorus and potassium (Singh and Chamroy, 2025)^[25], which in turn shape the physiological and nutritional profile of mulberry leaves. Improved nutrient availability often leads to higher chlorophyll formation, better protein synthesis, increased carbohydrate accumulation and favourable changes in crude fibre levels. Likewise, leaf nitrogen, phosphorus and potassium concentration reflects how effectively the plant absorbs nutrients from the soil. Although a variety of mulches, including paddy straw, dried weeds, leaf litter, sawdust, and aquatic weeds, are frequently used in field crops and orchards (Ganie *et al.*, 2025)^[13], little is known about how particular phytomulches impact the entire range of soil and leaf parameters in mulberries grown in temperate climates.

It is crucial to comprehend this relationship because silkworm growth and cocoon productivity can be greatly impacted by even little changes in soil nutrients or leaf biochemistry.

In this context, the present study evaluates the effect of seven phytomulches viz., paddy straw, dried weeds, wood chaff, dried leaves, aquatic weeds, Typha and sawdust on a comprehensive set of soil and leaf parameters. The study assesses soil organic carbon, available nitrogen, phosphorus and potassium, along with key mulberry leaf attributes including total chlorophyll, total protein, total carbohydrates, crude fibre and leaf NPK concentrations during spring and autumn seasons. The objective is to identify the phytomulch that most effectively enhances soil fertility and improves the biochemical and nutrient profile of mulberry leaves, thereby supporting better silkworm performance and sustainable sericulture.

Material and Methods

The study was carried out in the fall of 2022 and 2023 at the College of Temperate Sericulture Mirgund, SKUAST-Kashmir, as described below:

- Mulberry genotype: Gosheorami
- Type of plantation: Dwarf
- Rainfed/irrigated: Rainfed
- Number of phytomulches: 07
- Number of treatments: 08
- Paddy grass
- Dried weeds
- Wood chaff

Dried senesced leaves of plants other than mulberry

Aquatic weeds growing in water bodies (floating and submerged)

- Typha
- Saw dust
- Without mulch (control)
- Number of replications per treatment: 03
- No. of plants per treatment per replication: 06
- Design of experiment: Randomized Complete Block Design (RCBD)

The study was carried out on a well-established dwarf plantation of Goshorami, a prominent mulberry type used in the area for late-age silkworm rearing, that was kept under rainfed circumstances with consistent growth and vigor. In order to completely cover the soil in the plots in 2022 and 2023, seven phytomulches were spread or applied in 2-inch-thick layers: paddy grass, dried weeds, wood chaff, dried senesced leaves of plants other than mulberries, aquatic weeds growing in water bodies (floating & submerged), typha, and sawdust.

The various parameters recorded included:

- **N P K (kg/ha):** The method outlined by Bremner (1965) [7] was used to assess the amount of accessible nitrogen. While the available potassium was measured using a flame photometer (Jackson, 1973) [14], the available phosphorus was approximated using the method of Olsen *et al.* (1954) [18].
- **Soil Organic Carbon (%):** Walkley and Black's (1934) [27] quick titration method was used to quantify the soil organic carbon content.

- **Total Chlorophyll (mg/g fw):** Sadasivam and Manickam's (1992) [23] technique was used to calculate the total chlorophyll content.
- **Total Protein (%):** According to Ranganna (1997) [21], the Kjeldhal technique was used to calculate the total protein content.
- **Total Carbohydrate (%):** According to Dubois *et al.* (1956) [10], the Phenol-Sulphuric acid method was used to calculate the total carbs.
- **NPK (%) of leaves:** Jackson (1973) [14] outlined Microkjaldal's method for determining nitrogen (Plate-2). The Vandomolybdate phosphoric acid yellow color method was used to measure phosphorus (Jackson, 1973) [14]. According to Jackson's (1973) [14] protocol, potassium was measured using a flame photometer (Plate-3).
- **Crude fiber (%):** The ceramic fiber filter method was used to estimate crude fiber.

Results

The observations recorded on various parameters are described hereunder in brief:

Soil Nitrogen (Kg/ha)

Although T₆ (Typha) had the highest soil nitrogen content in the spring and autumn (338.74 kg/ha and 273.59 kg/ha, respectively), it was statistically comparable to T₁ (Paddy Straw), which had soil nitrogen content of 337.64 kg/ha and 272.21 kg/ha, respectively. In the spring and fall seasons, Control had the lowest soil nitrogen level of 320.71 and 259.47 kilos per hectare, respectively. The results are presented in Table 1 and illustrated in Figure 1.

Soil Phosphorus (Kg/ha)

In T₆ (Typha), soil phosphorus reached a high of 22.36 kg/ha and 18.39 kg/ha in the spring and fall, respectively. This was statistically comparable to 22.14 kg/ha and 17.72 kg/ha in T₁ (Paddy Straw). In both seasons, Control had the lowest soil phosphorus level (17.87 kg/ha and 14.02 kg/ha, respectively). The findings are presented in Table 1 and illustrated in Figure 2.

Soil Potassium (Kg/ha)

According to the study, applying phytomulches raises the potassium level of the soil. In comparison to the other treatments, T₆ (Typha) had the greatest (187.56 kg/ha in the spring and 150.41 kg/ha in the autumn). In T₁ (Paddy Straw), it was followed by 185.09 and 148.56 kg per hectare in the spring and fall, respectively. T₈ (Control) had the lowest potassium concentration, measuring 174.56 kg/ha in the spring and 138.03 kg/ha in the fall. The outcomes are shown in Figure 3 and provided in Table 1.

Soil Organic Carbon (%)

Soil organic carbon was highest (1.823%) in T₆ (Typha) during the spring season. It was statistically comparable to 1.700% in T₁ (Paddy Straw) and much higher than the other treatments, which varied from 1.187% in Control to 1.550% in T₂ (Dried Weeds). A similar pattern was seen in the fall, with T₆ (Typha) having the highest organic carbon content (1.947%), which was substantially greater than the other treatments but statistically comparable to 1.880% in T₁

(Paddy Straw) and 1.800% in T₂ (Dried Weeds). T₈ (Control) has the lowest amount of organic carbon (1.200%). The outcomes are shown in Figure 4 and provided in Table 1.

Total Chlorophyll (mg/g fw)

T₆ (Typha) had the highest total chlorophyll content (3.913 mg/g), which was statistically comparable to 3.860 mg/g in T₁ (Paddy Straw) and statistically significant over the other treatments. T₈ (Control) had the lowest total chlorophyll content (3.452 mg/g) during the spring. T₆ (Typha) once more recorded the greatest total chlorophyll content of 3.213 mg/g during the fall season, which was considerably greater than the other treatments. 3.147 mg/g in T₁ (Paddy Straw) came next. At 2.747 mg/g, T₈ (Control) once again had the lowest total chlorophyll concentration. The findings are presented in Table 2 and illustrated in Figure 5.

Total Protein (%)

In spring, T₆ (Typha) had the greatest total protein content in leaves (24.45%), which was much greater than the other treatments. T₁ (Paddy Straw), which had a total protein content of 24.14%, came next. The Control had the lowest protein level, at 22.21 percent. In the fall, T₆ (Typha) once more had the greatest total protein content of 21.94 percent, which was significantly greater than the other treatments and statistically comparable to T₂ (Paddy Straw) at 21.71 percent. At 19.44%, T₈ (Control) had the lowest overall protein level once more. The results are shown in Figure 6 and provided in Table 2.

Total Carbohydrate (%)

During spring, the highest total carbohydrate content (9.189%) was recorded in T₆ (Typha) being, however, statistically at par with 9.109 per cent in T₁(Paddy Straw) and significantly higher than rest of the treatments. The lowest carbohydrate content (8.413%) was found in Control. Total carbohydrate content in leaf during the autumn season followed a similar trend, with T₁ (Typha) registering the highest total carbohydrate content (8.307%) being, statistically at par with 8.190 per cent in T₁(Paddy Straw). T₈(Control) again had the lowest total carbohydrate content of 7.197 per cent. The results are furnished in Table-2 and depicted in fig. 7.

Crude Fibre (%)

In T₈ (Control), the crude fiber content of the leaf was 11.60 and 11.86 percent in the spring and fall, respectively, and was considerably decreased by the application of phytomulches. In T₆ (Typha), it was the lowest (9.27 and 9.53 percent, respectively, in spring and autumn). In the remaining treatments, it varied from 11.33 and 11.62 in T₅ (Aquatic Weeds) to 9.51 and 9.74 percent in spring and autumn in T₁ (Paddy Straw). The outcomes are shown in Figure 8 and provided in Table 3.

Nitrogen (%)

In comparison to the other treatments, T₆ (Typha) had the highest nitrogen concentration (3.912%) during the spring. T₈ (Control) had the lowest nitrogen concentration (3.553%). In the fall, T₆ (Typha) had the highest nitrogen content (3.511%), which was substantially greater than the other treatments and statistically comparable to 3.474% in T₁ (Paddy Straw). T₈ (Control) also had the lowest nitrogen concentration (3.111%). The outcomes are shown in Figure 9 and provided in Table 3.

Phosphorus (%)

In the spring, T₆ (Typha) had the greatest phosphorus concentration (0.292%), which was statistically comparable to 0.285% in T₁ (Paddy Straw). At 0.218 percent, T₈ (Control) had the lowest phosphorus concentration. In the fall, T₆ (Typha) once more recorded the highest phosphorus concentration of 0.218 percent, which was quite comparable to T₁ (Paddy Straw)'s 0.205 percent. Again, T₈ (Control) had the lowest phosphorus concentration (0.150%). The results are shown in Figure 10 and provided in Table 3.

Potassium (%)

In the spring, T₆ (Typha) had the highest potassium concentration (1.896%), which was statistically comparable to 1.856% in T₁ (Paddy Straw) and 1.785% in T₂ (Dried Weeds). The other treatments had values of 1.729 (sawdust), 1.663 (dried leaves), 1.652 (wood chaff), 1.593 (aquatic weeds), and 1.555 percent (control). In the fall, T₆ (Typha) once again had the greatest potassium content (1.515%), which was statistically comparable to Paddy Straw (1.440%) and Dried Weeds (1.424%) and much higher than the other treatments, which varied from 1.031 in T₈ (Control) to 1.290%. Table 3 provides the results, which are shown in Figure 11.

Table 1: Organic carbon, nitrogen, phosphorus and potassium content of soil as influenced by different phytomulches

Treatments	Organic Carbon (%)		Soil Nitrogen (Kg/ha)		Soil Phosphorus (Kg/ha)		Soil Potassium (Kg/ha)	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Paddy Straw	1.700 ^{ab}	1.880 ^a	337.64 ^a	272.21 ^a	22.14 ^{ab}	17.72 ^b	185.09 ^b	148.56 ^b
Dried Weeds	1.550 ^{bc}	1.800 ^{ab}	335.93 ^b	270.39 ^b	21.42 ^c	16.75 ^c	183.60 ^c	146.78 ^c
Wood Chaff	1.387 ^{cd}	1.517 ^d	325.87 ^e	264.18 ^d	19.13 ^{ef}	15.10 ^e	178.78 ^e	141.32 ^e
Dried Leaves	1.383 ^d	1.597 ^{cd}	328.76 ^d	265.17 ^d	19.54 ^e	15.63 ^d	181.43 ^d	143.00 ^d
Aquatic Weeds	1.290 ^{de}	1.460 ^{de}	323.66 ^f	261.56 ^e	18.40 ^g	14.41 ^f	176.96 ^f	139.64 ^f
Typha	1.823 ^a	1.947 ^a	338.74 ^a	273.59 ^a	22.36 ^a	18.39 ^a	187.56 ^a	150.41 ^a
Saw Dust	1.460 ^b	1.677 ^{bc}	332.82 ^c	267.05 ^c	20.55 ^d	16.56 ^c	182.68 ^c	145.55 ^c
Control	1.187 ^e	1.200 ^e	320.71 ^g	259.47 ^f	17.87 ^h	14.02 ^g	174.56 ^g	138.03 ^g
C.D.(p<0.05)	0.166	0.149	1.27	1.68	0.49	0.35	1.17	1.52

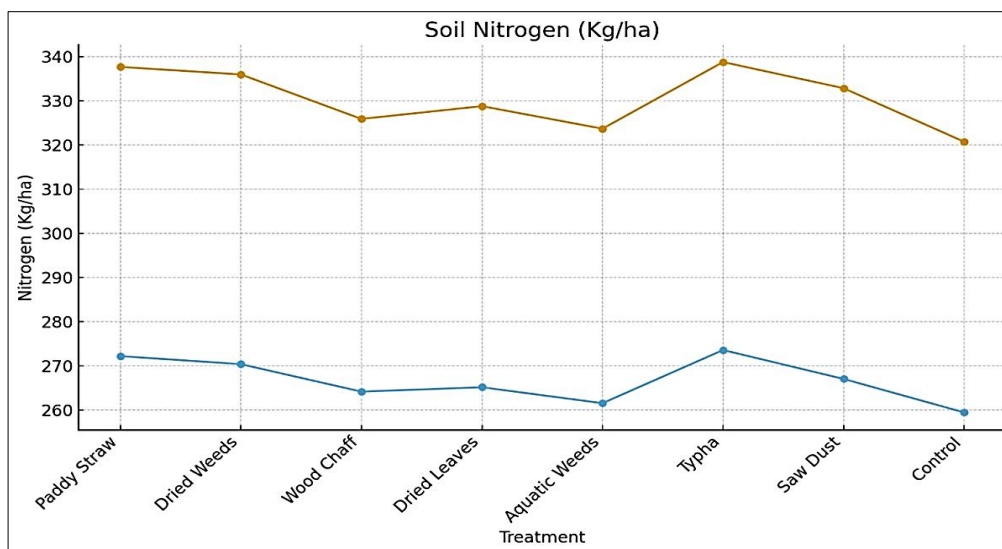


Fig 1: Shows how various phytomulches affect the amount of nitrogen in the soil.

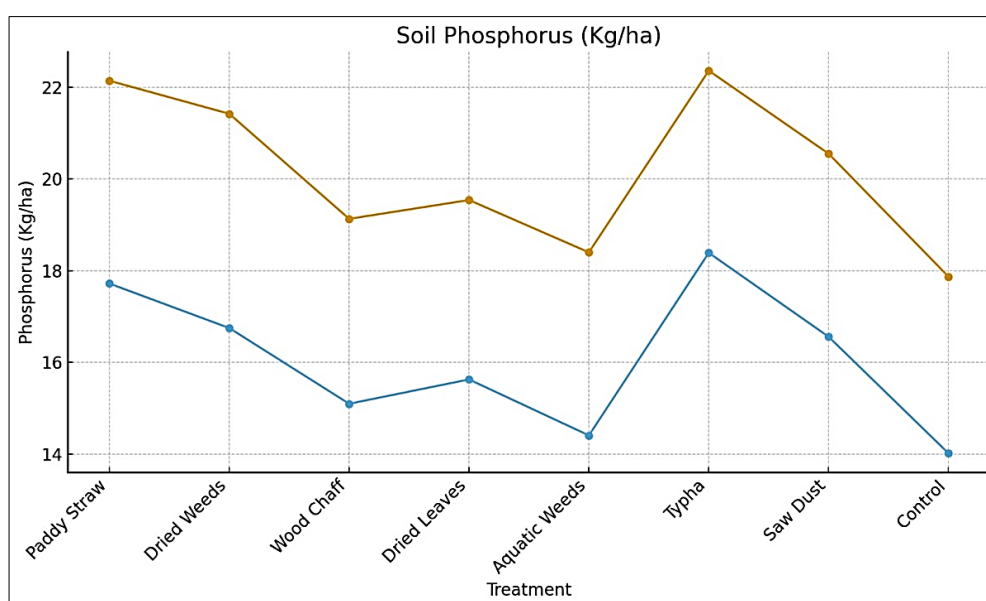


Fig 2: Effect of different phytomulches on soil phosphorus content.

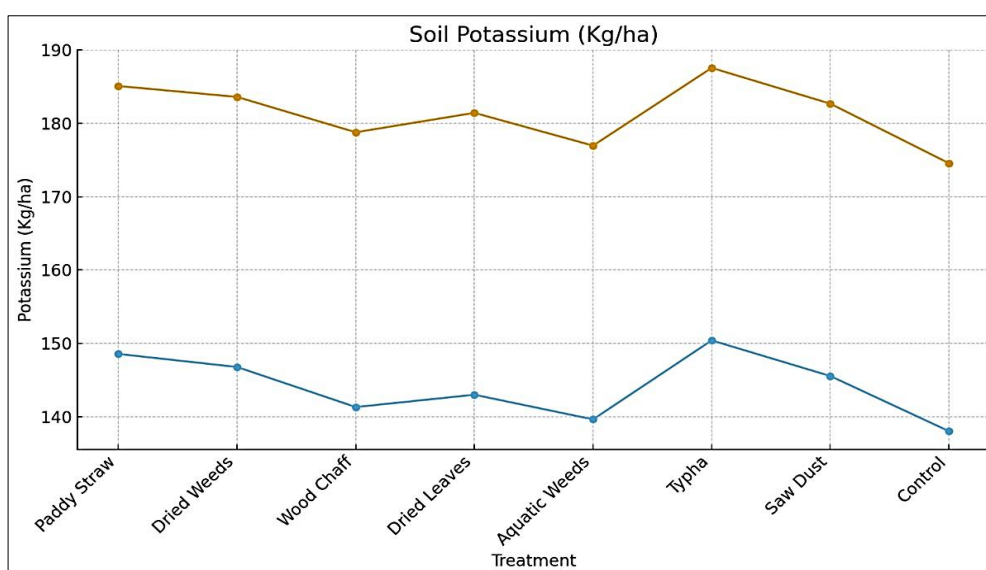


Fig 3: Effect of different phytomulches on soil potassium content.

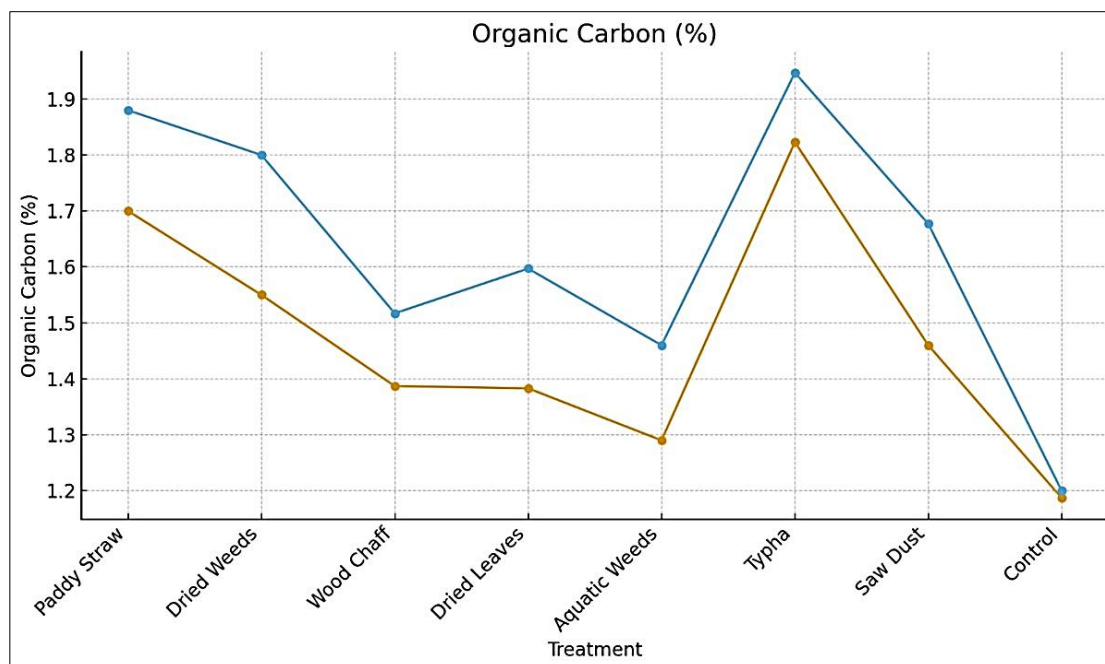


Fig 4: Effect of different phytomulches on soil organic carbon (%).

Table 2: Total chlorophyll, total protein and total carbohydrate content in mulberry leaf (*Morus spp.*) as influenced by different phytomulches

Treatments	Total chlorophyll (mg/g fw)		Total protein (%)		Total carbohydrate (%)	
	Spring	Autumn	Spring	Autumn	Spring	Autumn
Paddy Straw	3.863 ^{ab}	3.147 ^b	24.14 ^b	21.71 ^a	9.109 ^a	8.190 ^a
Dried Weeds	3.817 ^b	3.077 ^c	23.81 ^c	21.16 ^b	9.030 ^b	8.080 ^b
Wood Chaff	3.647 ^d	2.867 ^{ef}	23.24 ^e	20.60 ^c	8.711 ^d	7.583 ^d
Dried Leaves	3.727 ^c	2.917 ^e	23.34 ^e	20.85 ^{bc}	8.859 ^c	7.770 ^{cd}
Aquatic Weeds	3.543 ^e	2.813 ^f	22.80 ^f	19.96 ^d	8.634 ^d	7.353 ^e
Typha	3.913 ^a	3.213 ^a	24.45 ^a	21.94 ^a	9.189 ^a	8.307 ^a
Saw Dust	3.773 ^{bc}	3.013 ^d	23.56 ^d	21.08 ^b	8.934 ^b	7.887 ^c
Control	3.453 ^f	2.747 ^g	22.21 ^g	19.44 ^e	8.413 ^e	7.197 ^f
C.D.(p<0.05)	0.050	0.055	0.22	0.38	0.141	0.187

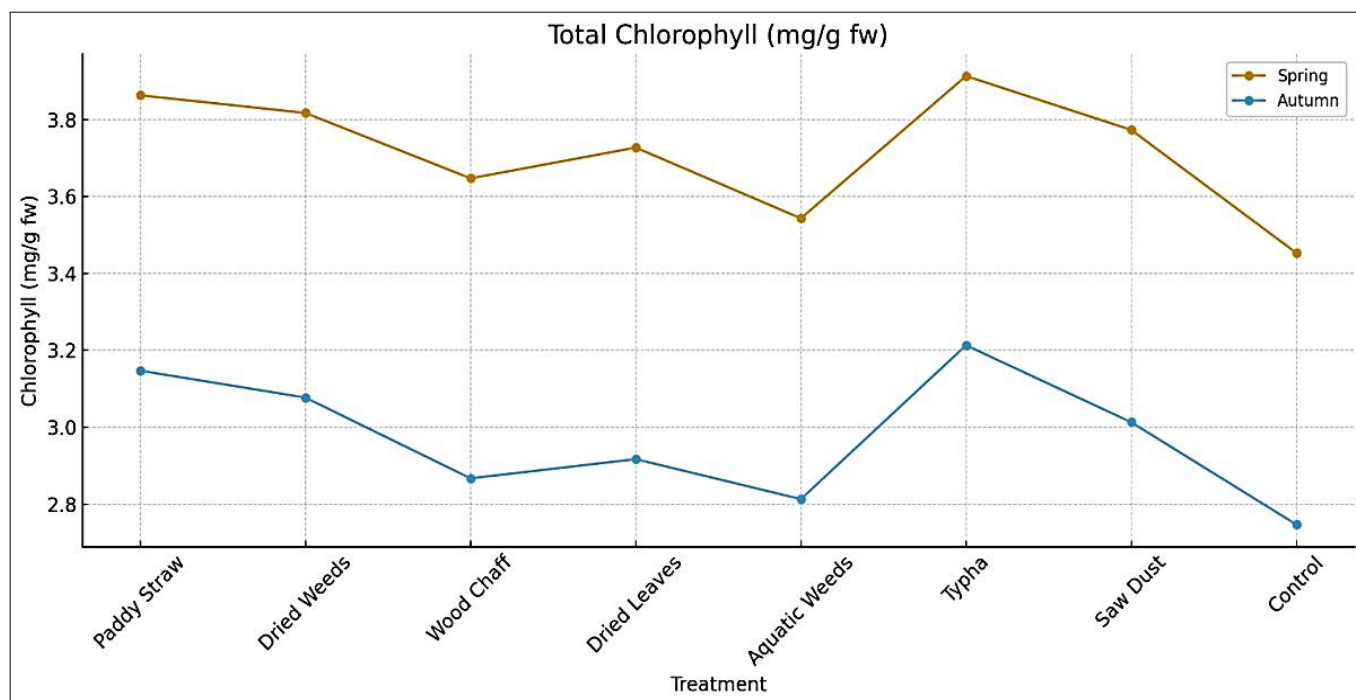


Fig 5: Effect of Phytomulches on total chlorophyll content

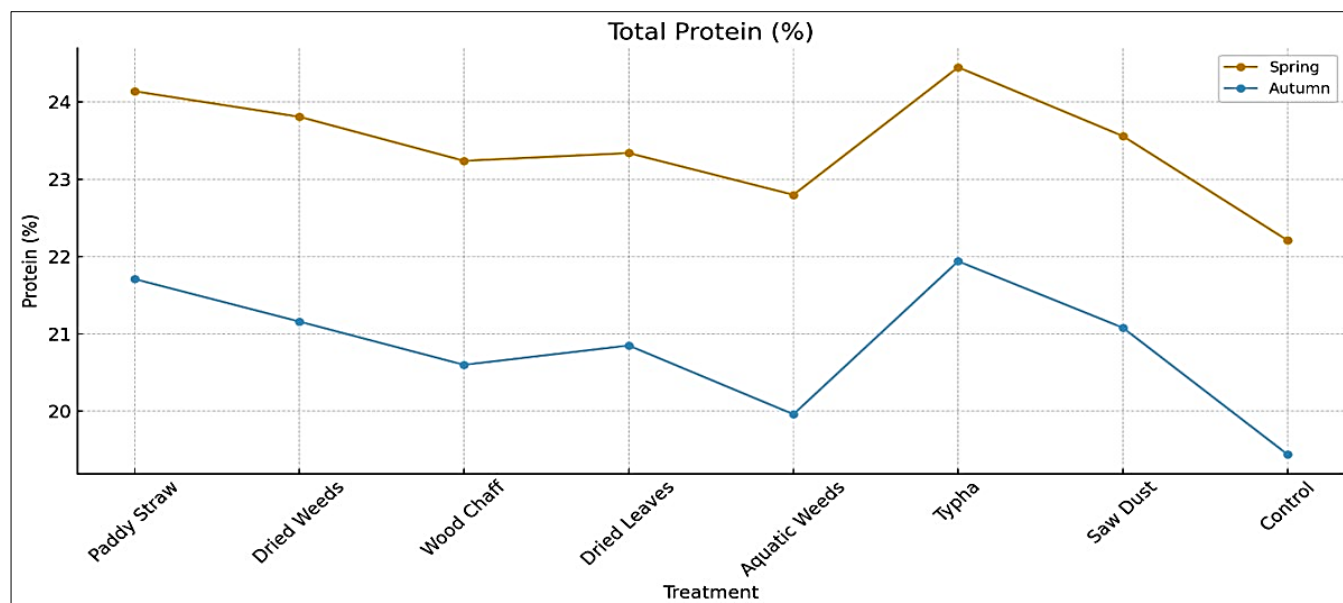


Fig 6: Effect of Phytomulches on total protein content

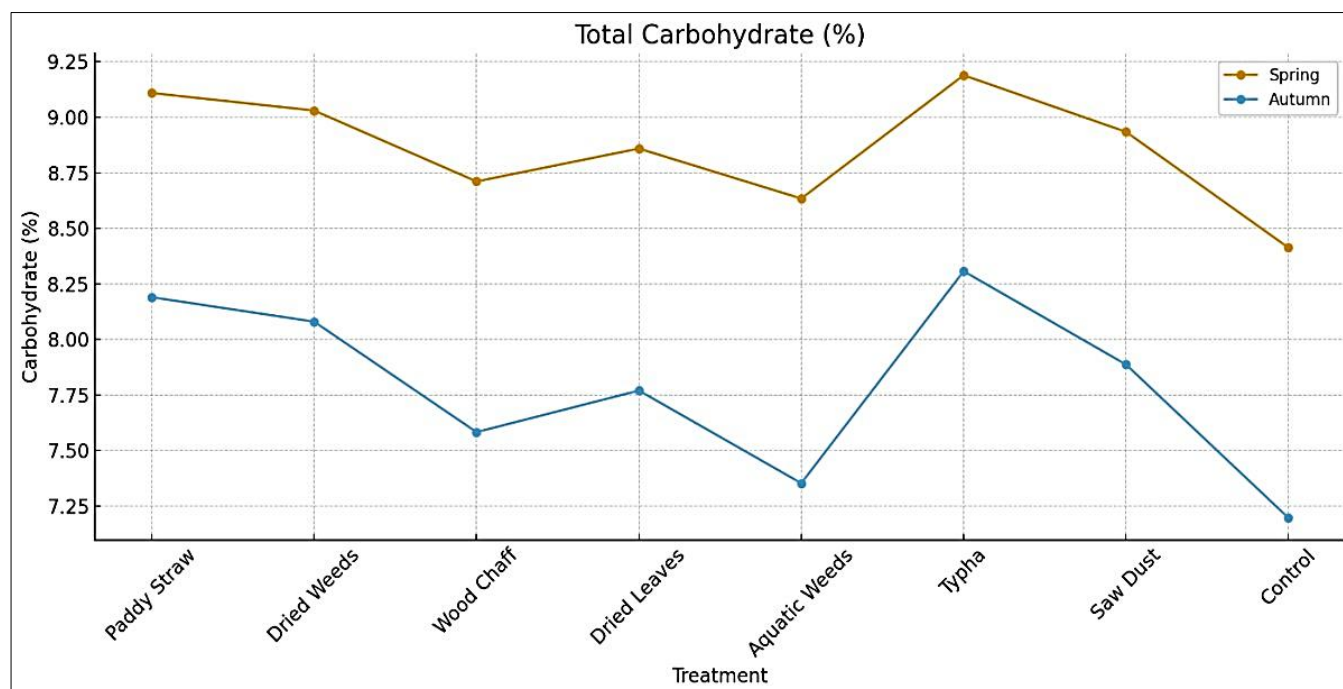
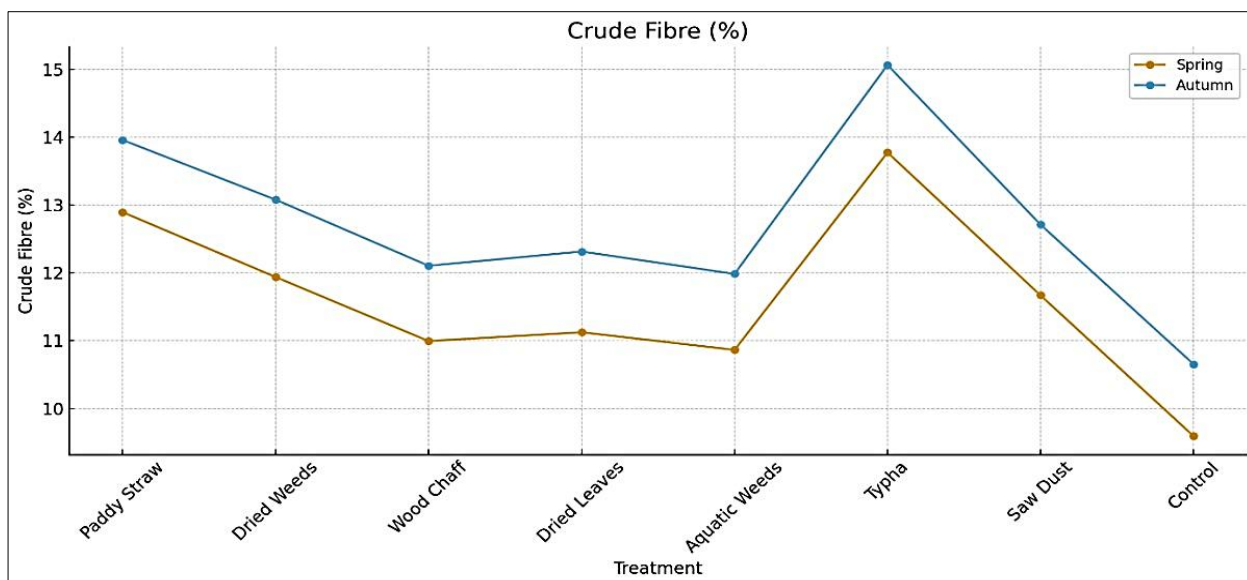
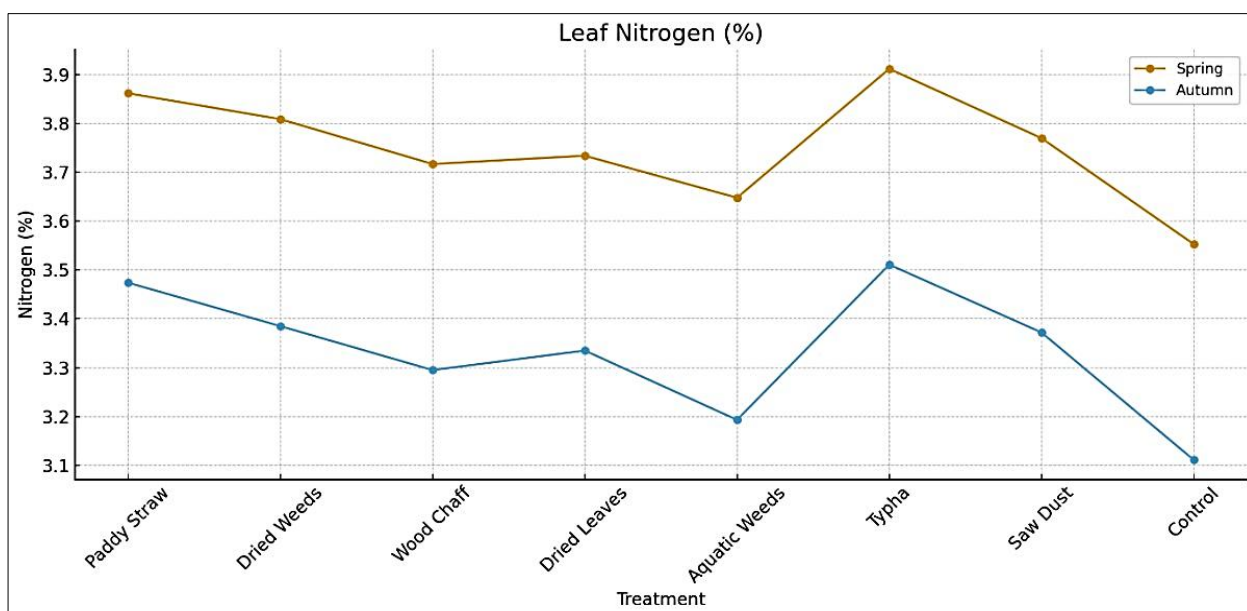
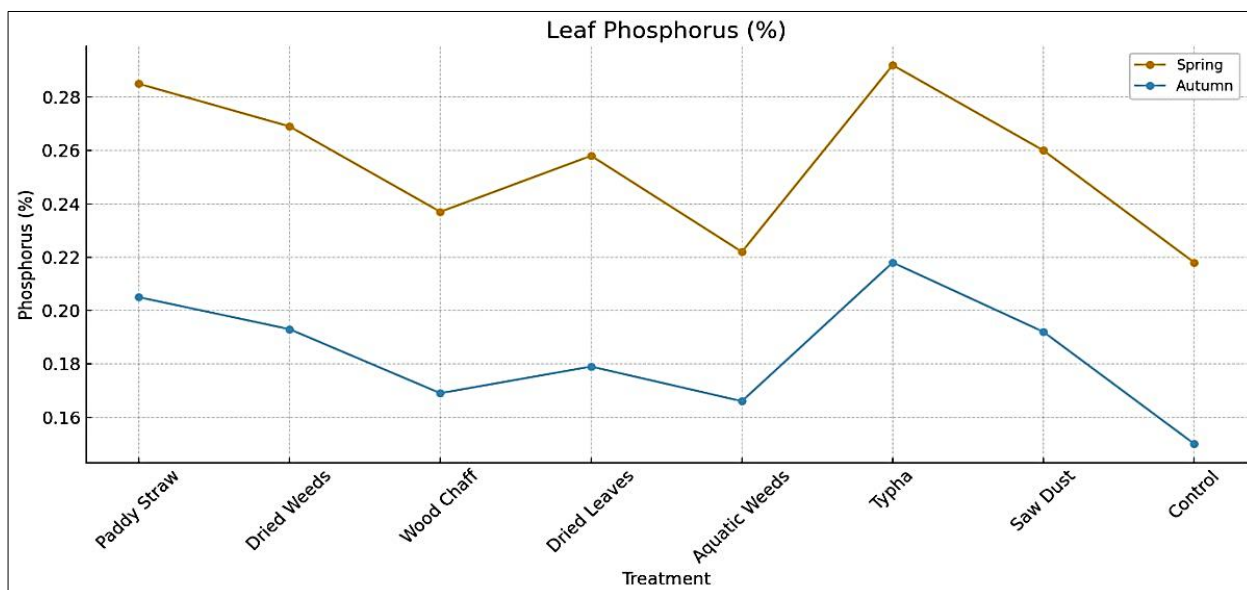


Fig 7: Effect of Phytomulches on total carbohydrate content

Table 3: Effect of different phytomulches on Nitrogen, phosphorus, potassium and crude fibre content in leaf of mulberry (*Morus spp.*).

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Crude fibre(%)	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Paddy Straw	3.862 ^b	3.474 ^a	0.285 ^a	0.205 ^a	1.856 ^a	1.440 ^a	12.893 ^b	13.957 ^b
Dried Weeds	3.809 ^c	3.385 ^b	0.269 ^b	0.193 ^b	1.785 ^{ab}	1.424 ^a	11.937 ^c	13.077 ^c
Wood Chaff	3.717 ^e	3.295 ^c	0.237 ^c	0.169 ^c	1.652 ^b	1.179 ^c	10.993 ^d	12.103 ^{ef}
Dried Leaves	3.734 ^e	3.335 ^{bc}	0.258 ^{bc}	0.179 ^c	1.663 ^b	1.281 ^b	11.123 ^d	12.313 ^e
Aquatic Weeds	3.648 ^f	3.193 ^d	0.222 ^d	0.166 ^{cd}	1.593 ^c	1.158 ^c	10.863 ^d	11.983 ^f
Typha	3.912 ^a	3.511 ^a	0.292 ^a	0.218 ^a	1.896 ^a	1.515 ^a	13.773 ^a	15.063 ^a
Saw Dust	3.770 ^d	3.372 ^b	0.260 ^b	0.192 ^{bc}	1.729 ^b	1.290 ^b	11.667 ^c	12.710 ^d
Control	3.553 ^g	3.111 ^e	0.218 ^d	0.150 ^d	1.555 ^c	1.031 ^d	9.593 ^e	10.653 ^g
C.D.	0.035	0.061	0.013	0.016	0.124	0.091	0.484	0.322

**Fig 8:** Effect of Phytomulches on Crude Fibre (%)**Fig 9:** Effect of Phytomulches on Leaf Nitrogen (%)**Fig 10:** Effect of Phytomulches on Leaf Phosphorus (%)

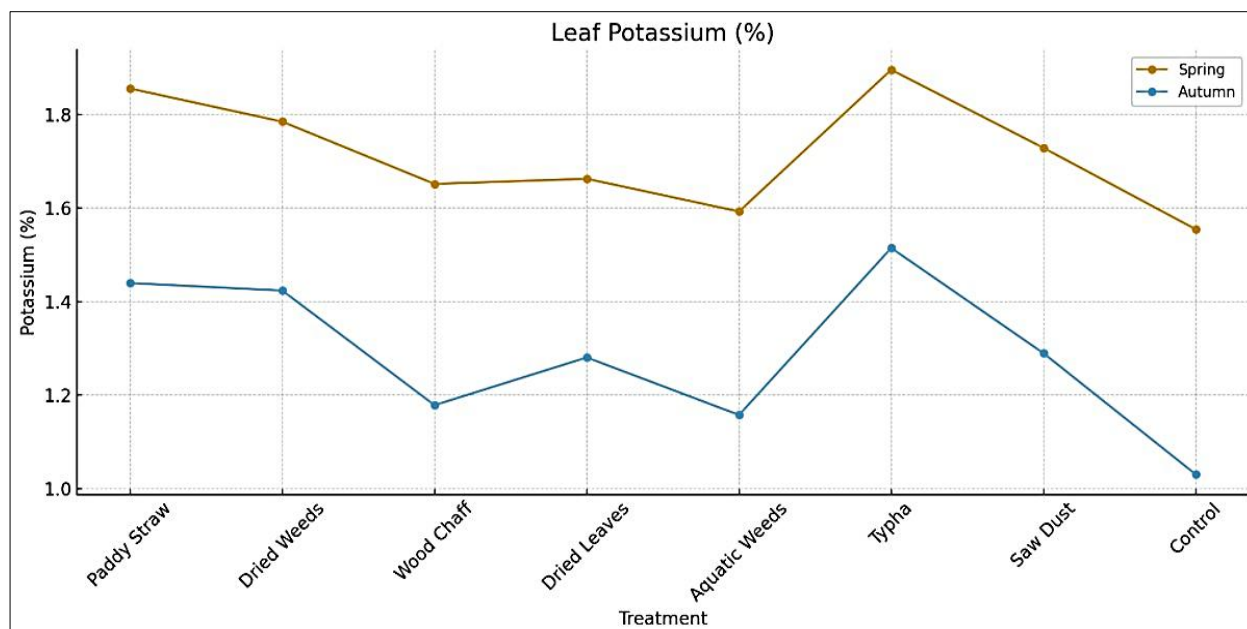


Fig 11: Effect of Phytomulches on Leaf Potassium (%)

Discussion

The observations recorded during the study are discussed here under:

Soil nutrients

Organic carbon is an indicator of health status of soil as it influences the soil physico-chemical and biological properties and is also the indispensable component of the soil system. The application of various organic mulches had a positive impact on the organic carbon content, with T₆ (Typha) having the highest (Spring: 1.823%; Autumn: 1.947%) and T₈ (Control) having the lowest (Spring: 1.700%; Autumn: 1.880%). Acharya *et al.* (1998)^[1], Balaji (1994)^[5], and Tindall *et al.* (1991)^[26] also noted an increase in soil organic carbon content under various mulches compared to control. The degradation of mulches, increased microbial activity, improved soil moisture, and decreased carbon loss could all contribute to the rise in soil organic carbon under various organic mulches (Bajoriene *et al.*, 2013)^[3].

Although there were notable variations amongst the various phytomulches, the application of phytomulches also improved the NPK level in the soil. The soil's nitrogen content was highest in T₆ (Typha) (spring: 338.74 kg/ha; autumn: 273.59 kg/ha) and lowest in T₈ (Control) (spring: 320.71 kg/ha; autumn: 259.47 kg/ha). Similarly, the soil's phosphorus content was highest in T₆ (Typha) (spring: 22.36 kg/ha; autumn: 18.39 kg/ha) and lowest in T₈ (Control) (spring: 17.87 kg/ha; autumn: 15.41 kg/ha). The findings are consistent with those of Qu *et al.* (2019)^[20], who found that mulching the soil with turf grass and green waste compost increased its NPK content compared to bare soil. Additionally, Bakshi *et al.* (2015)^[4] found that soil NPK content improved under various organic mulches, such as forest leaves, paddy straw, and paddy husk, as compared to no mulch (Control). Higher organic carbon contents, improved soil moisture and warmth, and effective weed management could all contribute to the rise in soil NPK concentration. Adequate moisture ensures the uniform distribution of nutrients, preventing their accumulation or leaching. Further soil moisture affects the solubility and

mobility of nutrients within the soil profile (Reisig, 2023)^[22].

Biochemical constituents

According to Murthy *et al.* (2013)^[17], the amount of chlorophyll in a plant is crucial for assessing its photosynthetic efficiency and foliage quality. Using phytomulches increased the total amount of chlorophyll. T₆ (Typha) had the greatest (Spring: 3.913 mg/g; Autumn: 3.213 mg/g) and T₈ (Control) had the lowest (Spring: 3.452 mg/g; Autumn: 2.747 mg/g). The results are consistent with those of Fan *et al.* (2021)^[11], who found that applying various organic mulches increased the amount of chlorophyll in *Dendrocalamus latiflorus* Munro leaves. Cozzolino *et al.* (2020)^[9] also showed similar outcomes with lettuce.

Proteins perform diverse enzymatic, structural and functional role in plants, including processes such as photosynthesis and biosynthesis. For silkworm larvae, leaf protein is a crucial factor in determining the quality of their diet. Mulberry leaf protein is immediately biosynthesized to provide around 70% of the protein in raw silk (Bose *et al.*, 1991)^[6]. Most cells use carbohydrates as an instant energy source, however in many photosynthetic species, a large amount of carbohydrates are used for the synthesis of storage goods like starch or for the formation of structural elements like cellulose in cell walls. Sugars are essential macromolecules that provide cells with energy and are essential for both primary and secondary metabolism. The total protein content (Spring: 24.45%; Autumn: 21.94%) and total carbohydrate content (Spring: 9.189%; Autumn: 8.307%) was the highest in T₆ (Typha) while as the values were the lowest- total protein (Spring: 22.21%; Autumn: 19.44%) and total carbohydrate content (Spring: 8.413%; Autumn: 7.197%) in T₈(Control). The findings of the study are supported by Pinjari (2007)^[19] who also reported increase in protein and carbohydrate content in sweetcorn (*Zea mays saccharata*) mulched with polythene as against control. This improvement in total protein and carbohydrate content may be attributed to improved soil moisture, better nutrient uptake and efficient photosynthesis.

For silkworm growth, silk production, and general health, an ideal crude fiber content is essential. Mulberry leaf crude fiber content is significantly correlated with average filament length, silk productivity, shell weight, and shell percentage (Lohithashwa *et al.*, 2024) ^[15]. The use of phytomulches considerably decreased the crude fiber content in leaves, which was highest in T₈ (Control) in the spring and fall at 11.60 and 11.86 percent, respectively. In T₆ (Typha), it was the lowest (9.27 and 9.53, respectively, in spring and autumn). The outcomes are consistent with the findings of Fan *et al.* (2019) ^[12], who found that maize mulched with plastic, biodegradable material, and straw had less crude fiber than the control. Additionally, Awopegba *et al.* (2017) ^[2] found that mulches reduced the amount of fiber in maize. The rise in leaf moisture, protein, and carbohydrate content could be the cause of the decline in crude fiber content.

Leaf nutrient status

One essential nutrient needed for the best possible growth and development of plants is nitrogen (Salvagiotti *et al.*, 2008) ^[24]. Photosynthesis, DNA synthesis, protein synthesis, respiration, and nitrogen fixation are only a few of the vital physiological activities in which it is crucial (Caliskan *et al.*, 2008) ^[8]. Phosphorus is essential for photosynthesis, protein synthesis, seed germination, flowering, and bud development since it is a crucial part of biomolecules such as nucleic acids, phospholipids, and coenzymes. In addition to boosting enzymatic activity and offering resistance to pests, diseases, frost, and other environmental challenges, potassium plays a major role in photosynthesis and water control.

T₆ (Typha) had the highest leaf nitrogen content (Spring: 3.912%; Autumn: 3.511%) and T₈ (Control) had the lowest (Spring: 3.553%; Autumn: 3.111%). Similarly, T₆ (Typha) had the highest phosphorus content (Spring: 0.292%; Autumn: 0.218%) and T₈ (Control) had the lowest (Spring: 0.218%; Autumn: 0.150%) and T₆ (Control) had the highest leaf potassium content (Spring: 1.896%; Autumn: 1.555%; Autumn: 1.290%). The outcomes are consistent with those of Awopegba *et al.* (2017) ^[2], who found that applying various mulches increased the nutrient content of maize. Similar findings were also reported by Bakshi *et al.* (2015) ^[4], who discovered that using mulches increased the NPK content of Aonla (*Emblia Officinalis* Gaertn.) compared to the control. Their enhanced availability in the soil, control of soil temperature and moisture, microbial diversity, and decreased competition with weeds could all contribute to the enhancement in leaf NPK content.

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